Internets: The changing role of Internet Protocols in evolving broadband technologies

Cramer, Dana Louise


master thesis

University of Calgary graduate students retain copyright ownership and moral rights for their thesis. You may use this material in any way that is permitted by the Copyright Act or through licensing that has been assigned to the document. For uses that are not allowable under copyright legislation or licensing, you are required to seek permission.

Downloaded from PRISM: https://prism.ucalgary.ca
Internets: The changing role of Internet Protocols in evolving broadband technologies

by

Dana Louise Cramer

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF ARTS

GRADUATE PROGRAM IN COMMUNICATION AND MEDIA STUDIES

CALGARY, ALBERTA

JULY, 2021

© Dana Louise Cramer 2021
Abstract

This study, drawing from Langdon Winner’s theory, which identifies the ways in which technology and infrastructure have the embedded politics of their designers, asks questions related to the power of the transport layer of the internet’s infrastructure. I use a mixed methods approach to study the transport layer including media history, primary document analysis, and utilize data derived from a network protocol reader called Wireshark. The findings show that traditional scholarly framings of the transport layer of the internet dubbed as a set of ‘dumb pipes,’ passive, and everything interesting happening at the internet’s edges (Lessig, 2006; Pickard & Berman, 2019), may soon be out of date following the introduction of ManyNets by Chinese corporation, Huawei from 2018-2020, through an introduction for a New Internet Protocol (New IP). I challenge the concept of ManyNets with ‘internets’ as a historic analysis of the development of the transport layer of internet infrastructure shows a pattern in this concept of multiple internets, opposed to the newly introduced ManyNets. As this study finds, developments in the transport layer have been changing due to the ways citizens use the internet (e.g., shifts from text-based platforms to live-streamed content). This study shows that the transport layer of the internet’s infrastructure is a growing politicized space in constant flux.

Keywords: standardization; infrastructure studies; telecommunications policy; ManyNets; 5G; New IP; User Datagram Protocol (UDP); internet fragmentation
Acknowledgements

I had the honour of my supervisor for this thesis to be Dr. Gregory Taylor. Through ups and downs he has been more than a supervisor, he has been a confidant, a reality checker, and overall, simply putting up with all my bullshit. After two theses, two degrees, and half a decade later I am thankful to have both worked with and known him. Words cannot describe the bitter sweetness of finishing up this thesis and my time working and studying under Greg at the University of Calgary. Thanks for all of it, pal.

I would also like to give my deepest thanks to my defence committee: Dr. Tamara Shepherd and Dr. Richard Hawkins. Dr. Tamara Shepherd especially, who has been amazing to work for as both a teaching and research assistant. She has provided invaluable career preparation and mentorship, been a financial crutch for me throughout my degree, taken me along multiple opportunities throughout my MA, and who I have been so thankful to have known and worked with. She also provided invaluable recommendations and mentorship on research funding proposals which aided in how I further researched this project. Dr. Richard Hawkins for continuous support in my research since his advanced research methods course which I took in the final year of my undergraduate degree, where this thesis’ research proposal was developed. Thank you to members both past and present of the University of Calgary community for their shaping, not just of this thesis, but as the person I leave my time in Calgary as. Dr. Sarah Skett who has been both a friend and mentor for years. Dr. Jessalynn Keller who has been an invaluable support structure to me. In addition, I would like to thank a team of liaison librarians: Christie Hurrell, Susan Beatty, Jennifer Lee, James Murphy, and Caitlin McClurg who I have worked as a research assistant for this past year. Especially I would like to recognize Christie Hurrell for her mentorship and scaffolding me as a researcher with teaching me new data...
collection and analysis processes, which I credit this training as the most beneficial experiential learning I have had the privilege to embark on throughout my graduate studies. I would also like to recognize Dr. Charlene Elliott whose COMS 601 course had me question the way I learn and analyze literature, completely reworking my brain to develop me into a better scholar which was instrumental in how I wrote this thesis. In addition, my College Head Dr. James Wasmuth for always keeping an eye out for opportunities to help grow my career and Dr. Craig Gerlach, Director of the Sustainability Studies program, who has kept the Faculty of Environmental Design as a welcoming space for me to turn to throughout my MA. To the students who I TA’ed for and developed strong bonds with. To all members of the Department of Communication, Media and Film, the Taylor Family Digital Library, the Graduate College at the University of Calgary, the Faculty of Environmental Design’s Sustainability Studies program, and the Taylor Institute for Teaching and Learning.

I would also like to thank two of my friends in particular: Signy Holm and Alora Paulsen Mulvey. Signy, my lifelong friend who is a large reason why I got through this graduate degree in her unwavering support. Alora, who has been the definition of a friend through graduate school who I could not thank more for this friendship. For being there for me through cohort bullying and standing with and up for me. For being my double bubble during the pandemic and bringing me a few groceries and a hug in those first few and uncertain weeks. For fangirling over Star Wars, Marvel, Taylor Swift, and Princess Diana with. I could not have been happier to have Alora in my life these past couple of years with more to come. All of my friends deserve so many thanks and appreciation for the impact they had on me; for their understanding of my reading and writing annotations of journal articles during coursework at our favourite bar, from my being late to hangouts (in person and then virtual) because of schoolwork coming first, from
meal prepped dinners premade and dropped off when I got in a writing groove, from teaching me some great workouts to sweat out my frustrations, from staying at their places when they were on holidays which gave me some solid time to think, from hugs, sleepovers, cuddles, Birthday blasts, Thanksgiving dinners, Halloween parties, being each other’s Valentines, New Year’s Eve countdowns, and Christmas presents. Thank you to the women who have been there for me these past two years: Emma Thorne, Larissa Ferreira, Neal Greywall, Maddy Van Belleghem, Nicolette Little, Crystal Chokshi, Jenna Kardal, Amanda Zanco, Megan Cloutier, Gabi Gee, and over in England, my childhood friend Maren Svensen, who flew across the Atlantic to spend Christmas 2019 with me when I was in a rut.

I would also like to recognize the computer scientists and IT professionals who graciously answered my questions about this topic over meals, podcast recordings, and in their blogs where they broke down technical reports to bite-sized chunks, allowing me to understand this complex world of the transport layer of the internet.

This research was funded by a Canada Graduate Scholarship - Master’s by the Social Sciences and Humanities Research Council (SSHRC CGS-M), and an Alberta Graduate Excellence Scholarship (AGES). In addition, during my graduate research I also received financial support through my winning essay for the Canadian Radio-television and Telecommunications Commission’s (CRTC) Prize for Excellence in Policy Research, a University of Calgary Faculty of Graduate Studies Master’s Research Scholarship, and a University of Calgary Graduate College Scholar Non-Resident Scholarship. These funding opportunities, along with teaching and research assistantships, allowed me to pursue this dream of mine to research an often-overlooked area of the internet’s infrastructure. Thank you to all of
those for the financial help to make this possible. I love this thesis with all of my being and will forever be grateful for the support.

Lastly, thank you to my since-passed Grandma, Dorothy May (Morris) Cramer. Thank you for teaching me from a young age gender equality and feminism. Thank you for loving me unconditionally and most in this world. Thank you for making comedy and humor as key to my being. Thank you for instilling in me the importance and value of education. Thank you for the legacy you left in me and the dreams you had which I will pursue. I miss you. I love you. (July 2\textsuperscript{nd}, 1923 – May 8\textsuperscript{th}, 2019).
Dedication

This one is for me.
# Table of Contents

ABSTRACT ................................................................................................................................. I

ACKNOWLEDGEMENTS ............................................................................................................ II

DEDICATION ............................................................................................................................... VI

LIST OF FIGURES ....................................................................................................................... X

LIST OF ACRONYMS ................................................................................................................ X

INTRODUCTION ........................................................................................................................ 1

CHAPTER ONE: INFRASTRUCTURE STUDIES AND GLOBAL STANDARDS ................................. 10

  1.1 DEFINING GOVERNANCE .................................................................................................. 10
  1.2 THE IMMATURITY AND CHANGING ENVIRONMENTS .................................................... 12
  1.3 EMBEDDED TECHNOLOGIES ............................................................................................. 16
  1.4 INTERNATIONAL INFRASTRUCTURE AND STANDARDS OF CONTINUATION ............. 18

CHAPTER TWO: THE PERVERSION OF TECHNÉ ........................................................................ 20

  2.1 PURITY AND THE NEED FOR PAUSE .............................................................................. 23
  2.2 SCIENCE, TECHNOLOGY, AND SOCIETY ........................................................................ 31
  2.3 TECHNÉ AND CAPITALISM’S PERVISION ...................................................................... 36
  2.4 STANDARDS AS POWER ..................................................................................................... 40

CHAPTER THREE: UNCOVERING THE STORIES OF STANDARDS ............................................ 46

  3.1 IN A SNAPSHOT: A ROADMAP OF THE Research METHODS .......................................... 47
  3.2 THE STARTING POINT: ICT POLICY AND THE PUBLIC’S (dis)INTEREST ...................... 51
  3.4 EVERYDAY INTERNET USERS: A QUANTITATIVE APPROACH TO SOCIAL SCIENCE IP RESEARCH ................................................................................................................................. 57
  3.5 CONCLUDING REMARKS AND REFLECTION OF INFLUENCING FACTORS .................... 60

CHAPTER FOUR: THE NEGOTIATED PROTOCOL .................................................................... 62

  4.1 A BRIEF HISTORY OF TCP ................................................................................................ 65
  4.2 UDP AS A DATA TRANSPORT PROCESSING FIX ................................................................ 69
  4.3 OSI AND THE PROTOCOL WHICH NEARLY WAS ................................................................ 72
  4.4 TRANSPORT DEVELOPMENT IN THE STARS .................................................................. 79
  4.5 21ST CENTURY SHIFTING USES OF INTERNET PROTOCOLS ........................................... 82

CHAPTER FIVE: A CALL FOR A NEW INTERNET ..................................................................... 87

  5.1 FG NETWORK 2030’S FINDINGS ......................................................................................... 97
  5.2 GATEWAYS .......................................................................................................................... 102
  5.3 THE UNCIRCUIT ANALYSIS OF NEW IP ........................................................................... 105
  5.4 NEW IP AND HOSTILITY TOWARDS THE MEDIA ............................................................... 108
  5.5 CRITIQUES FROM THE INTERNET COMMUNITY TOWARDS NEW IP ............................ 115

CHAPTER 6: DISCUSSION ....................................................................................................... 119

  6.1 THE ROLE OF NATIONAL POLICYMAKING FOR NEW INTERNETS ............................... 124
  6.2 THE INTERNET IS FOR USERS ........................................................................................ 126

CONCLUSION ............................................................................................................................ 127

  KEY FINDINGS .......................................................................................................................... 128
  CLOSING REFLECTION ............................................................................................................ 129

REFERENCES ............................................................................................................................. 131

APPENDIX ................................................................................................................................ 153

APPENDIX A: RATIONALE FOR EACH CHOSEN STREAMING SERVICE ................................. 153
APPENDIX B: NVivo codebook used in determining themes within the primary documents ........ 155
List of Tables

Table 1: OSI vs. TCP Layered Stack.......................................................... 74
Table 2: SG-13 Representatives and Other Roles (Study Period 2017-2020)........... 92
Table 3: Streaming Services' IPs Deconstructed Using Wireshark ...................... 154
Table 4: NVivo Codebook Used in Data Analysis ....................................... 156
List of Figures

Figure 1: Companies Where Most RFCs Come from to the IETF Per Year .................................... 5
Figure 1: IETF standard setting process ......................................................................................... 43
Figure 2: Success of a Protocol: Scale and Purpose ......................................................................... 63
Figure 3: Misleading 'On Air' Marketing of Crave's Streaming Platform ........................................... 84
Figure 4: Dr. Richard Li New IP Presentation at ITU IMT-2020 ......................................................... 88
Figure 5: Network 2030 Opportunities of Challenges Towards 2030 Diagram ............................ 99
Figure 6: New IP Header to Carry Packets with Different Address Families ................................. 104
Figure 7: Named Data Networking Protocol Layers ........................................................................... 121
## List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>5G</td>
<td>Fifth Generation</td>
</tr>
<tr>
<td>ARPANET</td>
<td>Advanced Research Projects Agency Network</td>
</tr>
<tr>
<td>ATM</td>
<td>Asynchronous Transfer Mode</td>
</tr>
<tr>
<td>BBN</td>
<td>Bolt Beranek and Newman</td>
</tr>
<tr>
<td>CCITT</td>
<td>International Telegraph and Telephone Consultative Committee</td>
</tr>
<tr>
<td>CIRA</td>
<td>Canadian Internet Registration Authority</td>
</tr>
<tr>
<td>CNO/ITU-T</td>
<td>Canadian National Organization for the International Telecommunication Standardization Sector</td>
</tr>
<tr>
<td>CRTC</td>
<td>Canadian Radio-television and Telecommunications Commission</td>
</tr>
<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defence</td>
</tr>
<tr>
<td>DTN</td>
<td>Delay/Disruption Tolerant Networking</td>
</tr>
<tr>
<td>DSN</td>
<td>Deep Space Network</td>
</tr>
<tr>
<td>FIA</td>
<td>Future Internet Architecture</td>
</tr>
<tr>
<td>Gbps</td>
<td>Gigabytes per second</td>
</tr>
<tr>
<td>HTTP</td>
<td>Hypertext Transfer Protocol</td>
</tr>
<tr>
<td>FG</td>
<td>Focus Group</td>
</tr>
<tr>
<td>FN</td>
<td>Future Networks</td>
</tr>
<tr>
<td>IAB</td>
<td>Internet Advisory Board</td>
</tr>
<tr>
<td>ICANN</td>
<td>Internet Corporation for Assigned Names and Numbers</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technologies</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>IETF</td>
<td>Internet Engineering Task Force</td>
</tr>
<tr>
<td>IMT</td>
<td>International Mobile Telecommunications</td>
</tr>
<tr>
<td>INWG</td>
<td>International Network Working Group</td>
</tr>
<tr>
<td>IRTF</td>
<td>Internet Research Task Force</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>IPN</td>
<td>Interplanetary Internet</td>
</tr>
<tr>
<td>IPv4</td>
<td>Internet Protocol version Four</td>
</tr>
<tr>
<td>IPv6</td>
<td>Internet Protocol version Six</td>
</tr>
<tr>
<td>ISED</td>
<td>Innovation, Science, and Economic Development</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technologies</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>ITU-T</td>
<td>International Telecommunication Standardization Sector</td>
</tr>
<tr>
<td>IXP</td>
<td>Internet Exchange Point</td>
</tr>
<tr>
<td>LTE</td>
<td>Long Term Evolution</td>
</tr>
<tr>
<td>Mbps</td>
<td>Megabytes per second</td>
</tr>
<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization/North Atlantic Alliance</td>
</tr>
<tr>
<td>NCP</td>
<td>Network Control Protocol</td>
</tr>
<tr>
<td>NDN</td>
<td>Named Data Networking</td>
</tr>
<tr>
<td>NEN</td>
<td>Near Earth Network</td>
</tr>
<tr>
<td>New IP</td>
<td>New Internet Protocol</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>NGN</td>
<td>Next Generation Networks</td>
</tr>
<tr>
<td>NPL</td>
<td>National Physical Laboratory</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation</td>
</tr>
<tr>
<td>NSG</td>
<td>Network Study Group</td>
</tr>
<tr>
<td>OSI</td>
<td>Open Systems Interconnection</td>
</tr>
<tr>
<td>RFC</td>
<td>Return for Comments</td>
</tr>
<tr>
<td>SCaN</td>
<td>Space Communication and Navigation</td>
</tr>
<tr>
<td>SDO</td>
<td>Standards Developing Organization</td>
</tr>
<tr>
<td>SG-13</td>
<td>Study Group 13</td>
</tr>
<tr>
<td>SN</td>
<td>Space Network</td>
</tr>
<tr>
<td>SSI</td>
<td>Solar System Internet</td>
</tr>
<tr>
<td>SSO</td>
<td>Standards Setting Organization</td>
</tr>
<tr>
<td>STS</td>
<td>Science and Technology Studies</td>
</tr>
<tr>
<td>Tbps</td>
<td>Terabytes per second</td>
</tr>
<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
</tr>
<tr>
<td>TCP/IP</td>
<td>Transmission Control Protocol over the Internet Protocol</td>
</tr>
<tr>
<td>TIRO</td>
<td>Tactile Internet for Remote Communications</td>
</tr>
<tr>
<td>TSAG</td>
<td>Telecommunication Standardization Advisory Group Standardization Bureau</td>
</tr>
<tr>
<td>UCLA</td>
<td>University of California Los Angeles</td>
</tr>
<tr>
<td>UDP</td>
<td>User Datagram Protocol</td>
</tr>
<tr>
<td>VPN</td>
<td>Virtual Private Networks</td>
</tr>
<tr>
<td>VoD</td>
<td>Video on Demand</td>
</tr>
<tr>
<td>VoIP</td>
<td>Voice over Internet Protocol</td>
</tr>
</tbody>
</table>
Introduction

“Standards generally go unnoticed. They are mostly quiet, unseen forces, such as specifications, regulations, and protocols, that ensure that things work properly, interactively, and responsibly. How standards come about is a mystery to most people should they even ponder the question.”

(Gibbons, 1992, p. iii).

Over 2020 and continuing into 2021, Canadians have relied on internet connections for work, school, and socialization as the COVID-19 pandemic has kept citizens home to keep one another safe. This ability to connect online is not a shared experience, as barriers of entry occur from poor connections specifically in rural, remote, and Indigenous communities in Canada (Auditor General of Canada, 2018), low to no digital literacy skills for getting online (International Telecommunication Union [ITU], 2018; Parsons & Hick, 2008), and no access to a personal computer (Napoli & Obar, 2014; Statistics Canada, 2020). Where Canadian telecommunications policy research has greatly focused on bridging the ‘last mile,’ being a connection to the home (R. McMahon et al., 2011; McNally et al., 2017, 2018) or digital literacy as a policy strategy across Canadian jurisdictions (Shepherd & Henderson, 2019), one area which has largely been ignored has been the internet as infrastructure with an acute awareness of the study of its individual layers. In ‘access research,’ policy frameworks tend to focus on the physical layer of the internet’s infrastructure and citizen use of the applications layer. This has resulted in a gap in the area of ‘transport/protocol questions’ which few in the international arena cover (DeNardis, 2009; Dourish, 2015; Galloway, 2004). This thesis works to fill the Canadian ‘transport research’ gap by asking, “What are the political and economic power dynamics involved in the transport layer of the internet?”
In this project I study the transport layer of the internet’s infrastructure and its embedded protocols to connect users along the Transmission Control Protocol over the Internet Protocol (TCP/IP) suite. The TCP/IP suite can be broken into five layers of its infrastructure thereby making our internet: the physical layer being the cables, satellites, and wireless towers. The network layer\(^1\) defined as the ways in which packets of data are coded and addressed then sent from sender to receiver.\(^2\) The transport layer, which describes the protocols Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) with these determining how data will connect end users. Next, the applications layer where software programs/applications are built from systems to ensure an ease of use of the internet.\(^3\) Lastly, the content layer as the words, images, and sounds which the internet transmits between users (Nuechterlein & Weiser, 2013). In this thesis, I focus on the transport layer of the internet: TCP and UDP, as well proposed and historic challenges to these two transport protocols. It should be noted, however, the overarching internet protocol which connects the network layer, transport layer, and allows applications to be built on internet technologies which the physical layer supports this flow of data, is TCP/IP, which is also termed as a ‘stack’ or ‘suite’ and is part of, and apart from, the transport layer IPs.\(^4\) In this thesis I focus on TCP and UDP of the transport layer, however, the TCP/IP suite is also referred to in later chapters.\(^5\) TCP/IP as a protocol suite with TCP and UDP

---

\(^1\) This layer is sometimes described as the logic layer, or that the overarching logic layer is separated into two parts being the transport and network layers. This layer is also sometimes referred to as the ‘internet’ layer because it is what makes decentralized internetworking possible. Consensus of the number of layers and their names differs greatly in the literature. For the purposes of this thesis, the transport layer will refer to Internet Protocols with the network layer denoting Internet Protocol addressing space (Nuechterlein & Weiser, 2013, p. 164).

\(^2\) This includes Internet Protocol version Four (IPv4) or Internet Protocol version Six (IPv6) which is the addressing space of the headers of data packets. Addressing space builds on transport layer protocols (TCP and UDP), however, is considered to be a separate layer in itself which is built off transport protocols.

\(^3\) An example is hypertext transfer protocol (HTTP) for communication between web browsers and servers.

\(^4\) Transport layer protocols can be mirrored in transport layers of other protocol suites. Chapter Six discusses this further.

\(^5\) Please note that this terminology is understandably technically confusing and has had a plethora of computer technicians’ public outreach on changing reference to the TCP/IP suite holding the name of ‘suite’ or ‘stack’ in its reference only. Readers of this thesis should be cognizant of these minute details in terminology of internet layers.
as transport layer protocols allow for a shared decentralized networking standard among computers encoded in their hardware and standards for software and applications built on these same protocols as a standard in their operating systems. Through this standardization, the internet was made available for users to access content and communicate with one another from various locations through this shared computer pathway. In this standardization, TCP and UDP have worked as ‘dumb pipes’ (Pickard & Berman, 2019) connecting users at ends of the network. This transport layer has very recently been undergoing developments and political challenges in internet governance bodies.

This thesis works to identify the historical and contemporary political processes of the standardization of internet protocols (IPs). As this thesis demonstrates, the transport layer has not been a set of ‘dumb pipes,’ but instead has undergone highly political debates in its standardization which are being challenged in contemporary internet development. As I wrap up writing this thesis, the study completed, the findings gathered, coded, and synthesized, the United States (US) Congress has introduced a bipartisan bill in the Senate on 8 April 2021 to ensure the US is dominant in international internet infrastructure to compete with China (United States Senate Committee on Foreign Relations, 2021; Wang, 2021). The bill is a comprehensive set of policy actions and is titled, the Strategic Competition Act of 2021. In it, s.209(b)(1) the bill states, “the United States and its allies and partners should maintain participation and leadership at international standards-setting bodies for 5th and future generation mobile telecommunications systems and infrastructure” (Strategic Competition Act of 2021, 2021). The bill has gone through two readings in the Senate Foreign Relations Committee as of 15 April 2021. As this thesis works to show, the international standardization processes for transport layer

---

6 Note, following submission of this thesis to committee the Strategic Competition Act of 2021 was engulfed into the US Innovation and Competition Act of 2021 which was passed in the Senate on the 8th of June 2021.
internet infrastructure is currently being battled at the ITU by China due to proposed developments in 5G and beyond, specifically with the emergence of increased mobile technologies and the Internet of Things (IoT). This proposed US Senate bill is part of larger ongoing and recent conversations of international internet standards which this thesis analyzes.

Chinese participation in internet standards setting has been growing in recent years. The below graph identifies Weyrauch and Winzen’s (2021) recent findings of Return for Comments (RFC) participation at the Internet Engineering Task Force (IETF), which is the internet’s primary standards organization, with Huawei becoming a dominant player in internet technical components and standardization. Historically internet pioneering institutions funded through the US Department of Defense’s (DoD) Advanced Research Projects Agency Network (ARPANET), also known as the Defence Advanced Research Projects Agency (DARPA), were these key RFC players. These ARPANET-focused RFCs, however, shifted in the 1990s when computer and software corporations like IBM and Cisco were most prominent once the internet was released to the public. A new third shift in RFC contributions identified by Weyrauch and Winzen show non-American companies beginning to become prominent IETF responders and developers of the transport layer of the internet (Weyrauch & Winzen, 2021). Huawei is currently the most prominent since 2018, as described by Weyrauch and Winzen’s data, aligning this thesis’ own findings of how China is taking a more prominent role in international internet standardization via Huawei.
The internet as it is known today originated from the US. Starting in the 1960s, the project worked to connect various US universities through a shared networking computer code called the TCP/IP suite with TCP allowing for end user communication to occur on this transport layer. This end user communication was later defined as the ‘end-to-end principle,’ stating that intelligence “of a network exists on its edges—in the users and applications that send traffic over the network. The “core” of the network acts as “dumb pipes,” as passive infrastructure that merely funnels traffic to the edges of the network.” (Pickard & Berman, 2019, p. 3). Through these ‘dumb’ pipes power is rested with users.

Although TCP/IP is our contemporary public internet, during the ARPANET program, other countries were also working to develop computerized communication for their citizens in their borders. These were called videotex systems where computerized tasks such as banking, telephone books, advertising, communications, and accessing online content were marketed to
The first videotex systems are reported to date back to the early 1970s in the United Kingdom (UK) through research and development by the British Post Office throughout the 1960s developing the Prestel system (Elton & Carey, 2013). Other national developments quickly followed in suite including countries like Canada (Telidon), the US (CompuServe and The Source, then later Viewtron and Gateway), Germany (Bildschirmtext), Japan (Captain service), and France (Minitel) (Elton & Carey, 2013). These systems quickly faded out of public purview in part from poor deployment efforts, however, France’s Minitel was a strong precursor to the American-released internet in 1993 but failed as any type of international communication standard like the TCP/IP suite. Part of this failure included the French government’s heavy hand in subsidizing Minitel opposed to leaving the system with its citizens and businesses to uptake and market (Dauncey, 1997; Maillard & Driscoll, 2017).

As is apparent, not all national computer systems will become internationally adopted technical standards. International standards allow for technologies to flourish in a global economy but must first be ratified by sovereign countries. This decision of whether to regulate is chosen based off a series of questions regarding national interest of the sovereign country. These questions, as modelled from Roberta Crane (1979), are as follows: What is the national political strategy and does regulation of a technology aid in this strategy? What are the nation’s technical needs? What is the public’s opinion about integration with the rest of the world through the specific technology? What are the estimates of the value of the service(s)? What is the economic status of the technology’s integration to the nation? How will payments of the technology be balanced? What costs are associated with the technology if the nation does not agree to use an

---

7 Even with ARPANET in the US, AT&T was developing out videotex for the masses, as the use of ARPANET at the time was restricted to the computer engineers building it at selected US universities and the DoD.
internationally accepted technology on their domestic front? What is the history of the technology and nation? What has been the experience of the nation with the technology or what the technology offers? (Crane, 1979). For the sovereign state, the choice then becomes whether to accept internationally recognized technical standards, or to develop domestic standards to a given technology to allow for the nation to have greater control over the technology. An example of an international technical standard was the QWERTY keyboard, first used in the Remington typewriter in the 19th century which is now the keyboard standard for computers (David, 1985). These standards, therefore, are not ‘dumb pipes’ but highly political in their introduction, maintenance, and potential challenges.

Standards are political and therefore the technologies which embed these standards also contain embedded politics in their design. As this thesis demonstrates, the area of the transport layer of the internet’s infrastructure cannot be characterized as a collection of ‘dumb pipes’ and instead has been purposely determined based on international political organizations, both during the development of the internet, as well more recently in the 2018-2020 period with emerging developments in the transport layer of the internet’s infrastructure through standardization challenges introduced by China at the ITU. This thesis asks questions of planes of power along the various layers of the internet, sustainability and future proofed IPs, and international governance models for the transport layer of the internet.

The thesis starts with a short literature review on infrastructure studies, internet studies, and telecommunications policy. Because the transport layer of the internet has not changed much in just under 40 years since the TCP/IP suite was embedded into internet infrastructure, research in this area has remained scarce with literature continuously identifying the end-to-end principle

---

8 This occurred in 1981 during the NCP/TCP transition and is further detailed in Chapter Four.
and the transport layer acting as ‘dumb pipes.’ Chapter Two provides a theoretical framework for this thesis tying the conceptual understanding of the transport layer with historic framings of the Sun through images of purity and everlasting to describe the transport layer, thereby preserving a sense of technē in this layer opposed to technē being under duress from capitalist perversion. This chapter argues in line with Langdon’s Winner’s famous theory that technologies and infrastructures are political because they are designed and built by people who embed their politics into these designs and the highly political nature of standardization as a social theory. Therefore, infrastructures like the transport layer and its standards are not passive. In the methodology chapter (Chapter Three) a mixed methods approach to studying transport layer internet infrastructure is outlined. This includes using a network protocol reader to quantitatively check the validity of characteristics associated with specified IPs, as well primary document analysis and ‘following the story’ with emerging developments in the transport layer of the internet’s infrastructure. Chapter Four begins the historic analysis of how TCP/IP as a protocol suite and TCP and UDP as transport layer protocols became the public internet. Through global communications governance and international standardization processes, this chapter outlines how the TCP/IP suite became the international dominant network protocol and corresponding transport layer developments it had to incorporate to ensure its survival against competing packet and virtual switching technologies. This chapter concludes with developing findings of the ways in which industry players in the Canadian market have used (and not used) specific affordances of TCP and UDP transport layer protocols. At the beginning of Chapter Five its title immediately frames what the contents of this chapter will include ‘A Call for a New Internet.’

This call began in 2018 with an ongoing international internet governance lobbying campaign by China still taking place during the time of writing. It is in this chapter we see that
the transport layer of the internet’s infrastructure it not a static entity, a set of ‘dumb pipes,’ holding and resemblance of purity, or being a ‘passive infrastructure,’ but one with embedded politics in its design and development. As this chapter demonstrates, the transport layer will require modifications as internet uses change, specifically with higher reliance on wireless technologies (i.e., IoT). The chapter transitions to the thesis’ discussion where the transport layer’s sustainability is analyzed and raises questions to what a future-proof technology is. Following this discussion, the thesis concludes with a researcher reflection on how transport layer research may grow and how this thesis aids in those knowledge trajectories.
Chapter One: Infrastructure Studies and Global Standards

“[E]very technological breakthrough is presented as a triumph for humanity in general, and thus we do not have to worry about the distribution of costs and benefits that attend its use.”

(Leiss, 1990, pp. 5–6).

This thesis, in its entirety, is a study of internet infrastructure. Where communications, media and internet infrastructure studies researchers often research internet access and ask questions pertaining to the physical layer of the internet’s infrastructure, or uses along the applications layer, this thesis works to analyze the transport layer of the internet’s infrastructure being IPs and their evolving relevance in standardization processes.

1.1 Defining Governance

In the study of standards setting, questions of international governance processes are at the forefront. As James N. Rosenau put it in his co-edited book titled Governance Without Government: Order and Change in World Politics,

[G]overnance is a system of rule that works only if it is accepted by the majority (or at least, by the most powerful of those it affects), whereas governments can function even in the face of widespread opposition to their policies…[G]overnance is always effective in performing the functions necessary to systemic persistence, else it is not conceived to exist.

(Rosenau, 1992, pp. 4–5).

In this, governance is not a single government but instead is enacted through varying systems which transcend both governments and national borders. The process of governance is not a single actor, but instead actors which may not be democratically elected, confined to a single country’s rule of law in which influence is exerted, or situated in a single timeline but may be
everlasting (Rosenau, 1992). These actors who hold governance capabilities may be either political players in the form of governance institutions, such as this thesis studies with the ITU and IETF, or international media companies (DeNardis, 2012). As Gorwa (2019) has studied in transnational media platforms, what constitutes as governance for online media companies can be listed as: they govern, they are governed, they are material companies.

Laura DeNardis, a professor and interim dean of the School of Communication at American University in Washington DC, states, “Internet governance generally refers to policy and technical coordination issues related to the exchange of information over the Internet.” (DeNardis, 2013, p. 557). In her chapter where she describes the then emerging field of internet governance, key topics of internet governance encompass five broad areas: critical internet resources, internet protocol design, intellectual property rights, security and infrastructure management, and communication rights (DeNardis, 2013). Where scholars have analyzed critical internet resources with scarcity of communications resources such as IP addressing (DeNardis, 2009), or radio-spectrum usage (Joyce, 2020; Taylor, 2018); as well areas of accessing physical internet infrastructure for those in rural, remote, and Indigenous areas (Ali & Duemmel, 2019; R. McMahon et al., 2011; Philpot et al., 2014)—which I myself have published work in this area of last mile connectivity in Canadian-domestic telecommunications policy as well (Cramer, 2020; Taylor et al., 2021)—this thesis instead works to fill the gap in internet infrastructure studies scholarship by asking questions of IPs in the transport layer of the internet’s infrastructure and its evolving relevance in global internet governance.

In their article, Epstein et al. (2016) argue that internet governance research oftentimes only focuses on naming addresses opposed to the operations of internet governance institutions. They critique that this mainstream internet governance research focuses on institutions and
oftentimes lacks an analysis of powerful private players, and that “researchers working in areas of telecommunication policy, information security, and cyberlaw all do [internet governance] research, even though they are avoiding the label.” (Epstein et al., 2016, p. 3). In this, telecommunications policy researchers are also internet governance researchers. Internet governance, however, can be immaterial as it does not have the same physical component, making it difficult to grasp (Dourish, 2015).

As Bowker and Star (2000) note regarding immaterial internet infrastructure in their article on standardization and classification,

[Standards] are often deployed in the context of making things work together; for example, computer protocols for Internet communication involve a cascade of standards, which need to work together well for the average user to gain seamless access to the web of information. There are standards for the components to link from your computer to the phone network, for coding and decoding binary streams as sound, for sending messages from one network to another, for attaching documents to messages, and so forth.

(Bowker & Star, 2000, p. 150).

Through standardization—and a layered infrastructure approach to ensuring communication—IPs are material in how they work as systems of collaboration opposed to single entities.

1.2 The Immaterial and Changing Environments

When discussing IPs and the study of their governance, DeNardis states that “Protocols are sometimes considered difficult to grasp because they are intangible and often invisible to Internet users. They are not software or material hardware. They are closer to text.” (2013, p. 562). The study of IPs is often neglected in internet infrastructure scholarship, thereby rendering the transport layer of the internet immaterial and invisible even to internet infrastructure and
telecommunications policy researchers. Oftentimes, infrastructure invisibility will focus on physical infrastructure which is hidden from citizens either through it being above one’s head at telephone poles, under the ocean, or disguised as other objects outside (e.g., wireless towers as trees). This concept of infrastructural visibility has been covered in scholarship regarding the importance of physical fibre optic cables for future proofed telecommunications (Crawford, 2018; Middleton, 2016; Starosielski, 2015b). As these scholars argue, this invisible infrastructure is paramount to international data flow and the benefits of a network economy (Crawford, 2018; Middleton, 2016). Others’ opinions differ about which infrastructures should even be used for connecting citizens, arguing for extending the bandwidth, for example, of copper cables due to economic factors of physical telecommunications infrastructure implementation (Kateeb et al., 2013). Glimstedt and Zander (2003), in their analysis of Sweden’s telecommunications and internet economy history, however, found that their country was able to adopt TCP/IP (i.e., the internet) because increased developments in fibre optic cables in Europe were apparent. Therefore, arguments to extend future proof physical infrastructure are not only impactful only to the speed of data, but also which IPs (technical standards) may be used in various jurisdictions, providing strategic choices of complexes of materiality when the internet’s infrastructure is viewed from a holistic approach. To establish these future proof technologies, governance for this coordination is required.

Science and technology studies (STS) scholar, Langdon Winner, has described one reason for why governing immaterial areas of technology may not be prevalent both in national and international jurisdictions: their complexity (Winner, 1977). In this, technologies are made incredibly complex which allows for easier lives through not having to consider all components of daily interaction with objects and infrastructures, but becomes a problem for governance of
technical spaces, with what Winner criticizes and terms the ‘manifest social complexity.’ This manifest of social complexity is defined as,

> The technological society contains many parts and specialized activities with a myriad of interconnections. The totality of such interconnections—the relationships of the parts to each other and the parts to the whole—is something which is no longer comprehensible to anyone.


This *myriad of interconnections* can be one associated with Bruno Latour’s actor-network theory, positing the idea that nonhuman actors—in essence objects—are a part of the communication processes as humans utilize the communicative affordances and interactions with these objects to extend the capabilities of communication between one another, or mediating this communication (Latour, 2006; Law, 1992). When these technologies are introduced, however, they may change the physical and social environments around them. In her field work in rural Zambia, Lisa Parks (2015) identified the ways in which the physical environment, energy, and water access will determine what types of technology use a given community is afforded through this resource access matrix and the fulfillment of the community’s needs. As she describes, in the rural community of Macha, Zambia, the issue of technological determinism was paramount by Western non-profits looking to connect Macha. These companies, Parks describes follow the “O3B” or “other 3 billion” ideology which is defined as “the mass of people still without Internet access who are alternatively imagined as a technologically disenfranchised class or a giant untapped market.” (Parks, 2015, p. 116). In her chapter, Parks (2015) notes that through international e-commerce afforded by newfound internet access, residents of Macha had bought vehicles from Asia, which then reshaped the Machan environment from roads used by walkers,
cyclists, and livestock, which were soon transformed to also accommodate Toyotas. As Parks notes,

This fieldwork in Macha fundamentally altered the manner in which I imagine “Internet infrastructure” and its materiality. […] Everyday experiences in the community brought forth the complexity of the Internet’s operational dynamism – its contingency upon the coordinated appropriation of natural resources, electricity and batteries, and human biopower.

(2015, p. 133).

As she concludes based off her experiences, internet infrastructure must not be imposed on communities, but instead for communities to ask for, accept, and be part of the internet infrastructure development conversation in a transparent manner (Parks, 2015). This ability for communities to choose their internet connections differ in physical layer internet infrastructure scholarship from transport layer scholarship in which this thesis situates itself.

This technological determinism which Parks speaks to falls in line with Sarnoff’s Law which posits that “[t]he value of the network is proportionate to the number of customers it reaches.” (Gunasekaran & Harmantzis, 2007, p. 29). This idea is, to ensure the sustaining power of a network, it requires more users connected to it for its value to hold and grow. Marshall McLuhan had critiqued Sarnoff in his book, *Understanding Media*, arguing that Sarnoff’s work ignored the power of the medium and focuses too greatly on the content which media audiences would consume (McLuhan, 1994). Additionally, scholars have found that the internet as a network is not made equal for users, but that algorithms specifically will result in existing power dimensions in the ‘real world’ to be replicated online, thereby disadvantaging opposed to liberating users of these technologies (Eubanks, 2018). This shows the ways in which immaterial
technologies affect citizens. Through these embedded technologies into society, communication is mediated and controlled.

1.3 Embedded Technologies

Technologies may be embedded in immaterial ways; however, the scholarship oftentimes discusses the material embedding of internet infrastructure. This has been explored by Parks (2009) in her discussion of ‘infrastructure in plain sight.’ In this, she identifies how wireless cell towers are sometimes disguised as trees in order to be more visually appealing and allow for the acceptance of this infrastructure in various communities (Parks, 2009). Through this concealment, Parks notes that the main function of the ‘invisible’ cell tower is that it keeps citizens/users “naïve about the systems that surround them and that they subsidize and use.” (para. 8). By keeping the infrastructure out of the public’s eye through concealing it, questions and concerns about the use of infrastructure and its political economy go unasked by the general populace.

In her work on undersea cables, Starosielski (2015b) coins the concepts of ‘strategies of insulation’ and ‘strategies of interconnection’ to identify the ways in which material infrastructures—undersea cables—are able to work in turbulent spaces, insulated from the public’s perception and scrutiny, while interconnecting through various business and political agreements for mutual benefit in providing this global telecommunication connection (Starosielski, 2015a). This is paralleled in Holt and Vondereau’s (2015) work on data centres located in places guarded off from the public, resulting in these data centres’ perceived immateriality, allowing for high levels of energy consumption and electronic waste, while in a climate emergency (Carruth, 2014). These technologies then are invisible when embedded into their surrounding environment.
Winseck (2017) in his article detailing the geopolitical economy of the global internet infrastructure argues that material—physical—infrastructure and regulation of these physical components is key in internet governance. In this article, he argues that platforms are not as significant international internet infrastructure components for regulators, but technologies along the internet’s physical layer are more significant and are increasingly becoming dominant with the European Union (EU) and BRICS countries (Brazil, Russia, India, China, South Africa). He argues that American platforms are not the key areas for the geopolitical economy, but these EU and BRICS countries instead.

In this conversation of platforms as significant media infrastructures, Plantin et al. (2018) describe in their article on the intersection of infrastructure studies with platform studies that, “[d]igital technologies have made possible a “platformization” of infrastructure and an “infrastructuralization” of platforms.” (p. 295). In this, digital media no longer have physical infrastructure falling strictly in STS research, with platform studies in media studies scholarship, but instead “tensions [arise] when media environments increasingly essential to our daily lives (infrastructures) are dominated by corporate entities (platforms).” (Plantin et al., 2018, p. 295).

The definition of infrastructure then moves from material objects to immaterial code. This mixture of STS and media studies has also been noted by others (Paré et al., 2014). Additionally, Jackson et al. (2007) has spoken to this notion of cyber platforms as infrastructure in discussing cyberinfrastructure studies as a form of scholarship which provides navigation tools and principles to better guide policymakers and citizens through technological changes. They argue that cyberinfrastructure is a different form of infrastructure studies as it is based on continuity and consistency with the past, opposed to novelty, looking at heuristics and principles of navigation through a historic comparison (Jackson et al., 2007).
1.4 International Infrastructure and Standards of Continuation

In her chapter on the US’s standardization institutions, which are often completed in industry opposed to government players—a break from international norms, Garcia (2011) argues that standards processes whether in government or industry must embed a public interest in their classifications. This success of public interest will be determinant on if the standards setting institution engages in public participation and consultation in their operational processes (Garcia, 2011). As Crane (1979) notes, American standards do tend to prevail, however, France has also had successes in media technology (Maillard & Driscoll, 2017). This US-France competition in standards setting mirrors their international economic institutions domination through the World Bank (US) and International Monetary Fund (France) (McCormack, 2020), showing the global political and economic aspects of standards setting. The discussion of global power in internet standards and flows of data then would be contingent on these two countries’ economic might, however, as the Winseck (2017) analysis shows, this is changing to incorporate the BRICS.

These standards and this flow of data around the world, follows what Jonathan Sterne identifies as a ‘network reality’ defined as “not a binary relationship between sender and receiver mediated by a medium but rather an ensemble of relations that only produce the moments of transmission and reception after the fact.” (Sterne, 2015, p. 35). When this transmission is disrupted, infrastructure suddenly becomes very visible to citizens and can become a question of politics. This question about the politics of information and communications infrastructure has been raised by Helga Tawil-Souri (2015) in her analysis of disconnected phone calls along the Israel-Palestine border. As she states, “Suffice it to say that, telephonically, Palestinians were enclavized and largely disconnected from the infrastructure, living under a regime that restricted
both their mobility and their access to the outside world.” (Tawil-Souri, 2015, p. 162). In her analysis, she identifies two prominent issues. First, disconnected communications infrastructure bring materiality to, specifically, phone calls and the political aspects of infrastructure in connecting two people through distance via wires (Tawil-Souri, 2015). Her second issue she works to raise in her analysis is addressing the politicization of technology and how agreements for access to use a technology will undergo formations and negotiations. This politicization of the internet has also been raised by Margetts (2013) in identifying how the internet is a space of political discourse. This continued conversation about the politics of accessing the internet and making for democratic spaces online can also be found in Sarah Harris’ (2015) study of how networks of people in a local economy will work together to be connected in Turkish cybercafés. She argues that service providers fall into the purview of digital media infrastructure when these networks of people come together for connection (Harris, 2015). Therefore, the internet and access to this infrastructure is not one of just international players, but also citizens and organizations who work with—and against—one another for access to this online sphere. The internet is then an incredibly political space in its access, usage, and as this thesis argues – standards and protocols.

As this chapter has traced, infrastructure studies as a field tends to analyze physical telecommunications infrastructure opposed to more immaterial layers, such as the transport layer. These layers, however, work in tandem with one another with layers such as the applications with its platforms more recently being argued as an infrastructure (Plantin et al., 2018). The next chapter will identify the theoretical framework of this thesis.
Chapter Two: The Perversion of Technē

“[T]he running code that results from our process (when things work well) inevitably has an impact beyond technical considerations, because the underlying decisions afford some uses while discouraging others. While we believe we are making only technical decisions, in reality, we are defining (in some degree) what is possible on the Internet itself.”

(Nottingham, 2020, p. 2).

On the 18th of December in 1610, Thomas Harriot observed and recorded the first sunspot through his telescope. Following this observation—although sunspots were noted by other astronomers prior to the telescopic era, a time of development for telescopes—scientists of the stars drew their telescopes towards the Sun to count the number of sunspots which they could observe. This observation and documentation was key, as counting sunspots soon became a number index to measure solar activity for further astronomical work which is still used in present day (Carrasco et al., 2020). Although Thomas Harriot was the first to record the date when he observed sunspots, Galileo Galilei had stated he observed sunspots in 1610 as well, however, had not recorded them. Galileo’s collection of sunspots is considered incredibly well-documented for his time in the history of astronomical discovery. Christopher Scheiner, who held the record of 766 sunspot observation days in the first two decades of the telescopic era (1610-1629), would argue with Galileo regarding the purity of the Sun during this race to record. Scheiner centred his beliefs about the Sun through an Aristotelian framing that the Sun was perfect, pure, and whole (Carrasco et al., 2020).

Sunspots are dark blemishes on the surface of the Sun, the surface area of this section of the Sun being called the photosphere (Chaisson & McMillan, 2014). The detailed observations about the Sun recorded by Galileo provided one of the first clues that the Sun was not perfect,
whole, and unchanging, but instead is in constant flux opposed to an unvarying creation
(Chaisson & McMillan, 2014). As these observations by astronomers of the 17th century showed,
the Sun was not and continues not to be a pure entity which has stayed static in its creation since
the early time of our galaxy, but instead is constantly undergoing change.

The conceptual framing of the Sun throughout time and space is similar to the
understanding of the transport layer of the internet’s infrastructure. Although the transport layer
has never been defined as perfect by its developers, it is often simply regarded as a set of ‘dumb
pipes,’ ‘passive infrastructure.’ As well, it is frequently remarked that the internet’s power and
excitement rests at its edges opposed to this transport layer core, thereby dismissing the power of
this layer of the internet’s infrastructure. Often overlooked in the field of communication and
media studies, the transport layer of the internet’s infrastructure has changed since its public
release in 1993. The changes which I reference to are specifically with regards to IPs, the code in
which data is transported around the world through our information communication
technologies. Where internet pioneers Vinton Cerf and Robert Kahn are credited with the
creation of the internet through their TCP/IP (Flew & Smith, 2018), studies such as Paul
Dourish’s (2015) on IPs related to Internet Exchange Points (IXPs) show that Cerf and Kahn
developed one IP which is the bedrock of the public internet, but not all internets and IPs.
Additional IPs, studied by Dourish, being Asynchronous Transfer Mode (ATM) were developed
by telecommunications companies in consortium with governments in the 1990s. ATM is a
standardized IP with the ITU since February 2000 (ITU-T, 2000) but had failed to gain
popularity as TCP/IP was both free and more reliable for mass use by the public (Dourish, 2015).
As Dourish’s study shows with the ways in which IXPs use ATM, Cerf and Kahn developed one
IP for the public internet, but not all areas of internetworking as it is used in its entirety and as its
growth in emerging IPs continue decades later (Dourish, 2015). The concept of one internet when referring to ‘the’ internet, therefore is one type of internet but should not be dismissed as it is the most popular and readily used for and by the public.

The transport layer of the internet, like the Sun, has not stayed static as a pure entity and continues to change and evolve. In its entirety, this thesis identifies the evolving changes of IPs in the transport layer through the study of TCP, UDP, their uses, and other non-public and emerging IPs. In this thesis’ theoretical framework, the internet has been conceptualized similarly to the 17th century understanding of the Sun, that its transport layer is pure or a set of ‘dumb pipes,’ and that the interesting aspects of the internet’s infrastructure occur at the edges (Lessig, 2006), this thesis in its entirety proves this to be a false narrative demonstrating the evolving and fluctuating power of the transport layer in internet infrastructure. This transport layer purist narrative has been held in the scholarship of communication infrastructure studies, which, when communications and media infrastructure is misrepresented, this framing can affect policymakers and the public’s understanding of an infrastructure’s materiality thereby not keeping this infrastructure in the public’s interest (Starosielski, 2015b).

This theoretical foundation will work to first identify infrastructure studies as a key field in communication and media studies scholarship as it relates to studying telecommunications networks and the internet. Through this understanding of infrastructure studies, a perspective informed by Winner’s theory of the embedded politics which technologies have, will identify the politics and power which is embedded into infrastructure. Following this tracing of infrastructure studies from a communication and media studies perspective, an understanding of the field of science and technology studies will be explored. In this exploration, ownership of technology will be identified along with how citizens shape technology through a social shaping of
technology and social construction of technology (SCOT) approach. As the chapter continues, understanding technology in its root Latin word, *technē* will be central to the overall argument of not just this theoretical foundation for the research, but the research’s significance as a whole. Finally, the chapter will close with identifying a need for shifting from a Kittler-type understanding of the internet’s components being a software-hardware-wetware approach to one which understands the study of communications infrastructure where all layers are seen to work in tandem with one another, thereby having power along each layer.

### 2.1 Purity and the Need for Pause

As described in the opening of this chapter, although a plethora of astronomers were identifying that the Sun was not a pure entity, but instead had flaws, some of these same astronomers faced moral difficulty with the realization that the Sun was not perfect. The importance of the Sun and its use can be seen chronicled in Plato’s classic ‘Allegory of the Cave.’ In this lesson, Plato identifies how a prisoner being given access to the light of day from their regular shackles in the dark of a cave, where the prisoner is unable to look up towards the flaming ball of fire, and instead cannot see their surroundings for what they truly are (Plato, 1988). Through the ‘Allegory of the Cave,’ Plato is specifically arguing for the importance of access to education and to bring all people this access in order to have a society where the truth of one’s surroundings may be critiqued, questioned, and worked against if the masses are dissatisfied with their once masters’ decisions over the organization of their work and living spaces (here being the Cave) (Plato, 1988). In this respect, without the Sun and its ability to transmit light to a person’s everyday environment, the person lives in darkness from the simplicity and progression which their lives could harness had this access been provided to them.

---

9 These astronomers included Christopher Scheiner, Thomas Harriot, Charles Malapert, Daniel Mögling, Joachim Jungius, and Galileo Galilei (Carrasco et al., 2020).
In the case of this thesis’ theoretical conceptualization in line with the ancient beliefs regarding the purity of the Sun, where nowadays the masses have been told that the transport layer of the internet’s infrastructure is static, ‘dumb,’ and unchanging (Lessig, 2006), the embedded hegemony of common sense not to question this logic prevails. When this common-sense perspective becomes embedded into the public’s framing of a technology, this results in the technology or infrastructure not to be questioned and instead be viewed as an insignificant part of everyday life. Through this embedded hegemony, done either by the State or capitalists, a belief of the universality of these ideas by these ruling classes become pertinent thereby allowing for this ruling idea to remain static in the public conscious (Marx & Engels, 2013). To break this universal understanding of a hegemonic concept, a public consciousness must prevail to challenge this status quo and give power to the masses from the narrow ruling class (Marx, 2013; Marx & Engels, 1848).

Unlike the framing of the Sun through space and time, the framing of infrastructure differs greatly. As Susan Leigh Star put it, infrastructure is “by definition invisible, part of the background for other kinds of work.” (Star, 1999, p. 380). One does not care about infrastructure unless it is either being unveiled or breaks (Starosielski, 2015b). The Sun is impossible for citizens through space and time to ignore given its centrality to our solar system, thereby it cannot be unveiled or break in the existence of humanity. This natural force of the Sun makes it an elemental media, to use the conceptual framing by John Durham Peters, in that it is a media infrastructure found in nature in our everyday environment which shapes our ability to communicate with one another and other aspects of our world (Peters, 2015).
Where infrastructure may be elemental, immaterial, or ‘hidden in plain sight,’ it is necessary for the organization of complex societies. Infrastructure is defined in Canada where this thesis has been written as,

Critical infrastructure (CI) refers to processes, systems, facilities, technologies, networks, assets and services essential to the health, safety, security or economic well-being of Canadians and the effective functioning of government. CI can be stand-alone or interconnected and interdependent within and across provinces, territories and national borders. Disruptions of CI could result in catastrophic loss of life, adverse economic effects and significant harm to public confidence.

(Government of Canada, 2009, para. 1).

Infrastructure, where its importance centres on loss of life, loss of profit, and loss of a favourable reputation, does not sit at the forefront of citizens’ minds. As Nicole Starosielski (2015b) notes, when infrastructure is brought into the public’s attention, it is usually framed in one of two narratives, connection narratives or disruption narratives. In connection narratives, the infrastructure is understood as a means of connecting nodal ends and allowing for collaboration and interconnection between people. In disruption narratives, these detail the fear of a disruption to the infrastructure and what this disruption could mean for safety, economic losses, and a loss of cultural order (Starosielski, 2015b). In essence, infrastructure is understood by policymakers as being key to a harmonious society, however, citizens for the most part do not pay much attention to this infrastructure unless it is unveiled, or if it breaks and disrupts their livelihoods.

Following the same logic as Star (1999), Christian Sandvig identifies, “The first such attribute of infrastructure states that it is normally invisible, becoming apparent only when it breaks.” (2013, p. 96). In this he argues for the importance of studying infrastructure to
understand their forms and boundaries. Because infrastructure is key to the functioning of a society which has embedded infrastructure within it, this infrastructure must have clear policy objectives and understanding by policymakers to ensure the public’s interest in its development and ongoing maintenance. In addition, Shannon Mattern (2015) discusses how from an urban historian perspective, media infrastructures are key to review as urban spaces throughout time and space have been designed to make communication between citizens more efficient. To recap, infrastructure may be thought to be invisible to the public’s radar, however, the design, maintenance, and positionality of these, specifically, communications infrastructures, shape a given society.

These infrastructures, as has been identified thus far tend to be invisible to the public either through physically being unable to be seen or hidden in plain sight. For hidden in plain sight, a bridge is not thought of unless it disrupts a commute, electrical wires and the electricity which flows along them not apparent unless a power outage occurs, and telecommunications networks not coming to the forefront of the masses’ minds until the ability to communicate with others is stifled (this stifling being a poor internet connection, a phone unable to send or receive calls, to name a few examples). In their work on communications infrastructure, Lisa Parks and Nicole Starosielski state in the introduction of their book, Signal Traffic: Critical Studies of Media Infrastructures, that a relational approach should be used in the study of communications infrastructure as this approach “recognizes the industrial, physical, and organizational interconnections of media infrastructures with other systems.” (2015, p. 7). By understanding communications infrastructure through this relational perspective, those who review these infrastructures thereby identify their materiality, or ‘realness’ of the infrastructures in a society.

As Bill Brown identifies,
Materiality can refer to different dimensions of experience, or dimensions beyond (or below) what we generally consider experience to be...[M]ateriality may seem to make the most sense when it is opposed to another term: the material services as a commonsensical antithesis to, for instance...the immaterial.

(2010, p. 49 original emphasis).

This commonsensical antithesis describes an opposing argument which is seen to be exhibiting good judgement and ‘common sense.’ In John Law’s work on actor-network theory (ANT), he states that ANT posits that “order is an effect generated by heterogeneous means.” (1992, p. 382). In this, people communicate with others not through them as sole actors, but through their interactions with various nonhuman actors—or objects—which extend their communicative abilities. In this extension, power may be formed through the use of a complex network of communication extensions, thereby solidifying societal control by means of communicative infrastructure. In this articulation, when studying communications infrastructure, understanding it as existing, or as having materiality, opposed to a state of invisibility is key for the theoretical conceptualization of this field of scholarship. An example Law uses to hone this point is his teaching a classroom filled with students using an overhead projector. He extends his communication capability with his students through his use of the projector, and the conversation is then shaped through the intermediary of this nonhuman actor (Law, 1992). The projector as a technology or infrastructure then shapes how a conversation may take place, thereby resulting in the interaction being commonsensical due to the network of objects which shape the interactions between the various actors communicating with one another. Communication then is not between people but instead through a large system of object intermediaries or nonhumans mixed to extend this interaction. These nonhuman actors in the network, however, may not always be
physical but also immaterial. This thesis makes a similar argument about the intermediary of IPs being immaterial as part of the communicative infrastructure landscape in shaping communication which otherwise would not occur if not for this technology. Through these communicative intermediaries, power and control are exhibited depending on the complexity of systems of shaping communications between people through nonhuman actors. Therefore, the technologies, or infrastructures, are not passive but part of the communication experience.

Studying how technologies and infrastructures affect communication includes physical/material objects, as well immaterial as this thesis does with the transport layer as internet infrastructure. As Star (1999) notes, however, there is a boredom to this type of work. With studying the boring, the mundane, and the hidden mechanisms of infrastructure, the role of the infrastructure studies scholar is difficult. This work, however, is crucial as Bowker et al. (2010) identify that uncovering these marginalized aspects related to infrastructure is necessary to have a complete understanding of the operation of society. Because infrastructures tend to build off one another (for example, for telecommunications networks to work electricity is needed to power them), this ecological framing of the study of infrastructures is necessary to uncover how these infrastructures should be governed to fit with the public’s interest (Bowker et al., 2010). As infrastructures build upon one another through layers, a layered and holistic systems-thinking perspective must be taken to gain a full and true conceptual understanding of these infrastructures.

Understanding infrastructure from a layered/systems-thinking/ecological perspective is key when dissecting areas of power and privilege built into a given infrastructure. Although infrastructures are both material and immaterial, without their own mind and ability to have agency, their construction, maintenance, and ability to administer and manage the masses of a
society are built into them by those who fund and design these infrastructures. In his key article, Langdon Winner asks the question, ‘Do Artefacts Have Politics?’ (Winner, 1980). In his article, Winner identifies because infrastructures—or to use his term ‘technologies’—were built by someone in a position of power in a society, the technology will mirror that powerful person’s ideological beliefs about the given society. Introducing his argument with the example of Robert Moses, a New York City planner from the 1920s until the 1970s, Moses designed New York City in such a way which excluded Black residents and the poor from specific areas of it, thereby fitting with his racist and classist ideologies of the social organization of the city. Moses accomplished this by designing highway underpasses to be too short for public transit busses to pass through, thereby limiting those without an automobile from visiting specific areas, most notably Moses’ acclaimed public park, Jones Beach. As is apparent in the Moses example, the infrastructure of the highway underpass was not neutral but instead was layered with politics of Moses’ racist and social class biases. Moses, a since passed city planner, still has his ideological beliefs embedded into the New York City plan as these large scale infrastructures oftentimes outlasts those who built them, thereby continuing this prejudice landscape even as a society is thought to have ‘progressed’ from these discriminatory times (Winner, 1980).

A second example which Winner identifies in his article is that of new mechanical tomato harvesters which had been designed by University of California researchers, beginning their research in the late 1940s (Winner, 1980). The tomato harvester as a machine allowed for automation of agricultural work in this field. By picking, processing, and packing the tomatoes, many farmers in this specific industry were left out of work. This reduction of jobs based off the new technology was then challenged through a lawsuit filed by the attorneys for the California Rural Legal Assistance. It was argued that the research which left many without jobs was funded
through public money, however, the public’s interest was not central in the development of this technology. Instead, the funds were used to aid in the economic betterment of the already powerful, or in Marxist terms, the bourgeoisie tomato industry (Winner, 1980). This identifies a central framing of technology which is, is all technology beneficial, and if not, what shall be done?

In her book, *Imagining the Internet, Communication, Innovation, and Governance*, Robin Mansell (2012) identifies how narratives will be in place regarding technologies, or the internet as infrastructure, as being good for everyone, however, this is oftentimes not the case. The narratives which are told that technology will be beneficial to all, and that the ‘add technology and stir’ as a policy framework, in that all in a society will benefit from technology added to it, follows one which is defined as technological determinism. Technology instead, however, must be purposefully planned in order to benefit a society thereby falling in its public interest as both Winner and Mansell observe. In Mansell’s words, “Technological change is, in its development and application, fundamentally a social process,” (2012, p. 10 original emphasis). In this, technologies and infrastructures will have social ideologies embedded into their system, resulting in the work of the policymaker to fund and create regulated environments which support a society’s whole opposed to only its bourgeoisie class. As technology is a social process, then technology should work for all those in the given society. Following in the work of Winner (1980) and Mansell (2012), this thesis addresses how the public’s interest must be pertinent in ongoing developments of the transport layer of the internet’s infrastructure. This thesis argues that research and development in the transport layer must refrain from a technologically deterministic frame of reference. Instead, one which centres people as beneficiaries of the introduced technologies is crucial as public interest with embedded infrastructures must be
paramount to limit any politics from internet developers which may be programmed into this communications infrastructure.

Thus far it has been argued that infrastructure studies is a key segment of communication and media studies scholarship. Studying the internet as infrastructure therefore provides a narrative to the public and policymakers which is not guised in an imaginary that all technology is neutral and will be beneficial to everyone in a society. In the next section, a continuation of this argument about the public’s interest and a social sciences and humanities perspective of infrastructure will be explored through a science and technology studies lens.

2.2 Science, Technology, and Society

Infrastructure studies, the primary focus of the previous section, is one branch of a larger area of scholarship called science and technology studies (STS). In STS, the continued purpose of this type of scholarship is to bring a public interest perspective and democratic values to the development, release, and regulation of science and technology in a society. STS derives from an understanding of technological development as it is rooted in automation, industrialization, and modernity, all central areas of political economy work. Political economy asks questions of the relationship between people, power, and capital. Dwayne Winseck, a Professor of Communication and Media Studies out of Carleton University, states, “To put it boldly, political economy is the mother of communication and media studies, if we look back far enough and carefully enough across the disciplines.” (2016, p. 75). Political economy of communication as a field of research in communication and media studies scholarship asks questions as to how power dimensions work in society and how this power influences the exploitation of everyday workers paid and unpaid labour.
Where Winseck (2016) argues that all communication and media studies scholarship have its roots in political economy research, Nicholas Garnham, a Professor Emeritus of Media Studies at the University of Westminster and the founding editor of *Media, Culture and Society*, writes in his frustrations about political economy of communication and calls instead for scholarship in political economy of culture stating, “The term “political economy” (PE) has become a euphemism for a vague, crude, and unself-questioning form of Marxism, linked to a gestural and self-satisfied, if often paranoid radicalism.” (2014, p. 42). In this he identifies his frustrations to be with political economy scholarship in the field of communication and media studies and argues that a plethora of research in this field analyzes media moguls and continuous calls for activism and democratization of media industries through public policy programs is both “theoretically and politically dubious.” (Garnham, 2014, p. 42). The critique of political economy scholarship by Garnham is also explored in articles such as Vincent Mosco’s (2017) with his argument that, by asking only questions of ownership, this results in a weak analysis of areas of power as it relates to the continued development of ICTs in the internet’s evolution.

As Mosco (2017) describes, key developments in ICTs being IoT, privacy and surveillance, big data, and data centres. He critiques recent communication and media studies scholarship as focused too heavily on social media and popular civilian use of ICTs without analyzing institutional power dynamics, specifically the US military’s involvement in ICT development. It is with this guidance regarding being more holistic in critical communications and media studies research that this thesis does not only ask questions of ownership and political systems, but also on people’s use of communication technologies, specifically their interactions with IPs, along with powerful institutional players in the ongoing developments in the transport layer of the internet’s infrastructure. The Marxist origin, however, which earlier Garnham points
to has political economy scholarship work to uncover how some people—the *proletariat*—are exploited through their labour by another class of people who own the means of production—the *bourgeoisie*.

These areas of ownership and exploitation fit the framework of STS when a technology and its ability to either work in the public’s interest or to generate profit for those in power is analyzed. In STS, technologies may be used by those in power—being those who own and develop the technology—specifically to control and manipulate the masses. In her fieldwork on lighting kits being introduced in less-developed countries, Madelaine Arkrich found that introduced technical objects help in constructing heterogeneous networks of both people and other layered technologies and infrastructures (Arkich, 1997). Although dated, Arkrich’s work still shows how a technology introduced into a society will work to create new markets, require new resources, and through these markets and resource needs operate as a system of administration and control over the masses. As she states, “This method of regulation is designed to “groom” the user. It offers a set of rewards and punishments that is intended to teach proper rules of conduct.” (Arkich, 1997, pp. 218–219). This issue of technology controlling the masses, however, does not always stand as a true argument.

A key term in STS research is the *social shaping of technology*. This is defined as the process whereby technology will shape a society, but society also shapes technology as its usage increases. Donald Mackenzie and Judy Wajcman (1999) detail the process of social shaping of technology and identify that inventions will occur no matter what, however, a society must be ‘just right’ for an invention to actually gain use. Technology therefore does not determine society, but instead people’s rate of accepting the technology can change society to an extent (MacKenzie & Wajcman, 1999). It is key to continue the earlier arguments made about the
scholarship of infrastructure studies that studying an introduction of a scientific phenomenon or technology into society must be analyzed to ensure the agency and interests of the masses is upheld with this introduction of a newfound technology, opposed to falling into a capitalist imposition of forced use. This importance of analysis is argued by Paul Edwalds in that technology, or infrastructure, must be studied at a micro, meso, and macro scale, thereby providing a holistic image of a technology or infrastructure to better serve the public’s interest through a shift in the society to modernity (Edwalds, 2003). This thesis follows this mode of analysis by asking questions of how citizens will use IPs and what political processes impose these IPs as only options for access to various technologies – specifically as this thesis describes, internet-based technologies.

Following along the same frame of thought of the importance in studying varying layers of science and technology throughout time and space, as well through a social shaping of technology approach, Trevor Pinch and Weibe Bijker provide an STS analytical mode of inquiry called the social construction of technology (SCOT). Rooted in the sociology of science and technology, SCOT as a mode of inquiry demonstrates how when studying infrastructure and technology, different groups of people in a society will interact with an introduced technology differently. This interaction results in changes made to the introduced technology, based on the manufacturer’s/designer’s decision of which group in a society they would prefer their technology to be utilized by. What this means for the technology or infrastructure, according to Pinch and Bijker (1984), and how the technology or infrastructure is understood is that these are socially constructed. Social construction is a concept in sociology which describes that nothing happens naturally, but instead the interpretation and negotiation of an event occurs which brings its understanding to the person experiencing an occurrence. In this, an event only holds reality
when it is constructed in one’s mind as real and true. Once this occurs, knowledge is built either through an individual’s experience, or another’s which is retold as the constructed experience for the knowledge-building process (Pinch & Bijker, 1984). This social constructivist approach when used to build knowledge about technology and infrastructure will have knowledge of these developments interpreted and negotiated by varying actors in a society, all who have varying opinions regarding the importance of the technology or infrastructure which had been introduced into their lives. With this study’s review of the transport layer, however, when citizens are not engaged with knowledge about fluctuations in their transport layer protocols, they may not negotiate how these technical standards work for them in their lives as the technology changes.

If social groups are successful, however, in the negotiating process, the manufacturer will then choose which group(s) to design their technology for (e.g., a critical mass of internet users for transport layer protocols, a business segment instead, etc.). In Pinch and Bijker’s conceptual development of SCOT, they use the analogy of the way bicycles have been developed throughout time. In 1892 the Rudge Ordinary bicycle was released to the public as a new form of transportation. With an incredibly large front wheel, a seat which was high to climb to, and tires which were not filled with air thereby having the rider of the bicycle experience tensions from the ground throughout their ride, the bicycle was deemed unsafe by women and elderly men. Through their complaints that they could not experience the bicycle with its speed, sportsmanship capabilities, and overall excitement of the new technology which could only be safely enjoyed by young fit men, the design of bicycles began to change with tires of paralleled similar shape, a seat level with the ground as not to climb up onto it, and air-filled tires which would reduce the tensions felt by the rider during a cycling trip. As the design of the bicycle changes through this social negotiation it became a more equitable technology for all in a
society, thereby working to enhance the public’s interest through its redevelopment. Where the need for new and easy transportation was filled by the Rudge Ordinary, it did not work for all citizens and was classified as a technology not willing to be embedded any further in its society (Pinch & Bijker, 1984).

This importance on having technology negotiated by the public to keep it in the public’s interest is a key understanding of the further development of communications infrastructure, specifically changes to the transport layer of the internet’s infrastructure. By users of the technology having agency, this empowers people to shape a technology to suit their needs opposed to a technology being imposed on them. As this thesis works to demonstrate, IPs and their early developments were a result of a need by the masses to have decentralized computerized communication processes. This history is further explored in Chapter Four. In the next section, the importance of keeping technology and infrastructure as a means to promote social progression and a more equitable society will be explored.

2.3 Technē and Capitalism’s Perversion

In the study of STS, it is important to analyze the language which one is drawing from. Here I will identify the term ‘technology.’ Technology as a word is comprised of two sections: ‘techn-’ and ‘ology.’ With ‘ology’ being the suffix of the word to identify a branch of knowledge, ‘techn’ is rooted in its Latin term ‘technē.’ Technē is defined as understanding technology as a form of craft, something which holds artistic value to it (Feenberg, 2013). As Andrew Feenberg (2013) describes, “Technē thus incorporates the ends as well as the means, the final cause as well as the matter, form and skills of the maker.” (p. 607). Technē gives agency to the person who developed it, it works as a tool for the betterment of others, it provides a body of
knowledge for how to realize the objective essence in natural objects. Technē, however, is in regular distress.

In his theoretical analysis of Marcuse’s phenomenology as presented in *One-Dimensional Man*, Feenberg describes the ability for technology to work to extend the livelihoods of citizens. When a technology, however, is consumed by capitalism and capitalism’s obsession with gaining profit and willingness to exploit people, planet, and place for this profit, technē moves towards being understood as ‘technology,’ which does not work for the betterment of all in a society. Instead, when a technology or infrastructure is twisted to the ideological beliefs and benefitting only the few, this results in a less equitable society where the masses are hurt.¹⁰ As Feenberg identifies, “under capitalism the final achievement of technical mastery has been perverted into a means of domination.” (2013, p. 609).

Using this understanding of technology as being a perversion of technē, the importance of protecting technē before this perversion occurs is imperative. Once a technology is released to the public, as the previous SCOT analysis shows with the conceptual framing of the bicycle by Pinch and Bijker (1984), the labour of making changes to the technology falls on the general public. The labour of the masses, to use a Marxist political economy perspective, is unpaid and continues to benefit the bourgeoisie as the negotiations needed for the technology through this social shaping of technology has this work being completed by the masses, with them then having to either continue using the released technology due to no other options, and/or having to purchase a second set of technologies once a more effective model is released which reflects this public interest. In both instances, however, the proletariat are exploited through labour and capital while the bourgeoisie continue to profit off this exploitation. It then becomes the role of

¹⁰ Reference the explanation of the ideology-driven planning of New York City by Robert Moses and the autotomized tomato harvester developed by University of California researchers detailed at the start of this chapter.
the policymaker to develop regulated environments which work to ensure technē is preserved for
the social, scientific, and technological progression of a society. In order to do this, however,
policymakers must be provided with research on technē, or as I will otherwise identify, research
on infrastructure.

This infrastructure studies research which follows a technē as art and craft perspective,
however, can become difficult. As identified earlier, not only has scholarship of infrastructure
been regarded as ‘boring’ and ‘mundane’ (Star, 1999), specifically transport-layer infrastructure
which this thesis studies is incredibly under-researched in communication and media studies,
who are meant to be those to bring a humanities perspective to communications infrastructures
along all of its layers. Part of the issue with this difficulty, specifically for the transport layer of
the internet’s infrastructure, is a lack of vocabulary identified in the scholarly theoretical
literature on computer networks which allows for a more accurate conceptualization of this type
of research.

For scholarship on various components of how computers operate, a key media theorist in
this area to turn to is Friedrich Kittler, a late leading German media theorist (Winthrop-Young,
2011). Kittler argued that in computerized environments there is no such thing as software, but
only hardware. As Kittler stated, “When meanings come down to sentences, sentences to words,
and words to letters, there is no software at all. Rather, there would be no software if computer
systems were not surrounded any longer by an environment of everyday languages.” (1995, para.
11). What he meant by this was that the software which a computer uses, for example a word
processing program, must take commands by the pushing of buttons to set instruction. Surfing
the Web requires for the user to float their fingers across keys and a mouse or trackpad. In this,
Kittler argues that the computer is hardware in its entirety opposed to a collection of various
software because each software requires a person to mechanically maneuver the computer to complete a given task (Kittler, 1995). This framing of software being derived from physical decisions made is found in the tracing of the word ‘software’ as identified by Geoffrey Winthrop-Young, originated “in the mid-nineteenth century, “software” first referred to woolen or cotton fabric and more generally to perishable consumer goods.” (2010, p. 190). The understanding of software, however, is one of code and with the transport layer of the internet’s infrastructure being a coded environment, then the binary of software-hardware as a frame of understanding data transportation is not accurate in the study of IPs which is this thesis’ objective.

It is here that a vocabulary and a mode of inquiry for understanding the internet’s infrastructure is required. In the early sections of this chapter I noted Lisa Parks and Nicole Starosielski (2015) as identifying the importance of studying communications infrastructure through a relational approach. Through this relational approach, Parks and Starosielski state they “address the different and uneven conditions that shape and characterize media infrastructures around the world as well as the labor, maintenance, and repair required to build and sustain them.” (2015, p. 7 original emphasis). In the study of the transport layer, this layer works in relation to both the physical and applications layers. The transport layer is often described as both ‘dumb’ as well a ‘bottleneck layer’ where the transport of data is only a shorter and smaller point of the internet as infrastructure (B. Paris, 2018). These descriptions further proliferate the framing that the internet’s ‘interesting’ components and power rests along its edges (Lessig, 2006), opposed to along all of its layers. These framings of the transport layer as abstract, render this transport layer immaterial, and do not recognize the ways in which IPs work in the relational model of infrastructure studies. By denoting this layer to minimalist language the transport layer
as infrastructure studies becomes difficult to reference, thereby not providing this crucial layer with materiality (Dourish, 2015).

Where Kittler described all software as being hardware, and John Durham Peters arguing that “[s]oftware often outlast its compatible hardware” (2015, p. 32), this thesis argues that the transport layer will often outlast both malleable software and material hardware, and that all infrastructure can be described through relational layers and hold materiality whether end users interact with a specific layer or not. Through this relational approach, the recognition that the transport layer is a material part of the internet’s infrastructure falls in line with Paul Dourish’s (2015) work on IPs. By recognizing this layer as infrastructure, critiquing its power within a society may be done by the communication and media studies scholar.

2.4 Standards as Power

With the theoretical underpin of technē, this thesis positions itself in understanding the internet as infrastructure as one of art and craft throughout each of its layers. Technologies—specifically the internet due to its open functions and affordances of interoperability—are developed using technical standards. Cargill and Bolin (2006) define standards as,

a technical specification that codifies a set of interfaces which describe the necessary methodology to achieve interoperation between disparate programs. The standard does not say how the interfaces are to be met, only that the interfaces must be open (that is, not proprietary), accessible, and fall within the realm of reality. It would also be nice if the interface recognizes that there are global requirements. This specification is the result of action by an SSO [standards setting organization].

(p. 311).
For a specification to become a standard, it must go through standardization. Standardization is the process, which may be formal through governments – making a \textit{de jure} standard, or informal through industry associations resulting in a \textit{de facto} standard (in essence, a specification) (Cargill & Bolin, 2006; David & Greenstein, 1990), in which a technical specification for an industry is decided to allow for interoperability, thereby allowing market participation, entrance of new players, and development of new markets (Thompson, 1954). Standardization processes will occur through standards setting organizations (SSOs) and/or standards developing organizations (SDOs). An SSO encompasses SDOs (e.g., working groups within a larger SSO) and, according to Cargill and Bolin (2006), have five basic variants. These SSO variants include: trade associations, formal SDOs, consortia, alliances, and the open-source software movement.

Trade associations have historically developed standards to allow for parts manufacturing and safety concerns. As Thompson’s (1954) examination of the early 20\textsuperscript{th} century American automobile industry shows, the use of standards accelerated the industry’s growth because of this interoperability in the manufacturing process. This was because suppliers were able to achieve economies of scale, as well, replacement parts were standardized in their fit, technical specifications, size, materials, etc., thus lowering the costs of repair and replacement (Thompson, 1954). As David and Greenstein have noted, however, Thompson’s analysis was dependent to timing of this then-emerging 1910-1920s American industry, as the timing of the introduction of standards into product development is key to ensure a standard is not ‘catching up’ to existing specifications, or that the proposal of the standard will not stunt a growing industry through changes to the production line (David & Greenstein, 1990). The time of writing with a focus on physical manufacturing may have affected Thompson’s definition of standards, which is similar but different to Cargill and Bolin’s (2006), as Thompson (1954) defines standards as,
In a broad sense, standards are simply agreements on common usage, and they have existed since the beginnings of organized society. Signs, language, weights, and common mediums are among the basic kinds of standards. They promote system and efficiency in social relationships. As a society advances industrially it begins to create other, more technical standards designed to make production more efficient and to facilitate use of the manufactured product.

Where Cargill and Bolin define standards as fitting into a larger resource matrix of interoperability between various technical interfaces, aligning to Winner’s (1977) manifest of social complexity in that these complexities are no longer comprehensible to anyone, Thompson’s definition of standards comes from one of society-accepted specifications to ensure harmonious activity and growth of industries.

In the early American automobile industry, standards were formed through then-emerging industry/trade standardization associations (Thompson, 1954). With the transport layer of the internet, this thesis’ focus, standardization is done through large international SSOs and intergovernmental organizations (in this thesis, the ITU is examined). The primary SSO for the internet is the IETF whose unofficial motto is “rough consensus and running code.” (Simcoe, 2006, p. 268). This motto shows the IETF’s non-formal approach to standardization and greater focus on the code than on any politics which may occur in the standardization process (Simcoe, 2006). In Simcoe’s analysis of the IETF and how standards come to be, multiple draft stages are apparent which are results of individuals and/or working groups. In this standardization process of the internet, *de jure* standards are limited due to the length of time taken for the IETF’s standard setting process, which oftentimes is too long to fit the needs of the speed of
development, and instead *de facto* standards are developed from vendor representatives in the early working group phase to allow for this leapfrogging. The following image describes this multi-faceted IETF standardization process of a central area of the global economy: the internet.

(Simcoe, 2006, p. 268).

*Figure 2: IETF standard setting process*

This standardization process has been criticized for its length of time (Simcoe, 2006), however, more often hailed for its well-managed scaffolding which has allowed the internet to grow as an increasingly central space for global economic activity (Cargill & Bolin, 2006; Simcoe, 2006). Where the IETF is a standards-setting organization, it does not afford regulatory requirements of its standards. Instead, inter-governmental telecommunications regulators which have Member States voting on the acceptance of a standard, then become more powerful players due to this oversight (Cargill & Bolin, 2006; Simcoe, 2006). In this, the ITU, a division of the United Nations, is king for standard enforcement. The ability of the IETF to ensure collaboration and compatibility—fundamental identities of a smooth-running SSO—allow for these standards, however, to be taken up by international technology companies, thereby cementing the *de jure* standard as decided in this organization, thereby still holding significant global power in the area of internet standards setting (Simcoe, 2006). The standard then as *technē*, becomes technology through these global players enacting standards for private gains.
Paul David, an economist who has done considerable work in the area of technology standardization processes, states that ‘market failure’ and ‘public goods’ need to be explained their relevance for “understanding the evolution of technology in a market economy.” (David, 1999, p. 3). To this, David identifies the development of the QWERTY keyboard as not the best keyboard, nor the most practical, but instead the standard keyboard due to E. Remington and Sons’ 19th century type writer, where a salesperson could use a combination of the top row of the QWERTY keyboard to type the words ‘TYPE WRITER’ branding the object (David, 1985, 1999). In this, the standard was never a piece of technē, but instead had already undergone perversion for capitalist gain. Standardization therefore is not an innocent process, but instead one which is formed to ensure market gains and public goods by creating complexity in manufacturing processes to then prevent market failure of a specified industry.

In other words, standards are political entities which are used to ensure interoperability between technical components to then allow for reduced risk of market failure. In standardization, the processes may be slow in comparison to market needs, thereby resulting in de facto standards opposed to formalized de jure standards. Standards then as a space of theory are entities which have the ability—and history—of serving the public good and public’s interest, however, they have undergone perversion in their international acceptance in the area of information communication technologies and telecommunications standards and specifications.

In this chapter I have identified and traced the scholarship of infrastructure studies through a communication and media studies scholar lens. In this I identified the importance of studying the invisible, the boring, and the oftentimes mundane work of infrastructure studies as this area of scholarship is key to having an accurate narrative about the materiality of
communications infrastructures. Developing a holistic understanding of the internet’s transport layer is key as the narrative of the transport layer as a collection of ‘dumb pipes’ and being unchanged, parallels that of pre-17th century conceptualizations about the purity of the Sun prior to the discovery of sunspots, which did not recognize the regular changes to its structure and its constant evolution. To best understand communications infrastructure, an identification of the field of STS through its origins in political economy work was investigated, thereby providing the understanding of the importance of preserving technē. It was finally identified that the role of the infrastructure studies scholar is to produce research which helps to preserve technē, but to do this a vocabulary for a social sciences and humanities approach which recognizes the materiality of all layers of the internet’s infrastructure. Through this theoretical foundation, I have positioned my work in the field of STS, specifically along with infrastructure studies, providing a foundation to understand the cultural phenomena of the narratives and reality of the transport layer of the internet’s infrastructure.
Chapter Three: Uncovering the Stories of Standards

“In my visits, I saw something the ITU and the rest of the standards bureaucracy seem to have missed. The Internet is here and it is not an academic toy.”

(Malamud, 1993, p. x).

In this chapter I outline the methodological framework used to complete this study. The transport layer of the internet’s infrastructure, with the evolving power dynamics of this layer, as an emerging body of research requires a mix of new methods. The study of IPs also require methods centred in the public’s interest, similar to Fenwick McKelvey’s (2014) work in algorithms and a need for democratic methods which focus on publics. To answer this thesis’ central research question, “What are the political and economic power dynamics involved in the transport layer of the internet?” a mixed methods approach was taken. I studied Internet Engineering Task Force (IETF) primary documents: their Return for Comments (RFCs). In conjunction to this RFCs, I studied internet development background information and historical contexts of engineering papers regarding the transport layer of the internet. For present-day analysis, these included watching recorded conference presentations—an affordance of the virtual conference landscape during the COVID-19 pandemic where talks have been recorded and uploaded to websites— and technical papers provided by the ITU. Finally, utilizing the network protocol reader Wireshark, I quantitatively analyzed a selection of high-bandwidth streaming platforms to determine how popular high-bandwidth websites are coded between transport layer IPs. This thesis’ methodology had four central goals: uncover the history of IPs and why TCP and UDP were chosen for the internet’s transport layer, determine key players in contemporary transport layer developments, identify how the public interacts with IPs in the transport layer, and determine the ways in which the transport layer is changing with increased
reliance on emerging high-bandwidth technologies. In this chapter I discuss how my methods were influenced by the wider body of literature and explain why mixed methods must be used in transport layer research opposed to only qualitative, or only quantitative methods.

3.1 In a Snapshot: A Roadmap of the Research Methods

The study uses four methods: three qualitative methods and one quantitative method. Through this qualitative-quantitative methodological framework, the study is defined as ‘mixed methods.’ Mixed methods as a mode of analysis uses both qualitative and quantitative methods to piece together data from various angles and solve a specified research problem (Creswell, 2015). The theoretical influence of using a mixed methods approach to research is that the researcher will benefit from drawing on the strengths of both qualitative and quantitative research methods. With this triangulation built into the research methodology, it is argued mixed methods will then limit any margin of error in the overall research results (Creswell, 2015).

The organizational format I took in the research to construct an analysis of IPs was as such; First, I completed a critical policy analysis of the 1993 Canadian Telecommunications Act in order to determine the ways international standards setting was incorporated into the legislation. The Telecommunications Act was necessary to analyze as a first step as this is Canada’s policy on ICTs. Through this critical policy analysis, I was influenced by the theoretical positioning that public policy has an obligation to serve the public’s interest (Shade, 2008). After outlining this positionality in my first analysis of Canada’s telecommunications policy, which I include in the discussion of this thesis, I began a historical analysis of the transport layer’s two IPs being TCP and UDP. Immediately I was drawn to information that while the ARPANET project was being researched in the US for connecting academic institutions, at the ITU there was information along Work Programmes X.1083 and J.369.1
regarding AT&T and other telecommunications and computer corporations’ requests for changes in IP network configuration for new supports in residential telephony features (ITU-T, 1998, 2012). This surprised me because the internet was an American project, so international standardization felt surprising. These programmes ended up being a result of virtual switching technologies, or videotex as was described in the introduction of this thesis. In my initial learning of these developments, however, I began asking question of how the international community were transitioning their nations to computerization and if other internet-type ventures were occurring. As this thesis identifies, this question of nation-states other than the US developing decentralized computer communication does show a pattern of what could have been multiple internets throughout its short 20th to 21st century history and the ways in which the TCP/IP suite has been negotiated to become the prevalent standard of ‘internet.’

To construct the history of TCP and UDP, I used media history as a method of reviewing both primary sources (coming from RFCs and published accounts of events from internet pioneers) along with secondary sources (academic books and articles). In media history research, the researcher uses a mix of primary and secondary sources to allow for specified questions which were gaps or out of scope in previous historic accounts to be filled (Merrigan et al., 2012). As I collected these primary documents, I organized them chronologically to build the story of IPs, specifically focusing on TCP and UDP. While I chronologically organized and analyzed the primary documents in my historical analysis, I continued my review of secondary documents in the form of published academic research, available government and industry reports on IPs and the conversations surrounding their standardization. These documents tended to be stored in the IETF’s database, with the exception of a handful of conference papers on internet standards and documented histories by pioneers for non-governmental organizations. This analysis of
discussions about IPs through the past 50 years identified a myth that TCP/IP is the sole and only IP the internet was built on through an end-to-end modeled framework (McKelvey, 2010; Pickard & Berman, 2019), with the exception of scholars identifying an analysis of other IPs in use today (Dourish, 2015) and ones which competed with the TCP/IP suite in its early days (Russell, 2013). Studies on IPs are limited as there are only a handful of IPs with the TCP/IP suite as the only publicly used IP.\(^{11}\) This limitation in the number of IPs and TCP/IP working as a set of ‘dumb pipes’ have resulted in research in this layer not necessarily needed. This, however, has changed since 2018 as this thesis identifies in Chapter Five with developments by China.

In the more contemporary history, I analyzed additional primary documents such as white papers, terms of reference documents for ITU study groups on transport layer internet protocol standardization, and conference presentations and slide decks which allowed for incredibly recent developments in this field to be assessed in this research. Additionally, I also studied blog posts by key players as identified from these earlier slide decks (these key players including the companies which specific computer engineers worked for) and journalistic coverage of the transport layer in 2020. Again, this provided the most up-to-date developments in this layer of the internet’s infrastructure.

In the completion of the data collation and to identify how TCP and UDP are used in common internet consumption for high-bandwidth websites, a network protocol analysis program, Wireshark, was used to collect quantitative data for identifying Canadian households’ IP interactions (with this testing done in my household in Calgary, Alberta). The high-

\(^{11}\) As this thesis shows NASA uses a separate IP for interplanetary communication. Paul Dourish’s work has also identified the ways telecommunications corporations will occasionally use Autonomous Transfer Mode (ATM), but that this is not used by the masses and had failed in its attempt when released to gain public traction.
bandwidth websites which were used for analysis were video streaming sites: YouTube, Netflix, Crave, CBC Gem, Amazon Prime, and Disney+. I chose these websites because they are identified as the most popular streaming websites in Canada by the Canadian Radio-television and Telecommunications Commission (CRTC) in their annual *Communications Monitoring Report*. These streaming platforms also contribute strain on our physical broadband networks through their high-bandwidth usage from audio-visual content. By choosing these websites, this then allowed for bias of websites to be limited for the scope of study by mirroring the websites which Canadians are using, opposed to the ones used in my household. My household simply acted as a lab space.

Following the collection of primary, secondary, and quantitative Wireshark data, I coded these documents and network data outputs in NVivo as a qualitative data analysis software program to determine themes and an organized chronology of conversations and events about IPs. I chose NVivo as a qualitative data analysis software tool for three reasons. First, it is an industry leading data analysis software program which I had experience using and has been tried, used, and promoted by communication and media studies scholars (e.g., Livingstone, 2008). Second, NVivo allows for a bibliographic software integration for Zotero, Mendeley, and EndNote, which allowed for my secondary documents from my Zotero account to easily integrate with my primary documents located in NVivo for a cross-analysis of nodal themes in how IP standardization has been documented and discussed over the past five decades. Finally, NVivo was used because my institution, the University of Calgary, covers the costs of an annual subscription for their employees and graduate students making this program easily accessible to me in the completion of this thesis. The codebook I used for my thematic analysis in NVivo can be found in Appendix B.
The above has provided an overarching roadmap and description of how the research for this thesis was completed. In the following sections I will describe the theoretical influences for my choice of the methods.

3.2 The Starting Point: ICT Policy and the Public’s (dis)Interest

I first began my research with determining which Canadian ICT policies to review and concluded with the 1993 *Telecommunications Act* as the most appropriate government document to analyze. The *Telecommunications Act* was chosen without additional Canadian ICT policies at either federal or provincial levels, as the process of standardization is completed by nationalities accepting international standards for varying reasons both of national sovereignty and access to the global economy (Crane, 1979). As part of Canada’s *Telecommunications Act*, s.15 states the areas of technical standards in Canadian telecommunications. This section was paramount to situating Canadian policy in telecommunications standards. Regarding a concern for the public’s interest, the *Telecommunications Act*, specifies in s.7 the objectives in which telecommunications ought to work for and be accessible to all Canadians (*Telecommunications Act*, 1993). In this, telecommunications policy enshrines the idea of ICTs working towards the public’s benefit, including the standards which these ICTs are built on.

Policy is defined as “any course of action (or inaction) relating to the selection of goals, the definition of values or the allocation of resources.” (Codd, 1988, p. 235). In this definition, policies have the ability to identify the moral character and how resources are allocated within a specified geographic region. This research of policy according to John A. Codd, follows his continued argument that policy is an exercise of power and its language legitimates this captured power. The role of policy analysis, according to Codd, is then to either analyze a policy’s
determination and effects on various groups, or analyze the policy’s content, which “examines the values, assumptions and ideologies underpinning the policy process.” (1988, p. 236).

In their book, *Net Neutrality: A New Deal for the Digital Age*, Victor Pickard and David Elliot Berman identify net neutrality as a policy through situating it historically and providing contemporary attempts of various players in government and industry working to dismantle it (2019). In the book, Pickard and Berman (2019) discuss how when policies are disbanded or warped to serve the interests of the powerful it takes a notified public to assemble and push back on these policy changes to ensure their public interest through the will of the collective. Using American net neutrality as a case study, the book analyzes how the policy had changed and continues to change, along with key public figures like former President Barrack Obama and comedian John Oliver as using their celebrity to propel public interest in ICT policymaking and policy preservation. In this book, the authors complete what policy theorist John A. Codd would identify as policy analysis, as the research works to identify the policy process of the net neutrality example for the reader. This book’s ability to clearly and critically complete policy analysis as a means of documentation and a call for public action over an internet policy piece informed my process for completing policy analysis as a method to answer this thesis’ research question. I was influenced by this specific case of net neutrality as an informed public on issues related to computational code was identified as the first step in the citizenry demanding their sustained public interest in their internet use.

With media policy analysis, however, a critical lens must be taken to establish an understanding as to why policies have developed the way they have (Merrigan et al., 2012). As Popiel, Pickard, and Lloyd (2017) argue, there is an “increasing need for critical [media] policy research that contributes to public debate and understanding of these issues, helping maximize
public input and mobilize action to counter these trends.” (pp. 4698-4699). In this, the role of the media policy researcher is one of praxis which works to apply, energize, or practice an idea. The writing of Vincent Mosco echoes this sentiment 30 years earlier that telecommunication policy ought to have a social element to it as telecommunications is a public good in contemporary societies (Mosco, 1988). This argument of telecommunication and media policy as working to also serve the public influenced the shaping of my research question to ask questions of power, then identifying recommendations of how to ensure the transport layer of the internet’s infrastructure works to benefit all citizens, opposed to those who have been educated in understanding code. Through this informed public interest perspective of the research method, the discussion of this thesis identifies specific policy acts which Canada may take, with Chapter Five identifying current policy processes in Canada’s international internet standards setting.

3.3 Overcoming the Myth: Building a History of Multiple Protocols

Part of the work of this thesis in answering questions about which IPs are used along the transport layer as internet uses shift (e.g., during the pandemic we have seen a shift to days spent on video conference software programs which affects whether TCP or UDP is used). This then becomes a question of affordances. As defined by Bucher and Helmond (2017), “the concept of affordances is generally used to describe what material artifacts such as media technologies allow people to do.” (p. 235). Affordances were originally developed in the field of ecological psychology, however, work well in the study of online spaces (Bucher & Helmond, 2017). As this thesis demonstrates in its analysis of RFCs, TCP was the building blocks of the internet, however, UDP is increasingly becoming a dominant player in users’ experience with their online activities. This shows how the internet is in constant change with UDP being used for more

12 Bucher & Helmond’s book chapter specifies social media platforms, which are part of the applications layer of the internet’s infrastructure but allow for similar understanding of these immaterial spaces built on code.
internet applications with the need for real-time data transfers, whether through Voice over IP (VoIP) video or audio calls made, broadcasts of live events like sports, or real-time video games played. Different IPs have different affordances, so analyzing the primary documents (being RFCs) of the technical affordances of both TCP and UDP was part of the research’s data collection.

Primary document RFCs which detail affordances were collected from the IETF. This institution was chosen as it holds all RFCs which are both outstanding and archived published on their website (https://www.ietf.org/standards/rfcs/). The documents were easily available and chronicled logically for me to review and build a complete history and ongoing analysis from documents spanning from 1972 until early 2021. As Christian Sandvig writes nearly 15 years ago with primary document analysis as a method in STS for analyzing power and key players in IP standardization,

Changing the Internet’s fundamental protocols is now accomplished through a public process negotiated in international standards bodies, and the resulting solutions are published and available for free to anyone, as is the specification of the Internet’s protocols. This means simply that challenging “technical” problems for the production of culture, or any human value, can be unearthed in these public documents and addressed. (2006, pp. 110–111).

Primary document analysis as a research method in historical and policy research works to aid the researcher in understanding the motives of all key stakeholders—being government, industry, and citizens—as part of the story for how an industry develops and how that industry is also governed (Merrigan et al., 2012). Not a primary document, but a key piece of Canadian telecommunications policy research which uses this same method is Robert Babe’s book,
Telecommunications in Canada: Technology, Industry, and Government. In this work, his historical and policy analysis as methods work interconnectedly through analyzing these primary documents in order to determine why telecommunications in Canada had developed the way it did (Babe, 1990). As his book identifies with the telecommunications industry, to understand how the industry is regulated by government, a student of telecommunications policy must also understand how the industry developed over this same time. By analyzing both key players, industry and government, Babe (1990) was able to piece together the specific motives of each player and what these motives meant for Canadians’ access to telecommunications services up until the 1980s during his time of writing. Questions of the public’s benefit of this regulatory field and the public’s interest were then able to be posed through a historical understanding of the field.

This analysis of all key stakeholders and how they progress in technological and policy discussions influenced me to keep an acute eye on emerging key players in transport layer development once they were identified. Following determining who the key industry and policy players were—in this thesis’ case the key policy institution was the ITU with an engineer from Huawei as the key industry player as Chapter Five will describe—I tracked any journal publications, authored white papers, blog articles, invited recorded talks, keynotes, slide decks, and bits of information I could find on the key players. In reviewing these items as primary documents, specifically the recorded talks and slide decks, this allowed for the most up to date conversations about fluctuating developments in the transport layer to be analyzed. Recorded talks, however, were a methodological affordance provided by conferences held over video conferencing software programs (e.g., Zoom), with an easy record and publish to a website option. Watching video discussions opposed to reviewing written material provided me the
ability to track themes of personal frustrations by key players (as I detail in Chapter Five, this included media coverage of the transport layer). In collaboration with these recorded talks and learning of frustrations by key players, I analyzed news stories as primary documents which covered developments in the transport layer of the internet’s infrastructure in 2020. The only news agency which published content on this topic was the UK’s Financial Times. Reviewing news sources contributed to the process of ‘following the story’ in the contemporary developing power fluctuations of the transport layer, thereby answering this thesis’ research question.

In his opening issue of Science, Technology, & Human Values, Malte Ziewitz identifies that in algorithms when research is not presented in an easy-to-follow layout, where an understanding of the development of a specific technology occurs, the public understanding of a given technology can move “[f]rom [m]yth to [m]ess” (Ziewitz, 2016, p. 6). Although my research does not work to better understand algorithms, this concept of a need for a calm, critical, and storytelling means of decontextualizing a complex technology lends itself to my work. Ziewitz further outlines how themes of agency, inscrutability, and normativity appear in research on this coded environment and a need for critical scholarship to identify that computer code is not a natural phenomenon, but instead one which was built by people, with their own motives, values, and politics which may not be in service to the public’s interest (Ziewitz, 2016). This ability to critically analyze how computer code, as presented by Ziewitz as not natural in its development, along with a need for the telecommunications policy researcher to analyze primary documents from multiple stakeholders to identify the story of how a technology has developed and been regulated through time, are the key influences for how I completed the historical and contemporary story of transport layer developments.
By working with a multitude of primary document formats (recorded videos, blog posts, RFCs, published emails, white papers, technical reports, presented slide decks) I could complete a thorough account on the development of IPs in use, or soon to be. This methodological approach of storytelling from the collection and analysis of primary documents fills the gap in the literature of the shifting power of the transport layer of the internet’s infrastructure. Sandvig et al. (2014) argue for the importance of the public being educated on the power dynamics of coded environments, however their work specifically writing about algorithms opposed to IPs. They state, “the public may need to know something about how algorithms operate even if there is no recourse to legal tools and it is not likely that a crime has been committed.” (Sandvig et al., 2014, p. 4). In this, the first step of ensuring the public’s interest with computer coded technologies is to first educate them on these issues and the technology itself and the power dynamics at play in this technological development.

Where tracing the story of IPs over the decades and more contemporary in 2020 aids to disseminate knowledge of this layer of the internet, these qualitative methods alone do not provide thorough understanding of citizens’ interactions with IPs. To address this, a quantitative method was incorporated into the study.

3.4 Everyday Internet Users: A Quantitative Approach to Social Science IP Research

For the quantitative method in this study’s mixed methods approach, a network protocol analysis software program, Wireshark, was used to deconstruct and read IPs of a selection of high-bandwidth websites. Network protocol analysis software programs allow for information technologies (IT) professionals to identify how packets of data are being transferred on a specific server, the characteristics of the transported packets incoming to the server and their code, and works as an overall tool for determining network problems (Wireshark, n.d.). By using this
quantitative method, my research was influenced by scholars like Fenwick McKelvey who study the way algorithms work together as areas of power and influence, and argues for coded environments to be studied as systems which interconnect with one another opposed to single algorithms, or in this thesis’ case, single IPs (McKelvey, 2014, 2018).

In understanding how ‘code affects code’ I looked at how the applications layer, software programs, would intersect with the transport layer, IPs. By using this quantitative method to review intersections of layers, it allowed me to further identify how websites will state their capabilities work along the affordances of one IP (UDP) while being coded in another IP (TCP). This was especially apparent in differing advertised affordances of streaming platforms, versus the affordances provided by specific IPs which these online platforms were coded in. Wireshark allowed me to review a website’s protocols and ask a yes/no question being, Do the advertised affordances of the website match the protocol? If no was picked, I analyzed why this may be the case. The end of Chapter 4 outlines the findings of the Wireshark data. As this thesis shows using this method, when studying IPs, creative methodologies which work as a ‘check’ of the outlined affordances of IPs is needed. Otherwise, the researcher would rely on recommendations of affordances without ensuring their accuracy in practice. Appendix A provides a table for more information regarding each streaming platform studied for this process.

McKelvey (2014) argues that STS researchers must find unique methods for studying coded environments and that these methods must be democratic in their implementation as scholarship and case studies have continued to identify the ways social, political, and cultural interactions between citizens can and are shaped by the use of these technologies which often reflect the values of the powerful and aid in further circulating this power among the top few in a society (McKelvey, 2010). Although my research does not focus on algorithms, the influence of
s scholarship in algorithmic media is beneficial as it provides a mode of analysis for studying and deconceptualizing coded environments with the power of the transport layer. By using Wireshark, and to a lesser extent the recorded talks, this aided in the ‘unique methods’ for studying coded environments from a telecommunications policy research standpoint.

This sentiment of the importance of analyzing coded environments is echoed by Lev Manovich (2013) in his book, Software Takes Command. In the book, Manovich argues for the importance of studying coded environments—specifically software for his work—as software continues to shape a globalized world through this administrative system of coded control (Manovich, 2013). As Manovich states, “To understand media today we need to understand media software—its genealogy (where it comes from), its anatomy (interfaces and operations), and its practical and theoretical effects.” (Manovich, 2013, p. 124 original emphasis). In this, the importance of understanding media code in practical use is key as these codes interweave within the social fabric, thereby influencing the actions of others which also introduce the risk of certain groups becoming disadvantaged from this continued use of technology (Bivens, 2015). Coded areas of the internet as a technology are key for analysis as media theorist, John Durham Peters states, “Software often outlasts hardware.” (Peters, 2015, p. 32).

For the Wireshark data, because I was checking transport layer IPs, I focused on reviewing portions of websites which were canned audio-visual content, as well advertised live-streamed content. UDP as a transport protocol is used for live streaming content whereas TCP cannot and is instead used in canned content. Chapter Four discusses the technical nature of each of these transport layer protocols. As McKelvey (2014) states regarding studying coded mediums, without the social sciences or humanities researcher able to manipulate the source code, the researcher of coded environments must use their methods instead to “observe their
objects of study in operation” (McKelvey, 2014, pp. 600-601). By using Wireshark, I followed this recommendation of observing objects (streamed content) as they operated and the transport layer which they used in this operation.

This work of observing technical objects in their operation falls in line with Dourish and Button’s (1998) term, ‘technomethodology’ which is defined as ethnomethodologically-informed system design of technology. This ability to work around system designs of the streaming services to research IPs falls in the call to action by McKelvey (2014) and Sandvig (2009), for a methodological tradition of the STS researcher to be unique in their study design.

3.5 Concluding Remarks and Reflection of Influencing Factors

I would like to conclude this chapter by noting that the data collection for this research officially began after completing the first year of my master’s program in 2020. Learning about IPs, however, began in 2018 when I was working in marketing at a local IT business in Calgary, Alberta. At this small business I was fortunate to have the opportunity to ask the computer technicians about how the internet works and some of the more technical aspects of telecommunications infrastructure. It was there that I learned about the existence of UDP which led my interest in IPs. Christian Sandvig (2009) notes the benefits of keeping up-to-date with knowledge of the technical fields as an STS scholar, which can be done through Google Alerts, continued technical training of emerging ICTs, and/or starting or continuing relationships with those in technical fields to pass insights about varying technologies to the STS researcher to then communicate this to policymakers and government funders, for example.

Finally, it should be noted that this thesis takes a critical stance on the Huawei and the Chinese government in their transport layer standardization tactics. In 2021 when this thesis was completed, there has been a rise in racist anti-Asian hate crimes during the COVID-19 pandemic.
This thesis, in critiquing China, is critiquing China as a nation-state opposed to Chinese citizens and should not be interpreted as the latter.
Chapter Four: The Negotiated Protocol

“Unsubstantiated claims that TCP/IP can’t work for new applications or higher bandwidth have repeatedly been made every time a new access technology has arrived. One can remember Asynchronous Transfer Mode (ATM) (Ethernet can’t go to 100Mbps), 3G (TCP/IP not suitable for handheld devices), and similar claims suggesting new technologies, particularly those championed by specific vendors or standards groups, were required. However, the track record of TCP/IP has been remarkable: it has been nimble enough to adapt every time a new underlying network technology has emerged.”

(ICANN Office of the Chief Technology Officer, 2020, p. 27).

Protocols are a type of standard which determine the technical specification of operation of a given infrastructure (DeNardis, 2009). These technical specifications may be procedures or systems of rules to enact in a given event or environment, workflows, or as this thesis understands technical specifications though an internet infrastructure lens – computer code to ensure the seamless processing and transport of information between technology users. In July 2008, Dave Thaler and Bernard Aboba, two members of the Internet Advisory Board (IAB) and employees of Microsoft, submitted RFC 5218 to the IETF titled, ‘What Makes for a Successful Protocol?’ In the RFC they use case studies of various successful protocols in comparison to their unsuccessful counterparts and list how certain protocols will succeed, while others fail. They identify that success is not always success of a technical standard, but sometimes just the ability to not fail. In this, they define strategies which may be used, and have been used in the past, to overcome potential failure of a protocol. These are summarized in five themes: (1) the protocol addresses a critical and imminent problem; (2) the protocol will work in conjunction with a “killer app” which has low deployment costs; (3) the protocol provides value for already
existing unmodified applications; (4) the protocol helps reduce “complexity and costs by narrowing the intended purpose and/or scope to an area where it is easiest to succeed” (p. 7); and (5) the protocol has been taken up by government or another entity who has provided incentives or disincentives which move the protocol to implementation and deployment (Thaler & Aboba, 2008).

In this list we see that a protocol may not be the best technical decision for infrastructure, however, will be what is most favourable and cost friendly for deployment to fill a gap in government, industry, and/or society more generally. When looking for true success of a protocol, Thaler and Aboba state that there is a mathematical relation in this definition in that, “a successful protocol [is] one that both meets the original [specified] goals and is widely deployed.” (2008, p. 3). This ability for success to be measured through a vision and implementation model, they further define as a protocol’s ability to succeed and exceed in its ‘scale’ and ‘purpose’ which can be graphically represented as such.

![Success of a Protocol: Scale and Purpose](image)

Figure 3: Success of a Protocol: Scale and Purpose

(Thaler & Aboba, 2008, p. 4).

As the protocol exceeds the original scope (visually represented above as the box) it shifts in terminology from being ‘successful’ to ‘wildly successful.’ Wildly successful protocols include
HTTP (hypertext transfer protocol), the protocol linking various website pages and information sources with one another (Flew & Smith, 2018), for example.

Wildly successful protocols, as Thaler and Aboba note, “can be good or bad.” (2008, p. 5). Positive perceptions of the wildly successful protocol occur when the protocol is so useful that it solves more problems and addresses more needs than what it was originally intended for. The two Microsoft employees state that when this happens, it is important to reevaluate the protocol to better accommodate its design space for the new scenarios it now occupies. With wildly successful protocols, they are considered ‘bad’ when the protocol is used in instances it was not designed for. Thaler and Aboba note four potential consequences being:

- [U]ndesirable side effects because of design decisions that are appropriate for the originally intended purpose, but inappropriate for the new purpose.
- [P]erformance problems if the protocol was not designed to scale to the extent to which it was deployed.
- Implementers may attempt to add to change functionality to work around the design limitations without complete understanding of their effect on the overall protocol behaviour and invariants.
- [The protocols] become high value targets for attackers because of their popularity and the potential for exploitation[.]

(Thaler & Aboba, 2008, p. 5).

It is here that we have a map of what protocols are and how they should be designed to ensure their success in extending the abilities by the users of these technical specifications.
4.1 A Brief History of TCP

The internet as we know it today is a collection of wildly successful protocols which have morphed for intentions the developers did not originally have. The history of the internet has its origins through the US military’s DARPA, which later named the networking project as ARPANET to then be titled the Internet.\(^{13}\) This history has been well chronicled, and this thesis will only lightly cover it from a protocol, opposed to holistic perspective. The internet being a protocol-based packet-switching technology which we know it today was developed by Vinton “Vint” Cerf and Robert “Bob” Kahn when the two computer scientists collaborated in the spring of 1973. The collaboration came after Kahn had realized while working at Bolt Beranek and Newman (BBN)\(^{14}\)—an American research and development company—that in order to have an open architecture networking program which would enable open communications, he would need to be immersed in each operating system’s implementation details to allow for any protocols to be embedded into this hardware.\(^{15}\) It was then that he asked Cerf, who was working at Stanford University and could fill this knowledge deficit, to work with him on this open computer architecture vision. The two were a perfect match with Kahn’s vision of an open architectural approach coupled with Cerf’s experience in Network Control Protocol (NCP, which was the predecessor of TCP/IP for ARPANET). In May 1974 they published their paper ‘A Protocol for Packet Network Intercommunication’ with the Institute of Electrical and Electronics

\(^{13}\) Scholarly writing in internet studies use both capitalized Internet and lowercase internet. This thesis uses the latter, however, historically it was capitalized upon the name change from ARPANET.

\(^{14}\) BBN is now known as Raytheon BBN Technologies with its headquarters located in Cambridge, Massachusetts.

\(^{15}\) At this time, computer systems were not able to connect together through a decentralized network as there was no internet. Instead, companies had computers which were all in the same building connected to one another as a single mainframe. These were costly initiatives which resulted in businesses, opposed to personal computers, being used. Computer networks were determined by the companies which operated them (e.g., IBM) and therefore on separate operating systems.
Leading to this 1974 publication of research on TCP/IP, there were many pioneers and collaborators in the invention of what would be the internet. In July 1961, Leonard Kleinrock who was working at Massachusetts Institute of Technology (MIT), published the first paper on packet-switching\(^{16}\) and later in 1964, first book on the subject (Kleinrock, 1961, 2007). Through his work on packet-switching he later went to mentor Larry G. Roberts, a DARPA pioneer (Leiner et al., 1997). Following working with Kleinrock, Roberts went to work on DARPA in 1966, finalizing a plan for packet-switching to become a reality one day through a project titled ‘ARPANET,’ which he published this in 1967 and presented this work at a conference the same year (Leiner et al., 1997). At this conference, Roberts networked with Donald Davies and Roger Scantlebury of the UK’s National Physical Laboratory (NPL) who were also studying networked computer communications. Scantlebury then advised Roberts that similar packet-switching work he was completing at DARPA was also occurring at the RAND corporation ‘group’ headed by Paul Baran ‘and others.’ The RAND group was keenly interested in packet-switching being used for the US military during the Cold War and published papers on it in 1964 (Leiner et al., 1997). These three research hubs on packet-switching, MIT (1961-1967), RAND (1962-1965), and NPL (1964-1967) were all completing similar work, however, had not crossed paths on the manner until the 1966 conference and were unaware of this similar research interest. The three groups went on to collaborate on the future of packet-switching (Leiner et al., 1997). In the footnote of discussions about the collaboration of the DARPA networking project with the RAND group and NPL project in the UK, the pioneers of the internet in a historic brief of their process in

\(^{16}\) This paper was his PhD dissertation proposal.
developing the internet written for the Internet Society in 1997, correct often-times myths about the beginnings of the internet with,

It was from the RAND study that the false rumor started claiming that the ARPANET was somehow related to building a network resistant to nuclear war. This was never true of the ARPANET, only the unrelated RAND study on secure voice considered nuclear war.

(Leiner et al., 1997, p. 3).

ARPANET was instead part of a broad research funding project by DARPA for research in computer engineering, which DARPA believed that communication between the various academic research hubs which were being funded would be beneficial. This was the business need for ARPANET opposed for strategic military use in its inception (Flew & Smith, 2018; Leiner et al., 1997).

Academic institutions which were then connected to ARPANET began with MIT, University of California Los Angeles (UCLA), and Stanford University’s Institute of Technology. The first node of ARPANET was set for UCLA even though most of the project had its origins in MIT. The node for UCLA was due to Kleinrock working in California, and him being the first to devise research on packet-switching, and his mentorship of Roberts. This led to the decision by DARPA to have Kleinrock’s Network Measurement Centre at UCLA be the first node of ARPANET in September 1969. The connection between MIT and UCLA was not one of strategic partnerships between academic institutions, or solely funding mechanisms by the US DoD, but instead one born from respect. As the project grew, military investment in it was of interest, but again, this was not the original aim for ARPANET, but a side effect of it (Leiner et al., 1997).
When these nodes were first established between MIT, UCLA, and Stanford University, the network protocol being used was Network Control Protocol (NCP).\textsuperscript{17} NCP as a foundation for ARPANET was developed in DARPA similar to how computer networks worked at that time—along circuit-switched networks in which connections were made between physical computers opposed to complex decentralized infrastructures. If a node on the circuit-switched network was offline or any packets were lost in the protocol, this would result in NCP having all packets come to a “grinding halt” (Leiner et al., 1997, p. 5). This frustration is what inspired Kahn for a decentralized, open-architecture network environment in which end-to-end host errors would be permitted, which NCP’s technical specifications would not account for. In this, TCP/IP was envisioned to be a communications protocol, whereas NCP had “tended to act like a device driver” instead (Leiner et al., 1997, p. 6).

The transition to TCP/IP from NCP began shortly after 1973 and 1974 once Cerf and Kahn’s paper on TCP/IP had been published. Finally, Jon Postel’s (another past employee of DARPA) RFC 801 published November 1981 titled, NCP/TCP Transition Plan states,

> It was clear from the start of this research on other networks that the base host-to-host protocol used in the ARPANET was inadequate for use in these networks. In 1973 work was initiated on a host-to-host protocol for use across all these networks. The result of this long effort is the Internet Protocol (IP) and the Transmission Control Protocol (TCP).


As Postel states in this Transition Plan, the transition to TCP/IP from NCP for ARPANET was set to be completed along all nodes no later than 1 January 1982, with a specification that this transition should be done ‘as soon as possible’ (Postel, 1981, p. 2). This need for the transition

\textsuperscript{17} NCP is sometimes also referred to as ‘Network Control Program,’ which should not be confused with IBM’s own Network Control Program which was a software program opposed to a networking protocol.
was spurred by Postel’s earlier brief to the US DoD two months prior to the NCP/TCP Transition Plan directive where the benefits and protocol specifications were presented in RFC 793 (Information Sciences Institute, 1981). The DoD took keen interest in TCP/IP and began planning how to transition their information and communications architecture to this protocol as well (Postel, 1981). As RFC 801 shows, protocols were not predetermined and underwent large changes as development in the transport layer continued, thereby making the transport layer of the internet a space in flux and continuous development.

It quickly became apparent that TCP as the sole base for the transport layer would also be filled with shortcomings, even with its superiority over the previous NCP. The technical specifications of TCP require it to perform one primary function: confirmation codes. The model of TCP as a transport protocol has programmed in its technical specifications that if a bit of data becomes corrupted or lost, the system will resend the datagram message. Where this technical specification was excellent in text-based communications and file transfers over the internet in which any parts of a message lost would be unacceptable for communication, it proved problematic for voice communications (being VoIP) where corruption of datagrams would need to be permitted to allow for an open channel of communication in this computer medium (Leiner et al., 1997). This resulted in further changes to the TCP/IP suite to incorporate in it User Datagram Protocol (UDP).

4.2 UDP as a Data Transport Processing Fix

On 28 August 1980 RFC 768 was submitted by Jon Postel identifying the technical specifications for UDP as to allow for its integration into the TCP/IP suite (Postel, 1980). By

---

18 Datagram was the original term for sending packets of data along the internet. This parallels historic roots in telegram (for telegraphs) and marconigram (for early wireless telegraphy communications by the Marconi Company) (Raboy, 2016).
integrating UDP in the TCP/IP suite, this would allow for voice and video communications to occur without being suddenly cut off due to a missed packet, with an attempt to resend the entire message. Through this integration, new affordances of the internet were introduced. The RFC for UDP does not identify any common humanity, greater good, or interconnection-type philosophy of the internet which previous RFC’s for TCP had done (Information Sciences Institute, 1981), and instead was a ‘cut and dry’ technical specification for how UDP would incorporate into the TCP/IP suite from an engineering perspective. Overall, the RFC was a notification to the internet community of this new technical specification and was not treated as a revolutionary development in the ARPANET project. As the specifications for UDP identified, it was to be a ‘transactional’ protocol, where “delivery and duplicate protection are not guaranteed.” (Postel, 1980, p. 1). This prevention of data packet duplication (or at this time in internet development was termed ‘octets’) would allow for an open channel of communication from both end users to occur, thereby rendering it beneficial for preventing latency and allowing for developments in internet communication in areas of VoIP and Video on Demand (VoD). This technical decision to have UDP embedded into the TCP/IP suite is what has allowed for software programs such as video conferencing (e.g., Zoom), live streaming of videos, music, and spoken word online, and live-action video games to develop and occupy our digital environments. The utility of this technical protocol cannot be overstated in the age of the COVID-19 pandemic with the shift to online communication for many.

Similar to TCP, UDP has also been revised and edited, specifically recently through research and development initiatives by Google, with further developments by Mozilla, and Fastly19 of Google’s original QUIC20 protocol in 2013 to aid in the streaming process by

---

19 Fastly is an American cloud computing services company.
20 QUIC is not an acronym but is the name of the protocol.
allowing concurrent streams to occur at once over UDP (Iyengar & Thomson, 2020). With its near real-time data flows, UDP has been an ideal transport protocol for emerging IoT devices and remote managed information technologies (IT) services. Due to the unprotected transferred data packets UDP processes, however, the corruption of these data through lag renders obvious areas of concern in cases such as self-driving vehicles, for example. Offers of overcoming these technical issues in TCP and UDP for future technology developments have included ‘HTTP failovers,’ which would have the HTTP application protocol work as a backup operational mode, resulting in hyperlinking as an automatic backup to any required switches of packets in their transport paths (Thaler, 2011). A solution for extending UDP and overcoming its limitations for IoT has not been realized at the time of writing. As the next chapter of this thesis will specify, consensus of how developments along the transport layer of the internet’s infrastructure for IoT have not been apparent, thereby leading to stifled development in the area of next generation networks and future network technologies.

TCP and UDP are able to connect as network protocols due to parallels in their header spaces. In the area of computer engineering, the header space allows for the smooth transition of data packets between users, similar to the size of a door being ‘just right’ for all parties who may walk through it. In essence, TCP and UDP work flawlessly because they will mimic the same addressing space of 32 bytes of data (on IPv4) and 128 bytes (on IPv6). The primary difference between TCP and UDP is that TCP has sequence numbers (confirmation codes) to ensure a logical progression of information as matching its sender to the receiver whereas UDP carries bytes of data out of sequence to allow for one streamed flow. Examples of these differences are an online shopping website that would be TCP as to ensure its match between the store (sender) and buyer (receiver). UDP may be exampled with watching a sports game on a streaming service.
with the pixels of the screen becoming fuzzy boxes and the sound attempting to ‘catch up’ to match the screen, until the stream works itself out to then have video and audio match again, not returning to pause and play from the moment the connection was disrupted. These are two user endpoints of interacting with internet protocols thereby conceptualizing regular interaction with these differences in the transport layer.

Although UDP was a fix for some of the technical specification limitations of TCP, the use of the TCP/IP suite and TCP was not a decided protocol because it was a failsafe in its technical abilities but underwent processes of negotiation in international technical and governance circles to then become what the internet is today.

4.3 OSI and the Protocol Which Nearly Was

The development of the TCP/IP suite and its transport layer protocols (TCP and UDP) has been identified up to this point, however, TCP/IP as the internet nearly did not occur as a competitor in the market, the Open Systems Interconnection (OSI), was nearly chosen for a packet-switching international protocol. As Andrew Russel, an STS historian out of Stevens Institute of Technology in New Jersey, states in his documentation of OSI, “OSI has been forgotten by all but a handful of veterans of the Internet-OSI standards wars.” (2013, para. 4). This war began shortly after ARPANET as the first packet-switched network, then using NCP, was stirring interest by various groups, specifically IBM and European telephone monopolies. These corporations, however, were concerned with the costs which may amount with packet-switching and lobbied for developments in ‘virtual circuits,’ which had computer-mediated communication circuit switches along existing technical and organizational routes (Russell, 2013). Through this interest and early research developments, an international consensus that a standard in computer packet switching communication was needed. This came to fruition in 1972
when the International Network Working Group (INWG) was formed with Vint Cerf as its first chairman.

INWG’s top priority was to promote and popularize datagrams as a form of communication. This could have been a hard sell as IBM and the telephone companies’ engineers were not in favour of datagram messages with their connectionless affordances (Russell, 2013). The INWG met multiple times and exchanged research among its international members, with finally in 1975 submitting their protocol to the international telecommunications standards body of the time – the International Telegraph and Telephone Consultative Committee (known by its French acronym as CCITT). The proposed protocol was quickly rejected by CCITT which was dominated by telephone engineers. They stated that they did not reject the concept of packet switching, but only “[so] long as it looks like circuit switching.” (Russell, 2013, para. 11). Following the blow from the CCITT, Cerf was incredibly frustrated, resigned as the Chair of the INWG, and left his faculty job at Stanford University to then collaborate with Bob Kahn on what would be the 1973/1974 TCP/IP paper published by IEEE.

Cerf’s abrupt departure from the INWG left the group unsure of their future direction. The members of the INWG (including Cerf) who were also part of DARPA went on to work on ARPANET and later the IAB, however, the remaining non-ARPANET group members reformed as an international alliance to begin shaping the OSI. The two groups – American and international\(^{21}\) – began a rivalry which never faded until the collapse of OSI. The OSI group was then put under the committee purview of the International Organization for Standardization (ISO).\(^{22}\) ISO was a nongovernmental standards setting organization developed following the end

\(^{21}\) The international group largely consisted of Europeans.

\(^{22}\) Note, ISO is the acronym for the International Organization for Standardization opposed to IOS. Because the ISO is an international organization and with its acronym being different in different languages, the organization’s name
of World War II and was much less rigid in the area of computer development than CCITT due to ISO’s purview of all technical standards, opposed to just computer standards (Russell, 2013). ISO approved the formation of a committee to begin work on OSI and named Charles Bachman as committee chairman.

Charles Bachman who was a winner of the prestigious Turing Award for his work on a database management system, ‘Integrated Data Store,’ was the one to devise the internet infrastructure layers proposal, in that various components of the computer communication system fit along several layers no matter the protocol. The layers work as a stack or ladder, and build off one another. In the OSI model, these layers would be (from bottom to top), Physical, Data Link, Network, Transport, Session, Presentation, and Application. In contrast, the TCP/IP suite would be represented with four layers as, Network Access (physical), Internet (decentralized network connections), Transport, and Application(s).23 The below table visually compares the OSI and TCP layered stacks.

<table>
<thead>
<tr>
<th>OSI</th>
<th>TCP24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Application</td>
</tr>
<tr>
<td>Presentation</td>
<td></td>
</tr>
<tr>
<td>Session</td>
<td>Transport</td>
</tr>
<tr>
<td>Transport</td>
<td>Internet</td>
</tr>
<tr>
<td>Network</td>
<td>Network Access</td>
</tr>
<tr>
<td>Data Link</td>
<td></td>
</tr>
<tr>
<td>Physical</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: OSI vs. TCP Layered Stack

instead denotes from what it does, opposed to who it is. The name ISO is denoted from the Greek word isos, meaning ‘equal,’ in that equal standards would be recognized internationally to then ensure an egalitarian world through this similarity through standards (ISO, n.d.).

23 ‘Application layer’ and ‘applications layer’ is interchanged throughout the literature in this field. This thesis works from Nuechterlein and Weiser’s (2013) spelling of ‘applications’ for this layer. The Russell (2013) table, however, matches Russell’s use of singular opposed to plural and uses four layers opposed to five, which is also contested in the literature of the number of layers in internet infrastructure. Where Nuechterlein and Weiser identify five with a ‘content layer,’ Russell omits this layer as part of the internet’s infrastructure.

24 Russell’s table states TCP, however, this would be TCP/IP. In early internet development, the name for the IP was TCP, which this did not change until the integration of UDP into the transport layer.
As Bachman specified for the layered approach to computer communication, “Once a layered architecture was established, specific protocols would then be developed.” (Russell, 2013, para. 18). What this identifies is that the internet has never been solely any one layer, but instead a system of infrastructures working along one another, with the transport layer connecting the physical and network addressing layers with the applications layer to then provide internetworking.

Through this OSI layered model by Bachman, this allowed for computers to peer onto one another, which was a shift from the traditional IBM format of terminal-to-computer architecture. This shift was highly attractive to General Motors (GM) who quickly became a strong proponent of OSI in the 1980s (Russell, 2013). This was because GM was using hundreds of computer suppliers for their dozens of operational plants, which all had incompatible hardware and software. By having a network architecture which allowed for peering no matter the machine, this would be cheaper and more efficient for business communities.

Because OSI was working through the ISO’s committee, it meant committee meetings with multiple stakeholders present. This resulted in multiple meetings of no clear consensus including a three-day meeting from 28 February 1978 until 2 March 1978 when delegates from 10 countries and four international organizations came together in a plenary meeting, which resulted in no clear consensus as each representative was arguing for technical specifications to benefit their individual countries and economies (Russell, 2013). The meeting was messy and from this messiness IBM’s representative, Joseph De Blasi who was IBM’s director of standards, was reported to have played the room ‘like a violin’ (Russell, 2013, para. 22). IBM came out of the meeting with their interests well met for the OSI’s future developments. Finally in 1984, the
reference model for OSI was published, 10 years following the publication of TCP/IP, however, it should be noted that TCP/IP and its transport layer protocols at this time were still only being used for computer scientists at DARPA-funded research institutions in the US. In sum, OSI was the first publicly available computer protocol for packet and virtual switching. The OSI model was then published as a standard in 1984, three years following the NCP to TCP/IP transition along ARPANET and TCP/IP’s integration in the DoD (Russell, 2013).

Attention surrounding OSI grew with its corporate backers, as well members of European nationalities. The US government even began to waiver its funded ARPANET in the hype of OSI, with the DoD publishing its intention to utilize OSI in RFC 939 in February 1985 (National Research Council, 1985). Even with the hype and backing of corporations like IBM and GM, OSI was having technical issues specifically in its addressing space which the TCP/IP suite overcame with IPv4 which allowed for up to 4.3 billion internet addresses, something at the time was enough, however, nowadays has proven scarcity in this area of the internet protocol (DeNardis, 2009). These technical issues required a clear head to overcome, which OSI did not have due to its international, multi-stakeholder committee format which allowed for representation and input from all members of the committee. This intent for collaboration became OSI’s downfall due to the length of time in completing necessary work which was needed for the fast-paced adjustments needed for new media technology to survive in a fluctuating digital playing field.

At this same time where OSI was having an identity crisis over its progression which were marked by conferences such as, OSI advocate Brian Carpenter’s 1989 talk ‘Is OSI Too Late?’ and Louis Pouzin’s essay ‘Ten Years of OSI—Maturity or Infancy’ published in 1991 (Carpenter, 1989; Russell, 2013); the DARPA computer scientists who had now formed the IAB
went on a retreat with the Internet Engineering Steering Group (IESG)\textsuperscript{25} in January 1991 to address big questions about the technical standards of the transport layer and the internet’s infrastructure (DeNardis, 2009). During this retreat they wrestled with the prospect of internet addressing space which they knew would one day hit concentration and a solution would be required (IPv4 to IPv6), as well if OSI should be the international public internet. As stated in RFC 1287, the developers contemplated OSI with,

\begin{quote}
The priority for solving the problems with the current Internet architecture depends upon one's view of the future relevance of TCP/IP with respect to the OSI protocol suite. One view has been that we should just let the TCP/IP suite strangle in its success, and switch to OSI protocols. However, many of those who have worked hard and successfully on Internet protocols, products, and service are anxious to try to solve the new problems within the existing framework. Furthermore, some believe that OSI protocols will suffer from versions of many of the same problems.
\end{quote}

(Clarke et al., 1991, pp. 2–3).

In their determination, they solved the problems of internet addressing space, allowing the TCP/IP suite to continue being a strong market contender for the future globalized computer networking system. Interestingly in RFC 1287 under the Assumptions header of the document, the prospect that OSI and TCP/IP would run concurrently for the public was listed first and foremost as a likelihood. Through this, the developers of the internet we know today believed that there would not be one set standard and one internet, but multiple due to the perceived success and hype surrounding OSI. Had OSI succeeded in its development there would have been multiple internets working concurrently around the world based on adoption by various

\textsuperscript{25} The IESG was the precursor to the IETF.
countries, which we can see OSI was backed by Europe and slowly inching into the American purview. This, however, did not occur thereby leaving one internet in which users around the world log onto in this single computer networking standard of the TCP/IP suite with its TCP and UDP transport protocols.

Although OSI had the backings of computer corporations, telecommunications monopolies, Europe, and a growing ratio of the US Government, the international collaborative approach of OSI through committees and a right for any interested parties to participate in its development, led to structural tensions, incompatible visions, and disruptive tactic characteristics (Russell, 2013). Bachman had predicted this in a 1978 conference stating,

The organizational problem alone is incredible. The technical problem is bigger than any one previously faced in information systems. And the political problems will challenge the most astute statesmen. Can you imagine trying to get the representatives from ten major and competing computer corporations, and ten telephone companies and PTTs [state-owned telecom monopolies], and the technical experts from ten different nations to come to any agreement within the foreseeable future?

(as referenced in Russell, 2013, para. 29).

Hence OSI fell and in this collapse TCP/IP filled the market demand for a decentralized, packet switching, and open computer communications network with its launch from academic circles to the masses in 1992 and 1993 (Russell, 2013). Network hardware and application software then only had to work on TCP/IP transport protocols opposed to also incorporating OSI.

Going back to the mass upheaval of internet infrastructure in the TCP/NCP transition, this was meant to occur prior to 1 January 1982, however, incentives were not available for this as well the rummaging discourses of network protocols with the OSI model were still in the air.
In order to overcome this, DARPA stopped supporting NCP on 1 January 1983 (exactly one year later) and provided financial subsidies for these hardware adjustments to the new protocol (Russell, 2013). It was a time crunch and the computer scientists who made this transition from NCP to TCP/IP commemorated the moment with button pins which read ‘I Survived the TCP Transition Jan. 1, 1983.’ The occasion has been chronicled by Vint Cerf as the day marking the birth of the internet (V. Cerf, 2013). The collapse of OSI provides a staggering lesson for future transport layer development in the internet: whenever possible, it is best to drop the bureaucracy and develop technical standards on a shared vision and philosophy opposed to varying ideals which may be dominated by the corporations with a seat at the table and countries which are not aligned in the same common interest of the internet transport standard. These learned lessons can be seen in the main organization which has been working to develop out the transport layer of the internet over the past decades for their own scientific usage, the National Aeronautics and Space Administration (NASA).

4.4  **Transport Development in the Stars**

Where the internet has only had two large-scale interference moments in its development being the transition to the TCP/IP suite from NCP, and the near transition from TCP/IP transport protocols to OSI, these have not been the only developments in separate transport protocols or network protocol suites. Still ongoing today is NASA’s research in network protocols in order to communicate with their terrestrial machinery exploring outer space. Their protocol is called Delay/Disruption Tolerant Networking (DTN) and its goal is interplanetary internet. TCP’s characteristics of confirmation codes and UDP having issues of lag in its open channel aspects, provided problems for lost communications in the case of interference from asteroids and, more specifically, moons. As NASA states in their explanation of DTN,
The network protocol that enables the terrestrial internet, Transmission Control Protocol/Internet Protocol (TCP/IP), relies on an uninterrupted connection for data transference. In space, missions can often have long delays, or latency, and disruptions due to orbital dynamics that make using TCP/IP challenging. DTN will make NASA’s networks flexible enough to overcome these issues.

(NASA, 2020b, para. 3).

The DTN project is a small portion of NASA in comparison to Mars missions, for example. In this immaterial portion of the space discovery institution DTN is updated and researched by a collaboration of representatives from various US universities. Who are these representatives? They are not faculty like in ARPANET, they are not postdocs, they are a group of eight interns in their twenties reviewing, updating, and planning the transport layer of Earth’s intergalactic internet infrastructure. Their names are Alex Scott (University of Maryland), David Trimino (University of Texas at Arlington), Ryan Daugherty (North Carolina State University), Rema Amhaz (New York University), Rowan Parker (Oregon Institute of Technology), Shane Hitch (Valley City State University), Brendan Blasius (University of California, Merced), and Jason Fantl (University of Wyoming). They are the 2020 representatives of the Space Communication and Navigation (SCaN) internship program with NASA’s Goddard Space Flight Centre in Greenbelt, Maryland (NASA, 2020b). The SCaN program’s directive in 2020 was to standardize DTN with the IETF. No record of this decision was found in the IETF’s RFC database, however, an Internet Research Task Force (IRTF) in 2014 submitted RFC 7122 examining if UDP would be a better contender for interplanetary internet with its open channels, but found UDP unable to perform NASA’s needed tasks (Hans et al., 2014).
In order for DTN to work across our solar system, NASA has implemented internet infrastructure through ground stations and space relay satellites which are called the Deep Space Network (DSN), the Near Earth Network (NEN), and the Space Network (SN) (NASA, 2020a). This physical infrastructure coupled with DTN is part of NASA’s long-term plan to one day launch the official Solar System Internet (SSI) (NASA, 2020a). As this shows, developments in the transport layer and a multiplicity of internets are not a far-off concept, but a far-world concept. This concept, in fact, was one in which Vint Cerf held in 1997 stating that an interplanetary backbone would one day be needed and be an extension of the internet (WIRED Staff, 2000). As Cerf stated to WIRED reporters at the beginning of the millennium, “I realized it had taken 20 years for the Internet to take off: from 1973 to 1993[.] So I wondered what I should be doing to prepare for our needs in the future. An interplanetary backbone was the answer.” (2000, para. 3). He began collaborating with Adrian Hooke who was a Jet Propulsion Laboratory (JPL) scientist and also working on space protocols which would be cheaper and more efficient (A. McMahon & Farrell, 2009; WIRED Staff, 2000). The collaboration resulted in the birth of the Interplanetary Internet (IPN) which worked separate from packet-switching due to an interplanetary network needing variations of digital communications, and instead introduced the concept of bundling from the TCP/IP packet switching, as bundling “builds a store- and-forward overlay network above the lower layers of underlying networks.” (A. McMahon & Farrell, 2009, p. 82). As Earth’s TCP/IP internet is a network of networks, the IPN was to be a “network of disconnected Internets” (A. McMahon & Farrell, 2009, p. 82).

This ‘network of disconnected internets’ can be found in IPN’s rebranded name, SSI, along with NASA’s plan to build 4G/LTE internet on the moon for late 2022 to launch this internet infrastructure initiative in support of a continued human presence past the international
space station (Browne, 2020). Developments in the network of disconnected internets continue through the SCaN internship program and NASA’s self-funded RFC portal, *Earth Data*, with the tag line, ‘Open Access for Open Science’ (NASA, 2021). Computer scientists can access *Earth Data* and submit to it so long as they follow the RFC template for standardization of communication documents. Although the primary researchers in NASA’s transport layer developments are currently interns, NASA’s space internet development does cater to working professionals and has its roots with computer scientists like Vint Cerf.

DTN is not a public internet or available to citizens outside of NASA. Where NASA’s documents continuously refer to TCP as the internet,²⁶ citizens’ protocol needs are shifting from TCP to UDP as internet usage changes to accommodate differing transport layer affordances (i.e., real time data flows). The following section will conclude this chapter with an analysis of how citizens in Canada, though this may be applied more globally, are on a mass scale shifting their protocol interaction since 2020 with the use of real-time software, such as video conferencing platforms and real-time online streaming websites.

### 4.5 21st Century Shifting Uses of Internet Protocols

Due to the technical affordances of TCP and UDP with their limitations and capabilities, users interact with these protocols on varying levels depending on the ways in which they use the internet. For users who spend their workdays on Zoom, for example, this live-stream audio-visual display would require UDP as the network protocol to be used for its open channel and disablement of error checks. For users who online shop, read the news online, and communicate through email, they would be interacting with TCP as this data would require a confirmed

---

²⁶ Multiple references of TCP being used synonymously with the TCP/IP suite can be found throughout the literature, RFCs, and engineering documents such as the mentioned NASA ones. TCP/IP is a network suite, with TCP along with UDP as transport protocols. The transport layer is part of the overall suite.
numerical sequence where all packets of data are in the same order as they transport from the sender to the receiver. This shows the adaptability of infrastructure – no matter the individual needs of it, the infrastructure will work to fill any of the perceived needs of the masses who use it.

Streaming services contribute to the vast majority of Canadian data demands (CRTC, 2017), and UDP and TCP are both capable IPs for streaming services, with UDP being the only option for live streamed content. In this, streaming services will choose how to code their websites. Due to TCP’s confirmation codes and sequential error checking, this protocol would be more reliable, however, when streaming services utilize both canned content and live streams, a mixture of the two protocols will be embedded into websites. Using an internet protocol reader, Wireshark, this was found with YouTube, CBC Gem, and Amazon Prime. Streaming services which do not air live television and instead rely on content libraries, thereby not needing UDP for delivering their services, included Netflix and Disney+ only coded in TCP.

Although an advertised live stream should be using UDP for a protocol due to its technical affordances, this sometimes is not the case with the live streaming option being a form of false marketing by streaming services. For example, when using Wireshark to analyze streaming services which advertise ‘Live TV,’ the protocol reader shows that where packets should have been travelling along UDP, they instead relied on TCP thereby not being a true live stream. This can be seen with Bell Media’s Crave streaming platform. For their advertised ‘On Air,’ Crave states that subscribers will be watching live programming similar to a cable subscription with a shared viewing experience with other Crave subscribers watching ‘On Air’

---

27 Although this data is out of date, the last time the CRTC’s annual Communications Monitoring Report tracked Canadian data usage was in 2016, with a change to revenues by streaming platforms and internet service providers predominating further Communications Monitoring Reports.
television. As their ‘Help and FAQs’ page states regarding the On Air experience, “The On Air section allows you to watch the linear live streams for Crave 1, Crave 2, Crave 3, Crave 4, HBO 1 and HBO 2 channels. This content is available for Movies + HBO subscribers.” (Crave, n.d.). In this, the subscribers of Crave who are paying an additional fee for ‘Movies + HBO’ in their regular subscription for added content,\(^{28}\) are not receiving the full benefits of their purchase due to this false advertising as per TCP being used for the stream of On Air content. Inasmuch, ‘On Air’ by Crave is not a live stream and is misleading in its advertising. This can be shown in the below image through the collected Wireshark data.\(^{29}\) The red boxes identify key markers of the produced data contributing to this finding.

![Figure 4: Misleading 'On Air' Marketing of Crave's Streaming Platform](image)

\(^{28}\) This addition doubles the cost of a monthly Crave subscription from $9.99 to $19.98.

\(^{29}\) Note, an external image of the collected Wireshark data had to be used over a screenshot in order to show the ‘LIVE’ advertisement as per the cursor hovered over the video.
What we see in this image with the red boxes is one of Crave’s ‘On Air’ sessions stating the documentary, *I Am Greta*, was ‘on now’ for a live stream. The ‘Live’ button highlighted in the bottom left red box. On the left-hand side of the screen, we see Wireshark identifying in the third red box that the website is coded in Transmission Control Protocol (TCP). By identifying the transport layer protocol of a popular in Canada audio-visual streaming website, we see the study of transport layer protocols as an area to determine the affordances and functionalities of websites. This finding is significant as it shows the need for mixed methods and ‘creative’ methods in the study of transport layer IPs (McKelvey, 2014).

Crave is owned by Bell, Canada’s largest telecommunications corporation. This finding of misleading advertising is not unusual marketing by a Canadian telecommunications corporation, as Rajabium and Middleton (2015) have found that telecommunications providers will often advertise internet speeds of ‘up to’ speeds, opposed to the services which citizens will actually receive. Although Crave is not advertising ‘up to’ live content, the parallels in Bell Media’s business model are apparent in this data. Crave’s misleading advertising here does not harm subscribers and would likely not warrant a penalty by Canada’s Ad Standards Watchdog, however, points to the ways in which streaming services are attempting to create imagined, live internet spaces. Where this Wireshark-Crave finding offers insights in future research on IPs and live-streaming, this falls out of the research’s scope, with this thesis mentioning this finding in identifying Canadians’ differing interactions with IPs based on popular streaming services, opposed to further meanings of how telecommunications companies’-owned streaming services mislead customers in advertised live-streamed content.

30 The Ad Standard’s Watchdog can be further viewed at https://adstandards.ca.
Due to the COVID-19 pandemic in 2020 and the transition for many to work and learn from home via online platforms, citizens around the world have been interacting with UDP at a greater frequency. Although data by the CRTC regarding video conferencing software in 2020 is unavailable, popular video conferencing software, Zoom, which relies on UDP for delivering its services had their profits raise by 4000% in 2020 (Massie, 2021). This market context, as well common lived experiences during the pandemic, show an increase in Canadians’ use of services which rely on UDP as a transport protocol from historically dominant TCP. If video conferencing via VoIP technologies continues as an outcome of the pandemic, an increase of interaction with UDP will be apparent due to the transport protocols which these software programs are built on. Thus, as our primary uses of the internet shift, so to our interactions with the transport protocols which support these applications.

As this chapter has identified, the internet as we know it has never been the only solution for digital, interoperable communications, but instead TCP/IP as a protocol suite has undergone negotiations to become the prominent standard with TCP and UDP comprising the transport layer of the internet’s infrastructure. In these processes of becoming the international standard, TCP/IP was prepared to be a concurrent internet, which would have resulted in internets, opposed to the one internet in which the world knows today. Through its updates to become a wildly successful protocol, such as including UDP in the TCP/IP suite, TCP/IP has shown its resiliency as an IP and kept it secure as the public internet comprising the transport layer of the internet’s infrastructure. As the next chapter details, however, this sole occupation of the transport layer by the TCP/IP suite is being challenged with incredible global political and corporate force in 2020.
Chapter Five: A Call for a New Internet

“The Information Age will continue to create new artifacts, some that carry great value. We should not stand idly by and let rights to the assets of this new Age be determined haphazardly, thereby almost certainly guaranteeing that they go to people in the best position to take quick advantage of them. We should try to analyze them thoughtfully, remembering our real-world experience with inequality and exploitation and trying not to recreate it in new worlds.”

(Chander, 2003, p. 797).

TCP/IP as a transport protocol suite has prevailed in decades of discourse surrounding the evolution of the transport layer of the internet’s infrastructure. That was challenged on 18 July 2018 in Geneva Switzerland, when Dr. Richard Li, Chief Scientist of Futurewei—Huawei Technologies’ United States-based research division—gave a 21-slide presentation at the Third Annual ITU IMT-2020/5G Workshop and Demo Day.31 This demonstration day was part of an ITU conference for determining working study groups across the ITU-T for the study of evolving 5G technologies (ITU-T, n.d.-c). Throughout the presentation, Li emphasized that the current TCP/IP protocol suite could not keep up with the trajectories of internet usage, which had progressed from text, image, voice, video, virtual reality, and on the horizon: holograms. He argued that TCP/IP as a protocol suite could not transfer the bits of data fast enough for evolving networks past 5G and with a reduction in latency. As he stated, “If we design a network to support 5G, we had better design it for a lifespan going over 5G.” (Li, 2018, p. 5). The slide where he first makes this argument, the thesis statement of his presentation, depicts a residential neighborhood road with map pins which state ‘Now,’ ‘2020+,’ and ‘2030+.’ The road is

31 IMT as an acronym stands for International Mobile Telecommunications.
separated by a barrier filled with trees where a second road is shown. The roads differ with one on the left-hand side of the image which showcases this internet evolution timeline allows for vehicles and/or cyclists to quickly move down it. On the opposite side a second road mirrors the augmented one and is blocked by multiple speed bumps, thereby delaying the time in changes of pace for development. The speed bumps parallel the time markers from its mirrored augmented counterpart. The symbolism of the roads with the decision of obstacles pertaining to travel is clear in the presentation. Below this image in a green font—maybe to symbolize a green and blue planet, a nod to nature and the United Nations’ top goal of climate action—is the ‘going over 5G’ quote, followed by the ITU’s logo as the footer of each slide of the presentation. Li’s slide where he makes a call to action for new transport layer development is featured below.

Figure 5: Dr. Richard Li New IP Presentation at ITU IMT-2020

(Li, 2018, p. 5).
His argument was clear, as 5G comes and passes there will be vast changes in data consumption due to changing uses of the internet. These changes would require terabyte per second (Tbps) data transfers, opposed to 5G-enabled gigabyte per second (Gbps) transfers along the TCP/IP transport layer. The projected uses for the Tbps transfers would first and foremost be for new adoptions of holograms. Li emphasizes this with a slide half devoted to a scene from the first *Star Wars* movie where Luke Skywalker has turned on the hologram of Princess Leia asking Old Ben Kenobi for help (Li, 2018, p. 8). Li, too as we see at the end of the slide deck, is also searching for help from the ITU. To conclude his presentation Li has a call to action for the ITU in big blue bolded font: “We are proposing a new Focus Group on Network 2030 in SG-13[.] We welcome and invite all of you to join us and help shape a New Internet!” (Li, 2018, p. 20).

SG-13 is a designation to represent ‘ITU-T Study Group 13 - Future networks, with focus on IMT-2020, cloud computing and trusted infrastructure.’ The objectives of the Study Group (SG) are to study next generation networks (NGNs) with a special focus on future networks and mobile telecommunications (ITU-T, n.d.-b). Their role is to study NGNs and make standardization policy recommendations which are more energy efficient, support new industries like intelligent transport systems, and overall standardizing enhancements for new introductions of ICTs which rely on these NGNs. NGNs refers to “the worldwide move from circuit-switched to packet-based network[s].” (ITU-T, n.d.-b, para. 2). In other words, the digital transition from analog systems to digital ones. Where NGNs continue to be the primary focus of SG-13, this is beginning to change. Now, SG-13 has also been mandated with the task of future networks (FNs), which are defined as networks past NGNs which will be the 5G and beyond era. The mandate of SG-13 is vast; they are expected to aid in standardization research on an international scale for analog to digital transitions, aid in NGN to FN transitions, provide research and
recommendations on standards to help energy consumption along these NGNs and FNs in cloud computing infrastructure and XaaS (X as a Service).\textsuperscript{32} They are also asked to continuously research IoT technologies and standards to support them, and are required to do all of this with a framework mission of environmental and socio-economic awareness (ITU-T, n.d.-b). Overall, SG-13 is given an incredibly large mandate in an increasingly relevant area of the global economy: internet infrastructure.

SG-13 publishes their research findings along the Q- and Y-series of the ITU-T Recommendations. One of SG-13’s largest achievements is their work on standards for virtual private networks (VPNs) which allow for greater cybersecurity for those who enable VPNs on their personal and working devices (ITU-T, n.d.-b). An example of a Canadian non-profit VPN is the Canadian Internet Registration Authority’s (CIRA) Canadian Shield VPN, available for free to residents of Canada to aid in cybersecurity protection, launched for Canadians in their transition to work from home during the COVID-19 pandemic (CIRA, n.d.). As being part of ITU-T, SG-13 is also a public-private partnership. What this means in relation to ITU-T is that this arm of the ITU cannot succeed without collaboration with industry as they are the ones testing and developing new technologies (likely with innovation grants from their national governments). Through this collaboration, ITU-T then prepares standards to promote global interoperability in emerging ICTs. Member States of the ITU are also collaborators in the ITU-T standardization division. These Member States are “entitled to unlimited participation in any of all of ITU-T’s Study Groups, conferences and assemblies.” (ITU-T, n.d.-a, para. 1). This participation by Member States through either written or oral submissions during the consensus building process of standards setting, which then leads to the production of Recommendations

\textsuperscript{32} The ‘X’ to denote an unknown technological development. For other examples, software as a service (SaaS) or hardware as a service (HaaS).
and Resolutions (ITU-T, n.d.-a). Where Member States have access to ITU-T working documents, industry and academics are required to pay annual fees for access to these databases of standardization documents and Member State submissions. For academics, this costs 3,975 CHf33 ($5386.15 CAD) and between 10,600 CHf ($14,363.07 CAD) and 31,800 CHf ($43,089.21 CAD) for industry members (ITU-T, 2021a).

Although Canada is a Member State of the ITU, representation in SG-13’s leadership team is slim. The only Canadian representation is Scott Mansfield who is an employee of Ericsson Canada, thereby being one of the industry collaborators with ITU-T. As this shows, no Canadian who is sworn under oath in their service with the federal government represents Canadian interests in the global technical standards setting process. The following table identifies the representatives making up SG-13’s primary leadership team (SG-13, 2021).

<table>
<thead>
<tr>
<th>Name</th>
<th>Entity of SG-13</th>
<th>Country of Residence</th>
<th>Employment Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rim BELHASSINE-CHERIF</td>
<td>Standardization Committee for Vocabulary</td>
<td>Tunisia</td>
<td>Tunisie T鬩com</td>
</tr>
<tr>
<td>Marco CARUGI</td>
<td>ISO/IEC JTC1/SC41 on IoT</td>
<td>China</td>
<td>Huawei</td>
</tr>
<tr>
<td></td>
<td>ITU-T SG13 Mentor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>JCA-IoT and SC&amp;C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babak JAHROMI</td>
<td>TM Forum</td>
<td>United States</td>
<td>Microsoft Corporation</td>
</tr>
<tr>
<td>Shin-Gak KANG</td>
<td>ISO/IEC JTC1/SC6</td>
<td>South Korea</td>
<td>ETRI</td>
</tr>
<tr>
<td>Gyu Myoung LEE</td>
<td>Home Networks</td>
<td>South Korea</td>
<td>ETRI</td>
</tr>
<tr>
<td></td>
<td>ICT and Climate Change</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kangchan LEE</td>
<td>ISO/IEC JTC1/SC38</td>
<td>South Korea</td>
<td>ETRI</td>
</tr>
<tr>
<td></td>
<td>ISO/IEC JTC1/WG 9 on Big Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leo LEHMANN</td>
<td>3GPP/3GPP2 SA (service aspect)</td>
<td>Switzerland</td>
<td>ITU</td>
</tr>
<tr>
<td></td>
<td>Joint Coordination Activity on Multimedia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

33 CHF is the currency symbol for Swiss francs, the currency of Switzerland where the ITU’s headquarters are located.
<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Country</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matthieu LERGE</td>
<td>Security</td>
<td>Switzerland</td>
<td>IDQuantique SA</td>
</tr>
<tr>
<td>Scott MANISFIELD</td>
<td>ATIS, Broadband Forum (BBF), IETF, Security</td>
<td>Canada</td>
<td>Ericsson Canada</td>
</tr>
<tr>
<td>Brice MURARA</td>
<td>JCA-AHF</td>
<td>Rwanda</td>
<td>Rwanda Utilities Regulatory Authority</td>
</tr>
<tr>
<td>Fidelis ONAH</td>
<td>ITU-D</td>
<td>Nigeria</td>
<td>Nigerian Communications Commission (NCC)</td>
</tr>
<tr>
<td>Luca PESANDO</td>
<td>ETSI Technical Committee Network Function Virtualization (NFV)</td>
<td>Italy</td>
<td>Telecom Italia</td>
</tr>
<tr>
<td>Janusz PUECZERAK</td>
<td>ETSI Network Function Virtualization (NFV)</td>
<td>Poland</td>
<td>Telekomunikacja Polska</td>
</tr>
<tr>
<td>Konstantin TROFIMOV</td>
<td>LS co-ordinator</td>
<td>Russia</td>
<td>Radio Research &amp; Development Institute (NIIR)</td>
</tr>
</tbody>
</table>

Table 2: SG-13 Representatives and Other Roles (Study Period 2017-2020)

As the table demonstrates, these 13 representatives are the primary advisors of an incredibly large agenda to determine the technological standards of the world’s digital infrastructure.

Overall, they are not representative of each country and are largely based in industry opposed to public mix.

Canada’s scarce representation is not unusual, as numerous countries—and specifically, countries also part of the G20—are not represented at all. What becomes problematic in the Canadian representation question, however, is the ways in which Canada collaborates with the ITU. ITU-T is a division of the ITU in which countries may have representation and submit Recommendations for Resolutions to, but Canada has not contributed to SG-13 from an open government, public policy perspective. Canada has, however, offered reports on areas of standardization which include Broadcasting Equipment Standards, Radio Equipment Standards.
(including RSS), Digital Television Standards (DTV), Interference - Causing Equipment Standards (ICES), Standard Radio System Plans (SRSP), and Terminal Equipment - Technical Specifications List (CS-03) (Government of Canada, 2018). In total, Canada is not contributing to areas of evolving internet governance, but instead focuses on broadcasting and physical layer infrastructure recommendations, thereby leaving a gap in Canada’s international affairs in this area of standardization proceedings. No report on Canada’s standard setting or recommendations for standardization processes of the transport layer is available on the Government of Canada website, whereas the above listed areas do have this information readily available.

For the study of international standardization in telecommunications, Canada does have series of National Study Groups (NSGs) to mirror each of the ITU-T’s SGs. These NSGs are Chaired, along with the Canadian National Organization for the ITU-T (CNO/ITU-T) Secretariat as both being comprised of Innovation, Science and Economic Development Canada (ISED). Steering Committee members include a public-private mix involving ISED, Bell Canada, Ciena Canada, Ericsson Canada Inc., InterDigital Canada Ltée, TELUS Communications Inc., Vidéotron s.e.n.c., AEPONYX Inc. (SG 15), Corinex Communications Corporation (SG 15), EXFO Inc. (SG 15), ISARA Corporation (SG 17), Renesas Electronics Canada Limited (SG 15), Tutela Technologies Ltd (SG 12), Concordia University, and Mila – Quebec Institute of Artificial Intelligence. In this breakdown of Canadian representation at ITU-T, we can see the committed SG Canadian representation not including SG-13 (Government of Canada, 2021). The CNO/ITU-T was established in 1973 with a set objective to “promote and coordinate Canadian participation in the activities of the ITU-T.” (Government of Canada, 2021, para. 1). This promotion and coordination of Canadian participation, however, seems to not include large
swaths of the ITU-T and raises questions to the efficacy of CNO/ITU-T in promoting plans for studies with Canadian values and interests in mind.

As it stands, SG-13’s leadership team conducts the plans for studies with the Recommendations and Resolutions which follow, however, does not always author all published content as members of given Focus Groups under their purview. In the case of Richard Li’s request for SG-13 Focus Group, representation came from the United Kingdom (UK) (four researchers), the US (three researchers), Russia (two researchers), Egypt (one researcher), South Korea (one researcher), Belgium (one researcher), Japan (one researcher), and China (three researchers, including Li who was the Chairman of the Focus Group). In this we see fewer countries represented in a call for a ‘New Internet,’ as to quote Li’s presentation, thereby concentrating global political representation to an even smaller pool. The Focus Group was finalized and launched on 27 July 2018, nine days following Li’s presentation at the Third Annual ITU IMT-2020/5G Workshop and Demo Day and concluded its activities in July 2020; a mere few weeks following this thesis’ submitted research proposal working to bring greater awareness to the changing landscape of internet protocols and their governance.

Since its conclusion, SG-13’s Focus Group has publicly released eight reports and a Terms of Reference. Six of these eight reports are technical in nature, however, analysis by ICANN (2020) have identified them to be too vague for any computer engineering merit to be derived from them for further internet development. The Terms of Reference and White Paper, which SG-13’s Focus Group produced, provide daunting recommendations and glimpses into the future of the internet as we know it through the development of FN broadband networks. It is also here that the name of the Focus Group, ‘Network 2030,’ identifies their purpose to have
these new technological standards in place for a 2030 internet and beyond. Focus Group Network-2030’s Terms of Reference state the objectives for the Focus Group (FG) are:

The objective of the FG is to carry out a broad analysis for future networks towards 2030 and beyond. In order to formulate a right vision, this FG is expected to identify the gaps and challenges based on latest networking technologies, and derive fundamental requirements from novel use cases. In addition, the FG intends to formulate an overall framework of Network 2030, while innovative technical enablers are expected to be proposed. Furthermore, this FG also can serve as an open platform for experts representing ITU members and non-members to quickly move forward the standard develop of future networks at ITU-T, mainly targeting on future networks in the coming decade.


In the Terms of Reference, the FG continuously refers to the importance of equipping next generation and future networks built on 5G/IMT-2020 the need to support multi-dimensional holographic multimedia in the 2025-2035 timespan. In addition, an acute awareness to the needs of protecting privacy, human safety, supporting future IoT technological development, and overall, “future-oriented new scenarios” is paramount (FG-NET-2030, n.d., p. 1). The Terms of Reference also identify that the FG study’s aim was to “answer specific questions on what kinds of network architecture and the enabling mechanisms are suitable for such novel scenarios.” (FG-NET-2030, n.d., p. 1). In sum, the study group would be analyzing technical standards of packet-switching technologies and their capabilities along physical broadband networks and the feasibility of this with the current transport and physical layers of
the internet’s infrastructure interacting with emerging technological development along the applications layer.

The Terms of Reference concludes the scope of the study that FG Network 2030’s research exploration would work to understand, many broader perspectives not restricted by existing notions of network layers or any particular technologies nowadays. Thus, it may be built upon a new network layer or new network architecture to carry information in a manner that may be an evolution and refinement of existing networks or quite different from. However, it should ensure that the future network systems and applications remain fully backward compatible.


In this, a bias towards a move to a new network standard and transport layer can be seen through the phrasing of ‘new network layers.’ Although the final sentence of the quote identifies an assurance of future network systems allowing for interoperability with existing and past systems, ICANN has criticized this point in their analysis of the Network 2030 documents, stating that the use of gateways would be needed, thereby dismantling the end-to-end principle of the internet, and an end to the core acting as a ‘dumb’ intermediary network with smart edges (ICANN Office of the Chief Technology Officer, 2020).

This hinting towards a new internet protocol, in conjunction with Richard Li’s slide deck where he makes a similar call, was realized on 10 September 2019 when China Mobile Communications Corporation, China Unicom, Huawei Technologies Co., Ltd. (China), and the Ministry of Industry and Information Technology (MIIT) (China) submitted their document titled, “New IP, Shaping Future Network”: Propose to initiate the discussion of strategy

34 Note that Richard Li was the Chairman of the Focus Group, so it is not out of question that there would be parallels with his argument and the Focus Group’s.
transformation for ITU-T’ (China Mobile Communications Corporation et al., 2019). A revision to this submission occurred on 24 February 2020. All documents are currently restricted to Telecommunication Information Exchange Service (TIES) users, which the costs of entry listed earlier were out of this research project’s budget. This submission by China was done halfway through the FG Network 2030 timeline when they were meant to be studying such future networks topics. A meeting over this submission of China’s ‘New IP’ was held on the 23 September 2019. This secrecy surrounding new technical standards and specifications along the transport layer of the internet’s infrastructure falls out of line with early internet development where RFCs were available for collaboration, thereby allowing for scaffolding of the internet’s development. This initial development, however, was openly accessible through the IAB and later IETF, opposed to through the ITU’s TIES database as has been done now with the China New IP proposal.

5.1 FG Network 2030’s Findings

The findings of FG Network 2030 conducted between 2018 until July 2020 fell in line with recommendations to consider the China New IP submission from Li’s presentation. The published White Paper titled, *Network 2030: A Blueprint of Technology, Applications and Market Drivers Towards the Year 2030 and Beyond*, is a short, 18-page overview of a study taking place for more than a year. Although all completed documents and technical reports by the FG were published by the ITU in July 2020, the White Paper was written and published in May 2019 (FG-NET-2030, 2019). This is significant for two reasons, first it is prior to the global COVID-19 pandemic, which is still ongoing during the time of writing this thesis and has resulted in broadband and internet infrastructure becoming much more essential to citizens’ lives.

---

35 TIES is the database which Member States have full access to, and which industry and academic representatives are required to pay thousands of Chf for access.
around the world. Second, this time of writing is significant as it hints that the report was being written during the standardization application by China for their ‘New IP.’ As Richard Li is the Chairman of the FG, and is an employee of Futurewei, it can be assumed that he was transparent with information on the study, which would not be out of question or overtly unethical for this FG as they were collaborating with industry on future network developments. This same observation has been made by ICANN who has questioned the direct relationship between Network 2030 and China (ICANN Office of the Chief Technology Officer, 2020). Regardless of speculation of whether Li should or should not have—or even was the one—sharing information; at the time of writing this thesis there are no publicly available documents on New IP’s technical components or historic background from Huawei or Futurewei. Because of this limitation in public knowledge of New IP, the relationship to Network 2030 in Network 2030’s documents on New IP offers a degree of confusion specifically regarding this relationship and the technical specifications of New IP. Li does appear to be the common node in this relationship, though.

Regarding the findings of the White Paper, it devotes a significant portion of its length to the discussion of holograms, thereby noting this as significant in future network technologies. It also discusses that in addition to the design of holograms, having “near senses,” being perceptions of reality which result in a direct chemical reaction of one’s biological receptors (FG-NET-2030, 2019, p. 6) would be beneficial for industries, specifically food and diet which could use digital technology to send magnetic pulses to the brain to mimic these ‘near senses.’ These sensory pleasures were flagged by Network 2030 as a potential high-profit industry in 2030 and beyond. The market benefits which sensory pleasures and holographic media intertwined are strongly favoured throughout the White Paper, as best described towards the end of the document in bold and italicized font, “Network 2030 strongly believes holographic media
and full-sensory immersive experiences will lead to new application opportunities in a range of market verticals." (FG-NET-2030, 2019, p. 14 original emphasis).

In addition to the excitement surrounding holographic media, which is peppered throughout the White Paper, the document also raises fears over the tensions between bandwidth needs of the future, and current capabilities of the internet. On page nine of the White Paper, a figure is presented which shows two arrows, one which allows current network capabilities to achieve holograms, and a second which does not. These two arrows are described by the FG as, “a situation where we see the trend of increasing penetration [in human use of connected technologies] of communication either stalling or being invigorated by innovations in the right communication technologies.” (FG-NET-2030, 2019, p. 9). The diagram this quote references, showing the continued push to holograms on the market in 2030 is shown below.

![Figure 6: Network 2030 Opportunities of Challenges Towards 2030 Diagram](image)

(FG-NET-2030, 2019, p. 9).

The diagram and quote are followed by the FG stating their concerns surrounding current network technologies not moving in the progression of the blue arrow. The worries which the FG raise surround a quantitative lens offered by Sarnoff’s Law, that the value of the network
increases in value as proportionate to the number of users it hosts. This approach, however, does not take a qualitative viewpoint of whether these developments are beneficial to society and in line with the public’s interest.

A significant moment of the report comes from the introduction of a concept, which now enters the internet infrastructure and internet standardization lexicon: ManyNets. ManyNets as a concept is introduced in the report as,

[A] seamless coexistence of heterogeneous network infrastructures: Networks overall, not only at the edge, have become increasingly richer in terms of technology, ownership and end user participation. Quite likely there will not be just one, but many public Internets. New technologies further widen the constraints for transmitting packets through the utilization of infrastructure-based wireless, wireless mesh, satellite, fixed line technologies (such as fibre optics), all of which must be accompanied by the fundamental packet transfer solution, while adhering to the underlying ownership relations when traversing those different networks.

(2019, p. 11).

As the above excerpt from the White Paper suggests, the SG-13 FG is no longer thinking in a single internet, and instead finished the second sentence with the prospect of a plurality of public internets. This would fundamentally change the transport layer of the internet’s infrastructure by introducing multiple public internets. It should be noted that Paul Dourish’s work has found that additional protocol suites are still in use today with ATM, originally developed by telecommunications corporations in the late 90s, however, the market acceptance of this protocol suite was not picked up by the public thereby only affecting certain business entities where large, single—opposed to synchronous and frequent—data transfers occur (Dourish, 2015). This
concept of a future filled with internets that the FG puts forward, and that we are on the tipping point of another public internet which users around the world will log into, is the inspiration for this thesis’ title and addressing the fluctuating changes of the transport layer of the internet’s infrastructure.

Following this introduction of ManyNets in the White Paper as a new key concept in telecommunications, Network 2030 further identifies the consequences of ManyNets, “As a consequence, the end-to-end realization of services across those many internet environments need strong consideration for Network2030 and is an increasing departure from the structures of networks as we see today.” (2019, p. 11 original emphasis). In other words, the end-to-end principle of internetwork connection is soon to be dead. This thereby tarnishes the original philosophy that the internet as a communications infrastructure should be one of connecting people in a decentralized manner, making the relevance of the transport layer of the internet’s infrastructure, not a research interest for emerging scholars like this author, but one of political and governance relevance with a direct effect on the masses of citizens who use internet technologies.

This concept of ManyNets, or internets has raised concerns by ICANN. In their critiques of New IP, they specify on the concepts of in-time service delivery as follows,

One of the key design principles of the Internet was to have ‘dumb’ intermediary network elements and smart edges. Introducing large, intelligent buffering systems into the data transmission path to provide minimum latency guarantees is an unproven technology and a major departure from that principle, without guarantees for success.

(2020, p. 21).
As the FG had specified, they were concerned with interoperability between the current network system and any future systems. Overall, the Chinese engineers of this New IP would have two options in the development of New IP/ManyNets/internets being,

1. Completely replace all TCP/IP suite network infrastructure and start anew with New IP to allow for evolution in data transfer capabilities to Tbps, in which Huawei would make this network infrastructure and force New IP upon the market.
2. Develop gateways which will allow for interoperability between the various internets but would then result in the effective dismantling of the end-to-end principle of connecting end users through this intermediary between the network infrastructures.

In these two scenarios, the latter is more attractive due to its ability to merge a technology into existing infrastructure, while allowing for development to occur. This integration would be done through various gateways, as ICANN noted, increasing the cruciality of the transport layer of the internet’s infrastructure as a space of politics and network power.

5.2 Gateways

The use of gateways is a prevalent theme in the critiques of New IP by the internet community (e.g., ICANN, IETF explored later). The technical affordances of New IP have been criticized for not allowing a seamless interoperability between the current TCP/IP’s transport layer and any further developments. This is because the header addressing space has been defined as being able to work along both IPv4 and IPv6, the 32 and 128-bit combinations of ones and zeros which constitute all website address spaces. This is not possible without a gateway to interoperate the IPv4 and IPv6. In addition, the submission of New IP says it may work along any internet addressing scheme, however, this again will not be able to be done without a

---

36 See Laura DeNardis’ book *Protocol Politics* for a thorough analysis of scarcity in the internet protocol addressing space and the governance surrounding transitions from IPv4 to IPv6.
gateway to allow this automatic communication to take place for interoperability to occur. As ICANN describes,

Using one format in the header has consequences on the payload. Because of the fixed Maximum Transmission Unit (MTU), usually set to 1500 on any given link, the maximum payload of the packet is equal to the difference of the MTU and the header size. If address families are changed anywhere en route, there is a chance that the payload will no longer fit, and the packet would have to either be discarded, in the case of the IPv6 protocol, or fragmented, in the case of the IPv4 protocol. This would have an adverse effect on end-to-end traffic. This situation is well known with the current translation of IPv4 packets to IPv6 packets. There are ways to mitigate this effect when using the TCP transport protocol, but none are satisfying when using the UDP transport protocol, which is the default for applications such as DNS.

(2020, p. 25).

The following image lightly describes the network routing plan for New IP as cited from ICANN’s review of Richard Li’s “What is New IP” Industrial Keynote Speech at IEEE Infocom in July 2020. It should be noted, that unlike his colleague, Dr. I.F. Akyildiz, the Ken Byers Chair Professor with the School of Electrical and Computer Engineering out of Georgia Institute of Technology, who put his keynote address as a saved YouTube video on InfoCom 2020’s website, Li has not made his talk accessible to those who were not attendees (IEEE InfoCom, n.d.), thereby resulting in this information second-hand via ICANN’s analysis.
ICANN continues to critique the technicalities of New IP’s proposed use of the header with,

Although the New IP header can carry IPv4 or IPv6 addresses, New IP would not appear to be fully compatible with IP; as such, it would have to be deployed in parallel to existing IP-based networks, forcing the use of gateways to connect to the current Internet.

The introduction of these gateways will mean increased operating and capital costs and added complexity to network operations. Such a deployment model places a very high bar for adoption, especially when considering the still lacklustre adoption of IPv6 [twenty-five] years after its definition.

(2020, p. 28).

In summary, gateways would be needed to connect internets to one another due to addressing space, however, this addressing space would need to be done with entirely new developments in the header space, otherwise the network would undergo frequent breakage. This uncritical review
by Huawei of their own New IP submission and a holistic review of how to integrate across the existing TCP/IP suite’s transport layer with New IP was a common theme found in the research.

5.3 The Uncritical Analysis of New IP

The Network 2030 FG also identifies that a next generation network technology affordance will be ‘tactile internet for remote communications (TIRO)’ (FG-NET-2030, 2019). In this, they state two possible scenarios will come from the remote sensing of the human body’s movement or muscular effort: remote surgery and real-time monitoring and control of industrial infrastructure. In addition to IoT commercial benefits of the acute sensing of human bodies, which the report identifies healthcare as a beneficiary remote sensing, this technology would also present military and warfare capabilities which has been left out of the Requirements report’s identification for the transition in technologies. As Vincent Mosco states, keeping an acute eye to military uses of next generation technologies is imperative by communications scholars (Mosco, 2017). TIRO would allow for real-time visual feedback and haptic information to be communicated between a robot and human operator. This discretion of potential military tactics which may be used in next generation technologies as afforded by the China New IP cannot be ignored through the promise of robotic healthcare and industrial development. A pattern of not providing full details of the scale in the affordances of New IP has become prevalent in both the released documents, as well in public relations and marketing of this transport layer development initiative.

Not all countries are comfortable with the idea of China’s New IP. Japan, for example, has been critical of it (ICANN Office of the Chief Technology Officer, 2020).37 Unnamed

---

37 Japan’s comments on the proposed questions for New IP are restricted by the ITU to ITU-T/TIES users. The comments were posted in English in a 58,877 bytes Microsoft Word document on 6 July 2020. The reference of these comments come from ICANN who have access to the ITU-T/TIES portal. The following link identifies this
sources reported by the *Financial Times* have also stated that opponents to New IP include, the UK, Sweden, and the US, with reports of concern by Western countries in this development being provided in “a forthcoming paper for [NATO] by Oxford Information Labs, whose authors are the UK delegates to the ITU” (Gross & Murgia, 2020, para. 11). On the other hand, political proponents of New IP have been reported to include Russia and Saudi Arabia (Gross & Murgia, 2020). Developing countries in Africa, the Middle East, and Asia have been placed in a crossroad in the geopolitics of New IP as China has agreed to supply many of these countries with telecommunications infrastructure and surveillance technologies under the “Belt and Road Initiative”38 (Gross & Murgia, 2020). These agreements then tie beneficiary countries to Chinese telecommunications infrastructural development through this intersection of power between physical infrastructure and transport layer infrastructure (being New IP) as a tactical use of monopolies of knowledge solidifying Chinese power of global communications infrastructure (Innis, 2007, 2008).

Where it can be expected that Huawei would be uncritical of New IP, we also see collaborations between Huawei with University College London’s faculty members: Dr. Alex Galis and Dr. George Pavlou. The first academic paper published on New IP, which the description and consistent marketing of *ManyNets* made to be a necessary and logical progression in the internet’s make was written by Huawei’s Zhe Chen, Chuang Wang, Guanwen Li, Zhe Lou, Sheng Jiang, and University College London’s Alex Galis, who is a professional portal to Japan’s ITU-T comments, which was inaccessible to the public at the time of writing: https://www.itu.int/md/T17-SG13-C-0915/en

38 The Belt and Road Initiative, also known as the One Belt One Road (OBOR) Initiative is a global infrastructure development strategy by China since 2013 to connect Asian, African, and Eastern European countries, and has been critiqued as a 21st Century form of economic imperialism (Kuo & Kommenda, 2018). More information on the Belt and Road Initiative can be found by the Organisation for Economic Co-operation and Development’s (OECD) report on it (OECD, 2018).
research associate studying 5G networking and software defined infrastructure and services (University College London, 2021). In the article, ManyNets is marketed as,

[T]he emerging and growth of ManyNets including the Internet of Things (IoT) network, the cellular network, the industrial network, the satellite network, etc., makes the Internet “fragmented”. The interconnectivity among ManyNets in order to make information and services from one network available (if permitted) to another network becomes a challenging task. Although it was designed for the interconnection of several regional academic and military networks in the 1970s, the current TCP/IP protocols and framework contain limitations for the ManyNets interconnectivity.

(Chen et al., 2020, p. 1).

As is shown, ManyNets is presented as ‘common sense’ in the internet’s evolution and is falsely stated that is can already be seen in internet architecture nowadays. Through this framing of ManyNets already occurring and a natural progression, this combination of force (being Huawei and China’s economic and infrastructure power) and consent (via the standardization process and global physical infrastructure agreements) establish the ‘normal exercise of hegemony’ (Gramsci, 2013) with the ManyNets key term. This concept is not old and established, as Chen et al. purport, as the FG Network 2030 White Paper showed ManyNets as a term has only emerged in 2019. The idea of a fragmented internet and that we are living in a plethora of internets, is not true from a public use of the internet perspective.39

39 There are a handful of internet protocols which are used by some industry players and NASA; however, these have little to no effect on the public as they are for streamlined, specialized communications opposed to regular internet operations and do not interoperate with the TCP/IP suite via gateways.
and Electrical Engineering’s Information and Communication Engineering Group had prepared a presentation for the ITU promoting the benefits of New IP and the ‘ultra-fast networking’ capabilities it would bring at the start of 2020 (Pavlou, 2020). This presentation was given on either 13 or 14 January 2020 in Lisbon, Portugal by George Pavlou, a professor of communication networks and fellow of IEEE (Pavlou, 2017). The date is not provided and further documents which would clarify this are behind the TIES database paywall, however, route linking the publicly released PowerPoint frames the presentation being given at the 6th ITU Workshop on Network 2030 Demo Day, three demo days following when Richard Li had first called for research in a new public internet. It is unclear of the further relationships between University College London and Huawei; however, it is apparent that its Department of Electronic and Electrical Engineering have worked to aid Huawei in the public relations campaigns of ManyNets and the network affordances of a New IP.

In summary, New IP is scarce on details as well critical reflection as to whether this technology should be introduced to the public. Documents on this proposed internet protocol tend to lean to the benefits of it in areas of holographic media, satellite (space) networks, and human physical wellness. Critical analyses of New IP which others offer have been met with hostility by Huawei and its subservient via Futurewei, Richard Li.

5.4 New IP and Hostility Towards the Media

Likely in 2020, however, a date in not provided, Huawei added a blog post to their website discussing New IP. They titled this blog, ‘A Brief Introduction about New IP Research Initiative.’ In this, the word ‘initiative’ is significant as Richard Li had given a presentation for

---

the Internet Society towards the end of 2020 specifying New IP as a research *initiative* opposed to set development. Framing this as an initiative, however, is incorrect as standardization attempts with both the ITU and IETF had already—and are still at time of writing—taking place; thereby making this not as much a research initiative for possibility, but a plan of action for a new internet protocol. The blog post consistently states how New IP is an emerging area of study, and not something which should cause worry as it is in the research and development stage. It is here that Huawei defines New IP as,

> New IP can be characterized as a technology study initiative, driven by vision on scenarios for utilizing Internet technologies in many facets of the future digital industry and society. As such research initiative, it is centered on study areas that address aspects of the Internet data plane as well as its associated infrastructure, technologies and protocols.

(Huawei, n.d., para. 4).

In sum, New IP is defined by Huawei as a research project, not a technology in its completion. This New IP project will intersect the layers of the internet as infrastructure along its physical, applications, and transport layers through new coding of the applications layer and embedding new capabilities in the physical layer to accommodate this new transport code. Although the physical and applications layers will have to be developed further, the ongoing standardization process shows that New IP is not still in development but inching towards its deployment phase.

Towards the conclusion of the blog post, Huawei takes a pointed critique at media coverage reported in the *Financial Times*. Huawei specifically quotes and references a line from a 27 March 2020 news article and counters the news article with, “New IP does NEITHER define governance models for the use of those technologies, NOR lead to ‘more centralised, top-
down control of the internet.’” (Huawei, n.d., para. 12 original emphasis). The blog then goes on to discuss Huawei’s positive contributions to preventions of DDoS attacks and ‘shut-off” protocols. This further elaboration on DDoS does not, however, excuse the way in which the corporation specifically works to undermine journalistic coverage of New IP. Discrediting and calling out journalists would soon become part of a pattern in Huawei’s public marketing of New IP while it is still under review by the ITU-T. The blog post continues to paint a sour image of opponents and critics of New IP and states,

Contrary to the current politicized debate, New IP invites an open and free discourse through inviting researchers from all countries and industries around the world to participate in the research that would see IP evolve along the requirements found in relation to New IP and therefore drive the sustainable development of the global communication industry.

(Huawei, n.d., para. 14).

In this, Huawei frames themselves to be international collaborators and inviting governments and industry representatives from various countries to participate in the development of New IP as a research initiative. They frame their critics as partisan rivals and dismiss their critiques stating that this development is not one of individual corporate profit, but instead as sustainable development in future and evolving internet infrastructure, specifically along the transport layer.

The attacks on journalists, and more generally ‘the media,’ do not stop with Huawei’s blog post. On 23 September 2020, Richard Li joined Dr. Milton Mueller, a Professor at the Georgia Institute of Technology School of Public Policy whose research focuses on the political economy of the internet (Internet Governance Project, 2021); and Andrew Sullivan who is the President and Chief Executive Officer of the Internet Society and is a dual Canadian-American
citizen whose research includes the philosophy of economics completed at Canadian universities (Internet Society, 2021); at the Internet Society to discuss New IP in a talk titled, “‘New IP’ and global Internet governance.’ In this talk, the technical and governance perspectives of New IP, with its discussions as a research initiative, and its need for future networks were analyzed by Li and Sullivan with Mueller as moderator. Where Li took an engineering stance, Sullivan continuously brought the conversation back to one of governance and the international structures in place to ensure the internet is an equitable space for users. All three participants of the recorded Zoom call critiqued the end-to-end principle and the original make-up of the internet for its shortcomings in how TCP/IP and its transport protocols can work along with issues surrounding internet protocol addressing through IPv4 and transitions to IPv6 to allow for less scarcity in this aspect of the internet’s make.41

Li and Sullivan both agreed in their moderated discussion that the perspective someone takes on a new network protocol depends on where they start with the following two questions:

(1) Do we want this?

(2) How do we do it?

When starting with the ‘Do we want this?’ perspective, this is where governance comes in. In other words, instead of thinking like an engineer, the student or researcher interested in internet protocols and the transport layer will ask questions of trade-offs opposed to technological possibilities. If one were to start with the, ‘How do we do it?’ question, this is one of engineering in determining if our current internet infrastructure, and here transport layer, can meet the needs of future technological developments. It is at this point in the conversation where Li critiques that in technology developments in 5G and beyond, our current TCP/IP suite will hinder the

41 For further scholarly analysis of scarcity of IPv4 and IPv6, a corpus of Laura DeNardis’ work on internet addressing space as resources for this understanding.
possibilities which this generation of wireless development may afford. From another perspective, without a new protocol suite and transport layer, any hyped development in 5G and beyond will not be able to come to fruition due to issues of latency and instability from the TCP/IP suite, as argued by the panel (Internet Society, 2020).

As presented by Li specifically, the argument of not a desire, either by profit or control, but a need for a new internet protocol and redesign of the internet’s transport layer is offered and agreed by all three members on the call. Mueller then asks Li a question and professes to his personal frustration that media coverage of New IP has framed it as one of overhaul of the internet for Huawei’s corporate benefit opposed to research and engineering possibility. It is to this that Li responds in the time markers 00:18:48-00:19:09 saying, “Firstly, I would say, don’t trust media. Media is a lot of misinformation and disinformation there. And it is quite misleading. So unfortunate, people even make a, like a decision and influenced from the media.” (Internet Society, 2020). Mueller and Sullivan do not flinch when this comment is made, and do not make any corrections to Li’s defamatory comments about the media. In total, the three panelists seem to hold a silent consensus about their disdain for media and use their presentation platform as an area to promote distrust in this democratic institution.

These critiques of media framing of New IP have come from two groups of sources: IT bloggers, and coverage by the Financial Times. Nor Huawei or Li have offered commentary to the IT bloggers, however, these bloggers’ analysis is fruitful in its critique; and exploration of IT bloggers in technology standardization is an interesting avenue, however, exceeds the scope of this thesis. The hostility towards the media by Huawei and Li as a general sense is one specifically targeting two female-identifying journalists: Anna Gross and Madhumita Murgia of the Financial Times, which is a legitimate UK daily newspaper. These two women collaborated
on a couple of articles in early 2020 to gain public attention to China’s standardization
application of New IP with the ITU (Gross & Murgia, 2020; Murgia & Gross, 2020). In their
first news article surrounding the New IP published on 27 March 2020, the two journalists
criticize Huawei and China stating,

China has suggested a radical change to the way the internet works to the UN [United
Nations], in a proposal that claims to enable cutting-edge technologies such as holograms
and self-driving cars but which critics say will also bake authoritarianism into the
architecture underpinning the web.

(Gross & Murgia, 2020, para. 1).

It is this opening sentence which has resulted in the hostility against the media by the key players
(Huawei and Li) who continue to work to legitimize a second public internet.

In Murgia and Gross’ second news article in the Financial Time released the same day
and is a significantly longer analysis of New IP, they provide a more storytelling means of
describing the emerging threat of a second public internet through the standardization of New IP
as proposed by China. In this article, Murgia and Gross continuously put the purpose of the
internet as a space for empowering individuals and not nation-states. This can be found in their
quote: “Whereas today’s internet is owned by everyone and no one, they [Chinese engineers]
were in the process of building something very different – a new infrastructure that could put
power back in the hands of nation states, instead of individuals.” (Murgia & Gross, 2020, para.
2). This second article later goes into the sentence, which Huawei critiqued in their blog post
citing Murgia and Gross, being,

[Huawei representatives at an ITU-T meeting] presented a simple PowerPoint. It didn’t
bother with much detail on how this new network would work, or what specific problem
it was solving. Instead, it was peppered with images of futuristic technologies, from life-size holograms to self-driving cars.

The idea was to illustrate that the current internet is a relic that has reached the limits of its technical prowess. It was time, Huawei proposed, for a new global network with a top-down design, and the Chinese should be the ones to build it.

(Murgia & Gross, 2020, paras. 4–5).

The article further goes on to analyze how the legitimization of New IP would result in a plethora of internets, as it would spark countries each having their own internet which then connects to others via gateways. This would then allow for more censorship of the internet within various nation-states, a direct opposition to the original philosophy of the internet as being one in which end users have the power to connect to one another, and the transport of data packets is done so through ‘dumb pipes.’ It is not surprising that this in-depth critique of China and New IP ruffled Huawei and Li’s feathers on the matter. As the journalists note, however, Li was contacted for questions and comments surrounding New IP but declined an interview (Murgia & Gross, 2020).

In Huawei and Li’s call for this media coverage as being illegitimate, it must be noted that Murgia and Gross had consulted experts in internet policymaking, such as Western country delegates to the ITU, along with Shoshana Zuboff, author of *The Age of Surveillance Capitalism* and is an academic out of Harvard University (Murgia & Gross, 2020). They also note one of the loudest critics to New IP as being Sweden’s Patrick Fältström, a credited ‘father’ of the internet who now works as a digital advisor to the Swedish government (Murgia & Gross, 2020).

To summarize the hostility towards the media by Huawei and Li in conversations surrounding New

---

42 He is given this title in his home country Sweden for when he was a student in Stockholm who in the early 1980s was tasked with helping bring and test the new US ‘internet’ to Sweden.
IP, this can be seen as one attempting to silence public contemplation of the internet as infrastructure, thereby mystifying this communications infrastructure. This mystifying has been well chronicled in the literature and allows for infrastructure and its developments to go unnoticed by the masses (Star, 1999). This shared contempt towards New IP has received loud oppositional agreement from key internet governance players around the world.

5.5 Critiques from the Internet Community Towards New IP

ICANN and the media have not been the only critics of New IP. Prior to undergoing the standardization process with the ITU, China originally attempted to negotiate the introduction of New IP with the IETF. This fact was mentioned in the Li-Sullivan-Mueller panel conversation, which this attempt had been unsuccessful leading to China and Huawei pursuing standardization with the ITU. Although this was mentioned by Li-Sullivan-Mueller, the IETF argued otherwise in a letter stating that they have not received formal submissions for extending or replacing the TCP/IP suite or transport layer protocols. In a letter to the ITU’s Telecommunication Standardization Advisory Group Standardization Bureau (TSAG-TSB), Dr. Alissa Cooper, a Fellow at Cisco Systems and the current serving IETF Chair (IETF, 2021), argued that there is no need for a new internet protocol (New IP) and that China and Huawei were misleading the ITU in its standardization request by framing TCP/IP as out-of-date and that this was not the case. She presents a thorough argument in this letter, referencing a plethora of RFCs from the 1990s until closer to present day and specifying research continuing at the IETF in the transport layer of the internet’s infrastructure. She also specifies the engineered physics of latency of TCP, which China and Huawei used as their main concerns in their desire for the development of holographic media arguing,
We expect those [research and development into strengthening TCP for live streamed communications] efforts to continue to meet the needs of newer real-time applications, including holographic communications, without the need for a new network architecture. We also note that any real-time systems requiring sub-millisecond latency inevitably have limited scope because of the constraints of the speed of light.

(Cooper, 2020, para. 7).

The letter continues with well pointed quips directed towards China and Huawei over the application for standardization of New IP through the ITU. She concludes her letter offering to collaborate with any interested parties in the extension of transport layer protocols and the TCP/IP suite and finished her argument with, “[W]e believe the creation of a top-down design effort to replace the existing IP protocol stack wholesale would be harmful. Doing so would most assuredly create network islands, damage interconnection, and jeopardize interoperability.” (Cooper, 2020, para. 14). A strong and to the point argument from the IETF Chair regarding the unneeded trade-offs of a New IP.

In this lettered email, she CC’ed Ericsson Canada’s Scott Manisfeld,43 the IAB’s ITU-T liaison email address, IETF’s Internet Engineering Steering Group (IESG), and the ITU Councillor for Canada who is also the Chairman of TSAG, Dr. Bruce Gracie through his Ericsson email address. As we see in this letter, Canada does have representation in areas concerning the public’s interest in this area of the transport layer’s standardization via Ericsson Canada, however, we do not have a further paper trail of our own public service interventions or complaints on the matter. There is only room for speculation for Canada’s role in SG-13 and views of New IP as we do not have publicly appointed members or reports on this area of

43 Manisfeld was the only SG-13 leadership representative CC’ed on this email. SG-13’s leadership as identified from the table at the start of this chapter.
international telecommunications standardization. As is apparent in Cooper’s email CC’ing list, however, Canadians are acting as key players in behind-the-scenes conversations regarding New IP. This may be due to ongoing Canada-China tensions surrounding the telecommunications sector following the detainment of Huawei executive Meng Wanzhou on extradition charges issued by the United States, which resulted in the Chinese detainment of Canadians, Michael Kovig and Michael Spavor (Proctor, 2020). This international affairs situation began on 1 December 2018 and continues during the time of writing this thesis. Overall, a clear reason as to links between Canada and New IP are not apparent in publicly available documents from the Government of Canada website, the IETF, or the ITU.

In her email, Cooper specifically asks the ITU to consider her letter as evidence in the proceedings leading up to the World Telecommunications Standardization Assembly (WTSA). WTSA is an international conference which occurs once every four years. At this conference, decisions surrounding commissioning of FG’s and areas of focus for the SG’s is decided through negotiations between government representatives, industry collaborators, and the ITU-T as identified through Article 18 of the ITU’s Constitution (ITU, 1992). At the time of writing, the conference has had its dates changed multiple times due to the ongoing COVID-19 pandemic before settling on being held in a virtual format (ITU-T, 2021b). As I complete writing this thesis, the WTSA has just finished its week-long events on 9 March 2021 where they aimed to determine research areas for the 2025-2035 period. Without any published information by the ITU regarding what the years 2025-2035 will mean for the ITU-T SG’s and the further pursuance of incorporating New IP into the global internet infrastructure through this standardization process, this thesis does not contain information on final decisions on the matter as this story on New IP continues to be written.
In this chapter, I have presented the findings of ongoing changes to the transport layer of the internet’s infrastructure. Since 2018, we have seen the beginning phases led by China and Huawei to integrate a second internet, thereby fluctuating the power and significance of the transport layer, within the decade. The next chapter will offer a discussion of the findings of the histories and trajectories of the transport layer and internet protocols and offer policy recommendations for Canada, who has historically been a silent voice in the area of transport layer standardization.
Chapter 6: Discussion

“Will we shoot virtually at each other over the Internet? Probably not. On the other hand, there may be wars fought about the Internet.”

(V. Cerf, 2008, para. 7 original emphasis).

As this thesis has shown, the changing developments in the transport layer are a direct result of faster physical broadband networks able to connect more devices and deliver Tbps speeds for emerging applications, with the transport layer as a processing power system lagging behind in this technological growth. When the physical layer lagged behind in internet application development, solutions have combatted this (fibre optic cables, low Earth orbit satellites/LEOS, shorter wavelength wireless spectrum bands). Changes to the applications layer have included smoother running apps, lower bit rate codecs for processing online videos and images, and multipath options for running concurrent programs on a single internet experience (Gold, 2020; Ul-Abdin et al., 2015). The transport layer is the one layer of the internet which has not received much development, thereby staying static and acting as ‘dumb pipes’ which do not need consistent reconfiguration due to its resiliency of the TCP/IP suite. This, however, has led to limitations in the promised hype for 5G and IoT technologies. In the analysis of China’s New IP, an alternative solution from an engineering perspective has entered the public purview, however, with trade-offs associated with this potential transport layer development.

The greatest impedance which New IP will cause, if successful in its standardization and mass deployment, will be an end to the end-to-end principle as the use of gateways will have to connect the various public internets of the world which has been predicted through the ITU-T SG-13 Network 2030 Focus Group along with ICANN. These internets may be geographically confined, as with New IP this submission was also completed by Chinese government agencies
(Ministry of Industry and Information Technology), however, it is more likely that similar to the current public IP, we will see multiple options for internets. This will bring higher importance to the study of how our data transmits, an area which has little scholarship on it with a few exceptions (Clement & Obar, 2015; Dourish, 2015). As I identified, however, there is pushback in this progression with its intended goal by Huawei of New IP’s completion within its scheduled next nine to 14 years.44

At the time of writing, only two articles and one PhD dissertation have discussed this internet fragmentation. David Weyrauch and Thomas Winzen, both political scientists, published an article in February 2021 where they used quantitative metrics to analyze IETF RFC submissions to document trends in the more prominent internet development players. Their findings were mentioned in the introduction of this thesis. In their article they note that since 2018, Huawei has become the key player in the IETF’s internet standardization RFC documents and that this marks a third shift in RFC and internet standardization participation. (Weyrauch & Winzen, 2021). The first wave in RFC participation was the internet pioneers, the second when the internet was released to the public with computer companies participating in greater numbers, and the third wave being non-American players contributing heavily at the IETF in transport layer standardization processes.

In a similar strain, Britt Paris’ (2018) PhD dissertation and a recent article published this year analyzed the American Future Internet Architecture (FIA) program, which is a National Science Foundation (NSF) funded research initiative to develop the next IP to either work with,

---

44 Dr. Richard Li’s work in both his presentation on behalf of Futurewei to the ITU-T in 2018 and as Chairman of the Network 2030 focus group had a plan of 2030 for this development. The WTSA, however, would be planning their Study Groups and areas of research for the 2025-2035 timeline at the beginning of March 2021 which released documents were not available at the time of writing, so a hypothesis of this New IP development between 2030 and 2035 has been predicted in this thesis.
or replace TCP/IP (B. Paris, 2018; B. S. Paris, 2021). FIA has resulted in three potential contenders for the next IP in the American context, however, are all still under review. Interestingly, one of the three which Paris identifies is Named Data Networking (NDN) which has a similar structure to the TCP/IP suite with providing more space for growth at the edges than in its transport layer. For its transport layer, TCP has been omitted but UDP suffices. As this thesis has shown, use of UDP has grown as internet demands have changed and continue to change to accommodate for live streams of content. The following diagram identifies the TCP/IP suite (left) in comparison to the NDN model (right).

![Diagram of TCP/IP and NDN models](image)

Figure 8: Named Data Networking Protocol Layers (L. Zhang et al., 2014, p. 66).

What the work of these early scholars show is that this thesis is not a stand-alone piece, but instead one which fits within an emerging field of internets and internet fragmentation (Paris

---

45 The FIA was originally titled the Future Internet Design (FIND) program which began in 2009.
is a recent PhD graduate, while David Weyrauch is a PhD candidate who co-authored his piece with Thomas Winzen who is a more experienced scholar).\textsuperscript{46} This thesis is the first study on China’s New IP which is undergoing standardization at international internet governance institutions, as well identifying the ways in which under the current TCP/IP suite, a shift in primary transport layer interaction from TCP to UDP continues due to changes in how citizens use the internet.

Although Alissa Cooper on behalf of the IETF made a compelling argument in her letter to the ITU-T regarding the New IP, as well ICANN arguing for the resiliency of TCP/IP, this thesis has found one crucially apparent reality, \textit{TCP/IP—and its TCP—is not a future-proof technology with its resiliency running short with the emergence of 5G technologies.}

Conversations about TCP/IP’s sustainability have been in question since VoIP and VoD which ATM attempted but failed to prove dominance. As Paris’ work found in her interviewing of principal investigators for future American internet projects, “TCP/IP is very old, and it’s causing people to do tons of things inside of HTTP to work around deficiencies in that transport. XIA [one of the three contending American emerging internets] is an attempt to be a more modern transport protocol that’s extensible” (D. Barrett interview with B. Paris, 2018, p. 42).

This comment regarding HTTP was also found in my analysis of RFCs as described in Chapter 4 with ‘HTTP failovers.’ What we are seeing in the work of internet engineers is a growing frustration with TCP/IP and a planned move towards a new internet. As noted earlier by ICANN (2020) and the Network 2030 FG, is that interoperability must occur with the existing TCP/IP suite. This will be the birth of internets and the death of the end-to-end principle, and as further

\textsuperscript{46}Thomas Winski completed his PhD in 2013.
recent literature by a new generation of scholars is showing, these internets are not going away, but are instead multiplying.

It should be noted that the TCP/IP suite, however, has been the only internet protocol available for mass market release as OSI had burned itself out through ‘death by committee’ and NCP had been discontinued over a decade earlier. In this thesis, China and Huawei’s tactics of how they have gone about standardizing New IP with their attacks on journalists covering the topic, use of scholars through University College London conducting New IP-heavy presentations to the ITU, and the overall secrecy behind the protocol to international computer engineers and scholars studying this area have been unfavorable and warrant the scrutiny which Cooper’s letter directs towards them. It should be noted, however, that predictions about a need for a new protocol once internet usage had transformed to require less latency and more instantaneous communication have been proposed for years (Dourish, 2015; Galloway, 2004). In Cooper’s letter, she does address the resiliency of TCP/IP, however, resiliency and sustainability are two separate concepts and should not be confused as synonyms.47 Again, the argument of TCP/IP as not being a future-proof technology is not new with this thesis or the previously mentioned emerging scholars (B. S. Paris, 2021; Weyrauch & Winzen, 2021). This conversation has been in place with scholars like Alexander Galloway (2004) for just under two decades.

Where areas of scholarship in next generation and future internet networks studying wireless applications’ use of radio-spectrum and the TCP/IP suite’s addressing space for internet routing, both of these fields of telecommunications policy and internet governance have focused on the topic of scarcity, whereas the study of network transport protocols shows not a question of scarcity and resiliency in that scarcity, but one of sustainability. As it stands TCP is not a

47 Resilient versus sustainable development can be found in Zhang and Li’s (2018) article which focuses on urban infrastructural development and municipal policymaking.
sustainable transport layer protocol with emerging developments in wireless technology through its error checking and embedded into the TCP/IP suite. The hype surrounding 5G and future networks will be incapable of coming to realization if the current TCP/IP suite continues as the bedrock of the global internet.

6.1 The Role of National Policymaking for New Internets

The development of the next internet will be tricky. National jurisdiction will be vital to ensuring seamless international gateways, as well with new encryption techniques to ensure users’ privacy. As a jurisdiction, Canada is not well-equipped to develop a new internet. Our limited scope of SG 13 in our mirrored NSGs, high reliance on Ericsson Canada at the ITU-T, and Canada’s digital policy trajectories and challenges not recognizing the transport layer of the internet’s infrastructure, leave us vulnerable. There are two opportunities which Canada may take for internets. One is for Canada to strengthen our CNO/ITU-T NSGs to better match the ITU-T’s. One reason why Ericsson Canada is so prominent, along with limited reports on the SGs, could be the CNO/ITU-T’s funding process for reimbursing companies and academics who are a part of this network. Currently, private sector members of the NSGs are not reimbursed their time, with travel expense renumeration restricted to specific events and the ITU-T Secretariat for Canada who is an employee of ISED, thereby not creating an incentive to be a part of these endeavors, nor the time in completing a memo or write up regarding meetings for the Government of Canada (ISED, 2018). Instead of being reimbursed, the Government of Canada argues that access to TIES and collaboration opportunities is the trade-off of this labour (ISED, 2018). A revisit of this process by the Government of Canada may warrant benefits to

---

48 ICANN’s report on New IP states that when separate gateways are introduced, encryption may not work due to the technical components of moving these secured messages between sender and receiver.
49 These policies include the Canada Future Challenges Area and Canada’s Digital Charter.
ensure timely research and information regarding the fluctuating power of the transport layer of the internet, as well the emergence of future internets is in the public’s purview.

A second area would be for incorporation of the CRTC into the CNO/ITU-T NSGs. Currently, the CRTC is not a member of this, however, the *Telecommunications Act* states regarding technical standards in s.15(1),

The Minister [ISED] may, where the Minister is satisfied that to do so will further the Canadian telecommunications policy objectives, by order made after consultation with the Commission [CRTC], establish standards in respect of the technical aspects of telecommunications and require the Commission to give effect to them.

*(Telecommunications Act, 1993, p. 8)*

Here we see the CRTC mentioned in the *Telecommunications Act* as being a part of the technical standards governance process of Canadians telecommunications, however, not provided a seat at the table in international telecommunications standards setting. This also directly contradicts the *Telecommunications Act* s.7(c) stating,

[T]elecommunications performs an essential role in the maintenance of Canada’s identity and sovereignty and that the Canadian telecommunications policy has as its objectives...to enhance the efficiency and competitiveness, at the national and *international* levels, of Canadian telecommunications.

*(emphasis added Telecommunications Act, 1993, sec. 7(c)).*

By not incorporating the CRTC into the CNO/ITU-T NSGs, ISED’s leadership in this area contradicts Canada’s *Telecommunications Act*, which in the time of establishing internets, strong public participation and knowledge of this coming change is needed in Canada. The CRTC could help perform some of this labour in preparing for internets in collaboration with ISED. The
CRTC would also likely be a stronger choice for more Canadian participation than ISED as has been remarked in studies of the Canadian communications policymaking process (Shepherd et al., 2014).

6.2 The Internet is for Users

In his RFC 8890, Mark Nottingham, a member of the IAB, states that the internet is for its users. Through his tracking of RFCs that support this argument, he provides suggestions for the ways in which the IETF can ensure that users are the ones benefitting from the internet, opposed to private companies or political actors. We are currently on the cusp of incredible change in the transport layer of the internet’s infrastructure, which we have not seen since the 1981 directive of the transition from NCP to TCP/IP which spurred what the internet is today. As Nottingham states,

At the very least, however, we [internet developers] must examine our work for negative impact on end users and take steps to mitigate it where encountered. In particular, when we've identified a conflict between the interests of end users and other stakeholders, we should err on the side of protecting end users.

(Nottingham, 2020, p. 7).

The internet is for us all, its philosophical architecture was one not to be held by any one state, corporation, or entity. Future internets would do well in remembering this public interest perspective to communications networks.
Conclusion

“[P]rotocols are political. They control the global flow of information and make decisions that influence access to knowledge, civil liberties online, innovation policy, national economic competitiveness, national security, and which technology companies will succeed.”

(DeNardis, 2009, p. 6).

When I first proposed this graduate research project, I had intended for it to be a study on the data consumption differences between TCP and UDP and what that meant for strain on physical telecommunications networks. Through an Honours thesis I wrote on the sustainability of current physical telecommunications infrastructure in Alberta, Canada, I stumbled across information that the transport layer can affect these wires, satellites, and wireless towers through the negation of how packets of data move. I did not intend for this project to take me to Chinese research and innovation developments, the ITU-T, an internet retreat of early 1991, misleading online live broadcasts by Canadian streaming services, or a NASA internship program. In my search for bringing more awareness to the transport layer of the internet’s infrastructure, which I saw as a fluctuating layer with internet usage being more aligned to UDP from traditional TCP due to audio-visual streaming and real time internet communications, I learned how imperative this layer and the globalized politics which follow it in suite are. This master’s thesis has highlighted the ways in which the internet’s infrastructure are not static at any of its layers, nor future proof in that regard, either. This thesis has attempted to address a gap in the literature with an analysis of the changing role of the transport layer of the internet’s

TCP’s sequence checks, also known as confirmation codes, will use slightly more data in order to ensure this accuracy in the transported message. Following conversations I had with computer engineers, it quickly became apparent that this was not a powerful component of the transport layer, but instead a technical necessity opposed to having politics embedded in this design.
infrastructure as future networks are adopted and prepared for the Internet of Things and other applications for the 5G and beyond era.

**Key Findings**

*The role of national governments and international collaboration in transport layer internet development must be central in our technological progression.* I have identified in this thesis by asking questions of power in the transport layer, a gap in which Canada has not been utilizing our political infrastructure of our National Study Groups to mirror those of the ITU-T’s. In order for Canada and other countries to be successful in the transition to internets, we must ensure we use democratic research programs with open government and transparency principles of updating the public of the changes to international standardization of the new internets. Canada specifically as analyzed in this thesis must ensure our ITU-T representation provides frequent updates to the public, as per published on the Government of Canada’s website, along with this representation coming from an increase in public servants, opposed to industry representatives, as profoundly evident with Canada’s representation at the ITU-T via Ericsson. This representation is not by chance, but instead by financial incentives. Canada must change the way we do business in ITU-T proceedings to ensure our interests are aligned with developments and organizational structures in the ITU’s standardization division.

*Like developments in the TCP/IP suite, future internets must be rooted in public stakeholder groups opposed to industry mixes with ongoing research in this layer.* In addition to transparency and ‘a little more Canada in the world,’ we need academic interest in this field and in this layer. Work which analyzes developments in international telecommunications standardization and critical scholarship of our own National Study Groups, which have consistently shown gaps in mirroring studies with ITU-T Study Groups, is imperative for
academia to be a check on functioning governance. Canada is in a unique position with the emergence of internets due to our strained relations with China since 2018. If China and its state-partnered corporations are leading developments in internets, Canada must also act to be ready with research on internets for this shift in internet development and governance.

Closing Reflection

Science and technology studies as an area of communication and media studies is technical in its nature and can simply be summed up as ‘hard work.’ In this thesis I had to make sense of technical reports and confirm them with existing analyses by internet governance forums and IT bloggers. In addition, I regularly utilized my network of computer scientists and IT professionals who were generous in their guidance of my technical questions. Work in STS requires a large bandwidth of skills of the researcher who has technical prowess, a strong network of technical specialists to consult from time to time, with an ability to synthesize these findings while framing them through their histories and implicated policymaking. Future work in the area of the transport layer of the internet’s infrastructure will need to ensure preparedness in this methodology and future methods51 for work in the field.

This thesis proposed the study of internet layers to be cognizant of technē in that technology prior to being touched by capitalism will contain ‘art’ and ‘craft’ in it. The internet’s pioneers had a similar philosophy during its inception and public release, as shown in the competition with OSI and the ISO.

The transport layer and developments in the applications layer as supported by increased bandwidth allowances in the physical layer, are all connected through shifting changes in data transport. Opposed to the transport layer sitting hierarchically between the physical and

51 I used Wireshark for triangulating that UDP would be used for live streams, thereby generating the finding of Crave’s TCP-based platform purporting live online television.
applications layers (Nuechterlein & Weiser, 2013), STS researchers studying the transport layer must view it as not part of the hierarchy, but along a vertical affecting all layers of the internet’s infrastructure based on transport layer IP affordances. It is with this theoretical conceptualization that the transport layer of the internet as an area of study for STS scholars will be empowered to grow from and utilize in emerging research on upcoming internets. With this research I hope a call to action by STS scholars may be given to ensure that the next internets that will be built, through social sciences and humanities research guidance, with a philosophy of openness, transparency, and internet being for the people, for its users, for our citizens.

In this thesis, I questioned whether the internet is truly a set of ‘dumb pipes’ and if this statement held 40 years following its public release were true. As the key findings have identified, the transport layer of the internet is not ‘dumb,’ ‘passive,’ nor are the only ‘interesting things’ about the internet occurring at its edges and ends. The transport layer as a an infrastructure with its embedded politics (Winner, 1980) is not static, secure, or safe. It is ever changing with highly impactful players in highly impactful spaces, changing global internet infrastructure in the design of these technical—and political—protocols.
References


http://dx.doi.org/10.2139/ssrn.418853


IETF. (2021). Alissa Cooper. IETF. https://datatracker.ietf.org/person/alissa@cooperw.in


http://eprints.lse.ac.uk/28638/1/Introductory%20essay%20LSERO%29.pdf


https://doi.org/10.22230/cjc.2014v39n4a2746


https://spectrum.ieee.org/tech-history/cyberspace/ossi-the-internet-that-wasnt


http://www-personal.umich.edu/~csandvig/research/Auditing%20Algorithms%20--


United States Senate Committee on Foreign Relations. (2021, April 8). *Ranking member Risch on new bipartisan, comprehensive China legislation.*


WIRED Staff. (2000, January 1). Vint Cerf is taking the Web into outer space—Reserve your .mars address now. *WIRED*. https://www.wired.com/2000/01/solar/
https://www.wireshark.org/docs/wsug_html_chunked/ChIntroHistory.html


Appendix

Appendix A: Rationale for each chosen streaming service

<table>
<thead>
<tr>
<th>Streaming Service</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>YouTube</td>
<td>YouTube is the most commonly used streaming website in Canada at 4.82GB/h according to 2019 Canadian Radio-television and Telecommunications Commission (CRTC) data. YouTube is also owned by Alphabet Inc., the parent company of Google. As Google has been building broadband infrastructure out over the years (Crawford, 2018; Cybera, 2016), this provides an interesting case through the incentives of coding a high-bandwidth website in such a way as to work along other invested physical telecommunication infrastructure projects.</td>
</tr>
<tr>
<td>Netflix</td>
<td>Netflix is the second most-used streaming website in Canada. In addition, Netflix was the first streaming website which contained movie and television show rentals all for a fixed monthly fee and was introduced to Canada in 2010.</td>
</tr>
<tr>
<td>Crave</td>
<td>Crave is one of a handful of Canadian streaming services on the market and is owned by Bell Media Enterprises (BCE), Canada’s largest telecommunications provider. BCE therefore being an owner of broadband infrastructure. Crave is also the third most-watched streaming service in Canada.</td>
</tr>
<tr>
<td>CBC Gem</td>
<td>CBC Gem is a service provided by Canada’s public broadcaster, the Canadian Broadcasting Corporation. Being the fifth most-watched streaming service in Canada behind GlobalTV, CBC Gem provides an interesting context of a service which receives part of its funding through Canadian tax dollars.</td>
</tr>
<tr>
<td>Amazon Prime</td>
<td>Amazon Prime has not been analyzed in the CRTC’s Communications Monitoring Report 2019 as one of Canadians’ most used streaming websites.(^{52}) This website has been chosen, however, as Amazon continues to build undersea telecommunications cables and is working to build satellites for broadband services. Based on this ownership of infrastructure, this has been the rationale for including Amazon Prime in the dataset.</td>
</tr>
<tr>
<td>Disney+</td>
<td>Similar to Amazon Prime, Disney+ has not been analyzed in the CRTC’s Communications Monitoring Report 2019 as one of Canadians’ most used streaming websites. This is because Disney+ had not been released when the CRTC was completing this data collection, as their data on</td>
</tr>
</tbody>
</table>

---

\(^{52}\) The CRTC’s Communications Monitoring Report only identifies the top five video streaming websites used by Canadians, and the top five audio streaming websites used by Canadians.
streaming website usage in Canada was from 2018. Disney+’s launch and hype made many news headlines as one of the most signed-up for streaming sites to date (Hayes, 2019). Based on the number of subscribers to Disney+ in its first week of launching, it can be projected that 2020 data by the CRTC would label Disney+ as a highly used streaming website by Canadians.

Table 3: Streaming Services’ IPs Deconstructed Using Wireshark
## Appendix B: NVivo codebook used in determining themes within the primary documents

<table>
<thead>
<tr>
<th>Code/Node Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaboration</td>
<td>Reference towards a need to collaborate across various bodies and industries.</td>
</tr>
<tr>
<td>Fibre</td>
<td>Fibre as a backbone is mentioned.</td>
</tr>
<tr>
<td>Future Networks</td>
<td>Refers to technologies which will support future networks. This includes mentions of holograms.</td>
</tr>
<tr>
<td>Governing Bodies</td>
<td>Refers to international organizations who hold power, status, or privilege to determine the technological landscape and public interest through global technical standards.</td>
</tr>
<tr>
<td>Guided Rhetoric</td>
<td>Describes comments made by an industry professional to guide the understanding of a specific topic.</td>
</tr>
<tr>
<td>Highlight</td>
<td>Refers to items of a document which the coder wanted highlighted for further review later on.</td>
</tr>
<tr>
<td>Hologram</td>
<td>Mention of holograms for future ICTs.</td>
</tr>
<tr>
<td>Industry Definition</td>
<td>A key term which is being proposed, or used, by industry. In other words, telecommunications 'lingo.'</td>
</tr>
<tr>
<td>Infrastructural Gatekeeping</td>
<td>Refers to technical specifications made to keep parallels of information communication infrastructure separated from one another unless an intermediary (or gatekeeper) is introduced to connect the two.</td>
</tr>
<tr>
<td>Interchangeable Rhetoric</td>
<td>Technical specifications which are given varying names to appear as different problems but are the same issues of media market concentration.</td>
</tr>
<tr>
<td>Internet of Things (IoT)</td>
<td>Refers to mention of IoT technologies.</td>
</tr>
<tr>
<td>Internets</td>
<td>The concept of multiple public internets. May also be referred to as 'ManyNets.'</td>
</tr>
<tr>
<td>Interoperability</td>
<td>The ability of computer software to work in tandem with one another due to the sharing of codes and pathways for an end-to-end principle.</td>
</tr>
<tr>
<td>IP Addresses</td>
<td>Refers to needs for changes in IP addressing.</td>
</tr>
<tr>
<td>Market Concentration</td>
<td>Technical specification which will increase the barrier and cost of entry to develop on the internet due to the difficulty in online space innovation.</td>
</tr>
<tr>
<td>Memorable Quotes</td>
<td>The code refers to quotes to potentially go into the long paper/thesis.</td>
</tr>
<tr>
<td>Military</td>
<td>Technological development which would have direct military/warfare benefit.</td>
</tr>
<tr>
<td>Next Generation Networks</td>
<td>Refers to the future projections of evolving media need and the networked technology needed to support these usage changes.</td>
</tr>
<tr>
<td>Privacy</td>
<td>Privacy concerns raised or may also describe the affordances of monitoring a citizen, organization, or government through the internet.</td>
</tr>
<tr>
<td>Public Benefit</td>
<td>Technology is developed (or not developed) in accordance with the public's benefit.</td>
</tr>
</tbody>
</table>
### Table 4: NVivo Codebook Used in Data Analysis

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Time Data Transfers</td>
<td>Mention of a need for real time data transfers. This could be through lowered lag and latency in transport protocols.</td>
</tr>
<tr>
<td>Relationships</td>
<td>Mention or question of relationships between various internet groups and/or stakeholders.</td>
</tr>
<tr>
<td>Secrecy</td>
<td>No public identification for how a technical code will work and be embedded into the existing TCP suite, also known as the internet as we know it.</td>
</tr>
<tr>
<td>Smart City</td>
<td>Reference to the technological uptick in cities where 80% of the global population resides.</td>
</tr>
<tr>
<td>Space</td>
<td>Refers to mentions of how to take bandwidth to a terrestrial level outside of Earth's atmosphere.</td>
</tr>
<tr>
<td>TCP Suite</td>
<td>Refers to mention of TCP.</td>
</tr>
<tr>
<td>The 90s</td>
<td>Refers to research and development of IP's which occurred in the 90's soon before and after the public release of the internet.</td>
</tr>
<tr>
<td>UDP</td>
<td>Reference to User Datagram Protocol.</td>
</tr>
<tr>
<td>Vertical Markets</td>
<td>Refers to vertical integration of services and hardware.</td>
</tr>
<tr>
<td>Wholesale Access</td>
<td>The concept that there should be limited backbone broadband infrastructure which has its space leased to private ISPs at wholesale rates.</td>
</tr>
</tbody>
</table>