

Defining and Exploring Broadband Connections and Education Solutions in Canada's North

Définir et explorer les connexions haut débit et les solutions éducatives dans le nord du Canada

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Abstract

The use of technology and need for connection across distance permeates all education environments; nowhere is this more important than in Canada's Northwest Territories. Broadband and telecommunications issues within the Northwest Territories are complex due to its vast geographical area and community dispersion, making connectivity and accessibility inconsistent. Due to these conditions, the North relies on a variety of broadband solutions to improve Internet speeds and access to education at a distance. This paper analyzes the impacts that broadband capacity and Internet access have on remote education by examining geographic information system data, which offers a framework that connects spatial and temporal data to analyse accessibility of remote education. Characteristics such as spatial location of communities, infrastructure (road systems), and the overlay of various broadband options will illustrate constraints and (dis)connectivity in various regions and inform readers about the complexity of remote connections. Analysis of current upload and download speeds from various regions and their impact on access to education supports geospatial data and analysis that the digital divide in remote regions of Canada has increased and is widening. Improving equitable access to postsecondary education will require a greater reliance on technology-enabled practices to improve learning opportunities.

Keywords: Accessibility; Broadband; Connectivity; Critical digital pedagogy; Geographical information systems; Remote learning

Résumé

L'utilisation de la technologie et le besoin de connexion à distance sont présents dans tous les milieux de l'éducation, et nulle part ailleurs cela n'est plus important que dans les Territoires du Nord-Ouest du Canada. Les problèmes liés à la connexion haut débit et aux télécommunications dans les

Territoires du Nord-Ouest sont complexes en raison de la vaste étendue géographique et de la dispersion des communautés, ce qui rend la connectivité et l'accessibilité inconsistantes. En raison de ces conditions, le Nord s'appuie sur une variété de solutions haut débit pour améliorer les vitesses d'Internet et l'accès à l'éducation à distance. Le présent document analyse les répercussions de la capacité haut débit et de l'accès à Internet sur l'éducation à distance en examinant les données du système d'information géographique, qui offre un cadre reliant les données spatiales et temporelles pour analyser l'accessibilité de l'éducation à distance. Des caractéristiques telles que la localisation spatiale des communautés, les infrastructures (réseaux routiers) et la superposition de diverses options de haut débit illustreront les contraintes et la (manque de) connectivité dans diverses régions et informeront les lecteurs sur la complexité des connexions à distance. L'analyse des vitesses actuelles de mise en ligne et de téléchargement de diverses régions et de leur incidence sur l'accès à l'éducation appuie les données et l'analyse géospatiales selon laquelle la fracture numérique dans les régions éloignées du Canada a augmenté et continue de s'élargir. L'amélioration de l'accès équitable à l'éducation postsecondaire nécessitera un recours accru aux pratiques axées sur la technologie pour améliorer les possibilités d'apprentissage.

Mots clés : accessibilité ; haut débit ; connectivité ; systèmes d'information géographique ; pédagogie numérique critique ; apprentissage à distance

Introduction

The Northwest Territories (NWT), Canada's west central territory that encompasses both arctic and sub-arctic regions and is home to 41,000 of Canada's most remote inhabitants and is the focus of this paper. Residents of the NWT live in 33 communities and on one reservation, dispersed throughout this vast 1.14 million square kilometer region (Statistics Canada, 2016). This region is the traditional lands of the Dene, Inuit, and Metis people, who comprise approximately 50% of the total population (Government of the Northwest Territories, 2021). Life and living in this region require individuals to be fiercely independent, yet adaptable and supportive of the interdependent needs of various cultures, communities, and community members, specifically in education. Given this environment, many of the NWT broadband and telecommunications issues exist because of the vast geographical territory and dispersion of people, resulting in a heavy reliance on a multitude of broadband solutions depending on the location and connection types available. The intention of this paper is to define and describe the broadband and telecommunications options available in the NWT using a geospatial framework and to discuss current data speeds based on the connectivity options available in the various regions. Understanding diverse capacities based on geospatial characteristics is central to understanding the difficulty in ensuring equitable access to postsecondary and higher education and the necessity in developing innovative solutions to reaching students across the NWT. The article concludes with thoughts on two predominant challenges of transmission and application, and consideration of innovations to improve equitable access to remote postsecondary and higher education.

Background

Many issues exist regarding equitable access to postsecondary and higher education in the NWT. Broadband and Internet connectivity are perennial problems that restrict reaching students at a distance. This is primarily due to the location of remote communities and the inability to get stable, affordable, and standardized broadband capacity into these locations. Infrastructure development is another issue that restricts the further development of wired connections into communities. Without road systems, developing high speed fibre-optic infrastructure and connections is not possible. Geographical dispersion of remote populations across a vast territory, coupled with inaccessible and unstable broadband capacity contextualize the difficulties in extending distance education to remote communities. Due to these characteristics, a variety of innovative solutions have been used to mitigate inequitable access to education using various broadband types depending on the location and access to each community.

Using Geographical Information System Data

Geographic information systems (GIS) offers a framework to connect spatial and temporal characteristics allowing for “the integration of a spatial component into a larger framework” (Marti-Henneberg, 2011, p. 1) and permits the integration of “geographical features with tabular data in order to map, analyze, and assess real-world problems” (Dempsey, 2021). The significance of GIS is that it allows for an overlay of spatial and temporal dimensions so that readers can better understand a social or political phenomenon. By providing context, GIS illustrates complexity of relationships, promotes advocacy, and elicits social awareness (McMahon et al., 2017). Within the scope of this paper, GIS offers a means to connect spatial characteristics such as infrastructure development (road access or lack thereof), spatial location (geographical location), broadband connection type (satellite, digital subscriber lines, fibre-optic/coaxial), and data speeds to understand the relationship of broadband capacity to equitable access in remote education at a distance.

How Broadband Travels in the Northwest Territories

Four types of broadband connection exist across the NWT including satellite, digital subscriber lines (DSL), coaxial/fibre-optic, and mobile connections. Figure 1 illustrates the current connection types by community. The predominant broadband connections currently used include satellite or DSL as illustrated in Table 1. Nine communities in the high arctic rely on high orbiting satellites, 20 communities rely on DSL, and five communities have access to coaxial and/or fibre-optic cable, or a combination of fibre-optic and DSL connections (Northwestel Inc, 2021).

Figure 1

NorthwesTel Inc.¹ Internet Type by Community in 2022



Table 1

Broadband Connection Type by Community

Community	Satellite connected	DSL connected	Coaxial/fibre-optic connected
Aklavik		DSL	
Behchoko		DSL	
Coville Lake	Satellite		
Deline		DSL	
Fort Good Hope		DSL	
Fort Liard		DSL	
Fort McPherson		DSL	
Fort Providence		DSL	

¹ <https://everycommunity.nwtel.ca/>

Community	Satellite connected	DSL connected	Coaxial/fibre-optic connected
Fort Resolution		<i>DSL</i>	
Fort Simpson		<i>DSL</i>	
Fort Smith			<i>Coaxial/fibre-optic</i>
Gameti	<i>Satellite</i>		
Hay River			<i>Coaxial/fibre-optic</i>
Inuvik		<i>DSL</i>	<i>Coaxial/fibre-optic</i>
Lutsel K'e	<i>Satellite</i>		
Norman Wells			<i>Coaxial/fibre-optic</i>
Paulatuk	<i>Satellite</i>		
Sachs Harbour	<i>Satellite</i>		
Tsiigehtchic		<i>DSL</i>	
Tuktoyaktuk		<i>DSL</i>	
Tulita		<i>DSL</i>	
Ulukhaktok	<i>Satellite</i>		
Wha Ti		<i>DSL</i>	
Yellowknife			<i>Coaxial/fibre-optic</i>

Source: Government of the Northwest Territories, Department of Infrastructure. NT.

Defining Connection Types

Each form of broadband connection has its strengths and its challenges. Connection types depend on community access and availability of infrastructure. Communities with road access can connect to fibre-optic and coaxial services. Communities with limited or seasonal winter road access must rely on existing wired options including DSL. Remote fly-in communities rely predominantly on satellite connections. The following section describes each of the options currently used in the NWT.

Satellite Connections

Geostationary Satellites

Geostationary satellites are high-orbiting satellites stationed at the equator approximately 35,000 kilometres above the earth's surface. Each satellite revolves with the earth, rotating at the same speed as the earth's orbital spin, so the satellite moves at the same rate and speed as the earth's axis. These satellites have a line of sight with 40% of the earth's surface except for small spherical areas at the north and south poles; each separated by 120 degrees of latitude, requiring only three satellites to cover the entire planet. These satellites use an earth-bound directional antenna, accessible by small

dishes on the earth’s surface and left in one position once established. Highly directional antennas reduce interference from other surface-based connectivity. The major drawback of this type of broadband connection is the narrow orbital zone around the equator limiting the number of potential satellites that can be used without risk of collision. Other limitations include the latency time required for signals to travel up to the satellite and return to earth; the gravitational interaction that disrupts the speed consistency of connections; and solar fades from electro-magnet interference from the sun, which creates noise with the receiving station on earth (TechTarget Contributor, 2021).

Personal computers access satellite connections through modems to household satellite dishes. This dish sends and receives signals from orbiting satellites, allowing broadband access. There are varying levels of connectivity for the end user depending on the type of satellite, the position of the end user, and the satellite and potential disruptions. Table 2 identifies remote NWT communities that currently rely on satellite for broadband connections (Varga, 2021). All these communities are predominantly fly-in communities and accessed by airplane.

Table 2

Broadband Satellite Communities

Community	Satellite or Terrestrial	DCN2011 Bandwidth Up/Down (Mbps)	Offload Bandwidth Up/Down (Mbps)	Offload Monthly Cap (GB)
Colville Lake	Satellite	2/3	768Kbps/5	200
Gameti	Satellite	2/4	768Kbps/5	200
Lutsel K’e	Satellite	2/4	768Kbps/5	200
Paulatuk	Satellite	2/5	768Kbps/5	200
Sachs Harbour	Satellite	2/5	768Kbps/5	200
Trout Lake	Satellite	2/3	768Kbps/5	200
Ulukhaktok	Satellite	2/5	768Kbps/5	200
Wekweti	Satellite	2/4	768Kbps/5	200

Source: Varga, 2021.

Low Earth Orbital Satellites

Low earth orbital (LEO) systems are a collection of satellites, called swarms, orbiting a few hundred kilometers above the earth’s surface. These satellites rotate around the earth’s surface and take between 90 minutes and a few hours to complete a full rotation around the earth, connecting with various points on the planet. These swarms of satellites are strategically placed so there is always one satellite in line of sight for connectivity. These LEOs act as repeaters in a global network, carrying signals in a continuous connection across the network. “A LEO satellite system allows the use of simple, non-directional antennas, offers reduced latency, and does not suffer from solar fade.” (TechTarget Contributor, 2021). Figure 2 illustrates that by 2023, the planned broadband connection to

most remote satellite-connected communities in the NWT will rely on LEO, not geostationary satellites (Northwestel Inc, 2021). LEOs are generally used in industry such as at remote mine sites.

Figure 2

Map of Proposed LEO Satellite Communities for 2023



Source: Northwestel | Every Community Project (nwtel.ca).

Digital Subscriber Lines

Digital subscriber lines use analog, low pass filters that refine connection quality through existing phone cable lines. Many of the remote communities with road access (all year or winter road) run on DSL connections which are considered low bandwidth connections and run through established copper telephone lines into communities. These copper lines can accommodate multiple forms of data; however, because they were initially constructed to distribute voice data, transferring other forms of data is slower.

Services within the NWT, and specifically in communities outside of Yellowknife, are off loaded to DSL services and shared between government offices and education (K-12 schools and community learning centre) sites in the community. Currently education Internet traffic in communities outside of Yellowknife is offloaded through an NWTel DSL service. The offload bandwidth column in Table 3 below confirms the NWTel DSL service speeds (Varga, 2021). These data illustrate the reduced service capacity when high speed connections transfer to slower, more inferior, DSL connections.

Table 3*Community Bandwidth Speeds and Caps*

Community	Satellite or Terrestrial	DCN2011 Bandwidth Up/Down (Mbps)	Offload Bandwidth Up/Down (Mbps)	Offload Monthly Cap (GB)
Coville Lake	Satellite	2/3	768Kbps/5	200
Gameti	Satellite	2/4	768Kbps/5	200
Lutsel K'e	Satellite	2/4	768Kbps/5	200
Paulatuk	Satellite	2/5	768Kbps/5	200
Sachs Harbour	Satellite	2/5	768Kbps/5	200
Trout Lake	Satellite	2/3	768Kbps/5	200
Ulukhaktuk	Satellite	2/5	768Kbps/5	200
Wekweti	Satellite	2/4	768Kbps/5	200
<i>Additional 4 Mbps of Satellite B/W</i>				
Aklavik	Terrestrial	6/6	1/15	250
Behchoko (Edzo)	Terrestrial	2/2	1/15	400
Behchoko (Rae)	Terrestrial	10/10	1/15	400
Deline	Terrestrial	6/6	1/15	250
Dettah	Terrestrial	2/2	1/15	250
Enterprise	Terrestrial	2/2		
Fort Good Hope	Terrestrial	4/4	1/15	250
Fort Liard	Terrestrial	4/4	1/15	400
Fort McPherson	Terrestrial	6/6	1/15	400
Fort Providence	Terrestrial	5/5	1/15	400
Fort Resolution	Terrestrial	4/4	1/15	400
Fort Simpson	Terrestrial	20/20	1/15	400
Fort Smith	Terrestrial	30/30	100/100	Unlimited
Hay River	Terrestrial	40/40	30/120	Unlimited
Inuvik	Terrestrial	50/50	100/100	Unlimited
Jean Marie	Terrestrial	2/2	1/15	250
Kakisa	Terrestrial	2/2		
Nahanni Butte	Terrestrial	2/2	1/15	250
Norman Wells	Terrestrial	15/15	6/80	1100

Community	Satellite or Terrestrial	DCN2011 Bandwidth Up/Down (Mbps)	Offload Bandwidth Up/Down (Mbps)	Offload Monthly Cap (GB)
Tsiigehtchic	Terrestrial	4/4	1/15	250
Tuktoyaktuk	Terrestrial	6/6	1/15	400
Tulita	Terrestrial	5/5	1/15	400
Wha Ti	Terrestrial	3/3	1/15	250
Wrigley	Terrestrial	4/4	1/15	250
Yellowknife	Terrestrial	300/300		

Source: Government of Northwest Territories, Department of Infrastructure, Yellowknife, Canada.

Digital subscriber lines are a stable broadband option; however, lower rates of data transfer negatively affect connection limits, data capacity, widespread access, consistent use, and reliable availability. The exponential growth of data sets and sources has reduced the usefulness of DSL connections.

Cable or Coaxial Connections

Coaxial cable is comprised of two layers of copper used to connect satellite antennae to home devices such as televisions and computers. The central layer is a conducting wire, wrapped in an electric insulator, used to protect and stabilize the electrical current of the coaxial core. Braided copper mesh covers the electrical insulator, allowing both copper lines to run parallel to one another. The outer insulating layer stabilizes and protects the transmission of both copper lines inside the housing. The cable is typically grounded at both ends to dissipate any interference that may occur (McCarthy Earls, 2021). Coaxial cable can increase download speeds and carry larger volumes of data. Bandwidth is generally shared amongst users so when high demand for Internet occurs, speed is generally reduced. Coaxial cable is also used as an Ethernet to connect devices within an organization or home. Ethernet employs a twisted paired cabling system to reduce distortions and increase speed and data size; it is a reliable, traditional, networked method used in schools and organizations, connecting computers using a physical cord. Although Ethernet is popular because it is inexpensive, reliable, and compatible across devices and is still widely used because of speed, security, and reliability, it is more complex than Wi-Fi due to the need for physical connection (Chai et al., 2021; McCarthy Earls, 2021). Internet through coaxial cables have download speeds comparable to fibre-optic speeds; however, comparable upload speeds are not attainable.

Fibre-Optic Cable

Fibre-optic cable carries and transfers data at the speed of light, using glass or plastic fibres. Data can be carried over higher bandwidth and greater distance than DSL or coaxial cables. Fibre-optic cable is considered a medium and a technology containing strands of glass or plastic, as thin as a strand of hair. These strands of glass or plastic are arranged in bundles and used to generate light signals that

carry information using light-based technology, pulsing through cables by bending incoming light. A smaller opening in the cable isolates light and provides better connections and transmission of information as light pulses along glass or plastic fibre. The smaller the fibre-optic cable, the greater the distance the information can travel. Single mode cable is used for longer distances because of their limited core size and higher bandwidth capacity by focusing a glass laser light beam. Multimode cable is used for shorter distances as the larger diameter of the cable allows for multi data transfer, happening simultaneously. This is possible because there are larger multiple light pulses, allowing more data transmission and providing higher bandwidth and better connections. Fibre-optic cable can reach transfer speeds greater than 1,000 Mbps. Currently only five communities in the NWT have access to fibre-optic connections including Hay River, Inuvik, Fort Smith, Norman Wells, and Yellowknife. Northwestel developed fibre-optic connections in 2021 to extend fibre-optic cable to the communities of Fort Providence, Fort Simpson, Fort Liard, Behchoko, and Dettah (Northwestel Inc, 2021).

Theoretical Position

Creating more equitable access to stable and consistent Internet is necessary to ensure that NWT residents have consistent access to postsecondary and higher education. This theoretical position is grounded in critical digital pedagogy (CDP), a non-neutral approach to teaching and learning that challenges the status quo in education, supporting social change and raising consciousness while shaping society through liberatory praxis. Critical digital pedagogy fosters agency and empowers learners through “reflective dialogue within web-based tools” (Stommel, 2014). Critical digital pedagogy deconstructs power structures and social impediments to learning within digital spaces and is a deeply personal, political, and subjective endeavor. CDP invites the whole person in an ongoing and recursive process of discovery (Hall, 2016). Critical digital pedagogy is defined here as a strategy and practice of teaching that deconstructs and dismantles institutional and societal impediments to learning by liberating social, technical, and political structures.

Digital refers to more than educational technology. It is about using right technology to improve learning conditions and create equitable access for all in learning spaces. Our use of digital pedagogy needs to consider the relational needs, accessibility of tools, and openness to learning resources. Digital use also needs to positively direct improvements to institutional supports and opportunities for students’ engagement between students. Stommel et al. (2020) states the importance of human connections in the use and development of digital learning. “Digital pedagogy is about human relationships, the complexity of humans working together with other humans – the challenges of finding ways to teach through a screen, not to a screen” (Stommel et al., 2020, p. 7).

Critical digital pedagogy, arisen from work around the globe, embraces a social justice lens. Many advocates, researchers, and pedagogues have enlisted social action to dismantle power structures and embrace a more equitable and fair education system that embraces diversity and invites non-traditional and unrepresented voices in education. This has been accomplished through various means, including the politicizing of CDP through liberation and care and pedagogies of kindness (Denial,

2020; Stommel, 2014) and through innovative practices such as dismantling classroom power structures, inviting students' voices, and deconstructing traditional curricula through new instructional design strategies (Bali, 2014; Friend, 2020). Critical digital pedagogy also invites pedagogical alterity through praxis specifically through elevating conversations and voices involving people with disabilities, minority groups, immigrant populations, Indigenous nations, and underrepresented populations such as prisoners (Godden & Womack, 2020; Stommel, 2014; Stommel et al., 2020). Finally, CDP elevates pedagogy through its practical applications to the scholarship of teaching and learning through conversations around design, trust, and discovery (Morris & Eyer, 2020). Critical digital pedagogy is a platform that invites exploration of paradigm-altering ways of improving and expanding engagement and discovery through non-traditional approach to both teaching and learning. It is through this CDP lens that efforts to improve fair and consistent access to postsecondary education for all NWT residents is explored.

Discussion

To understand the challenge of improving access we need to first understand the problems of transmission and application. Much work is being done to understand the current environment and this discussion focuses on the work of DigitalNWT and their research conducted to improve digital literacy at the community level, to influence digital impacts on courses and programs, and to improve affordable digital access through reliable connections and affordable Internet options (McMahon et al., 2021). Their research results summarized below provide evidence of the broadband and telecommunications challenges that exist in the NWT.

Upload and Download Analysis of Communities

The following data was collected by DigitalNWT using Canadian Internet Registration Authority Internet performance test results from 2019–2021 (DigitalNWT, 2021).² This report analyzed data regarding the type, speed, variability, and broadband connection across the NWT. This organization compared broadband data in literature to infer how NWT's broadband services compared to standard upload and download ranges. Table 4 summarizes the range of normal speeds experienced using various broadband connection types. Based on existing literature, the average speeds observed are at the low end in each connection type. There is concern that those with the least amount of access and slowest speeds are the ones with band usage caps and extra service charges for the services

² During this time 1,438 speed tests were conducted throughout 24 NWT communities. These tests summarized the community observed, the download and upload speeds the number of test counts, and connection types. This research was conducted to “strengthen digital literacy”, to “inform course development and delivery” to conduct “research activities regarding internet access, affordability and reliability” (DigitalNWT, 2021). The findings are summarized in the Telecom notice of consultation CRTC 2020-367, “*Call for comments – review of the Commission’s regulatory framework for Northwestel Inc. and the state of telecommunications services in Canada’s North.*” and on the DigitalNWT website.

provided. Below is a summary and analysis of each broadband type based on community location and data speeds.

Table 4

DSL vs. Cable vs. Fibre-optic Speeds

Technology Type	Download Speed Range	Upload Speed range
DSL	5-35 Mbps	1-10 Mbps
Cable	10-500 Mbps	5-50 Mbps
Fibre-optic	250-1000 Mbps	250-1000 Mbps

Source: Cooper, 2021.

Analysis of Satellite Community Data

Satellite-connected communities are primarily located in the high arctic with limited road access and are typically reached through air access. Download speeds for these communities have a high positive skewness due to digital research data from the community of Lutsel K'e located in the sub-arctic region (DigitalNWT, 2021). Upload speeds are more modestly skewed across the communities, demonstrating more consistency in upload speeds. Unfortunately, satellite data speeds are not available in the literature, so no comparisons can be made for NWT download and upload speeds.

Analysis of DSL Community Data

Communities connected through DSL may or may not have road access, are located across both arctic and sub-arctic regions, are smaller more remote communities, and have existing phone lines. If road access exists, the access may be seasonal. When NWT communities using DSL connections are compared to national averages of communities across Canada that rely on these connection types, the NWT communities are on the low end of documented ranges in the literature. Typical download speeds range from 5–35 Mbps and upload speeds range from 1–10 Mbps, as illustrated in Table 4. Considerably lower than average download and upload speeds for DSL, NWT communities were observed from the data collected (DigitalNWT, 2021). Some communities have access to both DSL and coaxial connections. In some of these communities, identified with DSL usage, moderate positive skewness resulted. An example of this is the community of Inuvik that uses coaxial connections for health care and education but DSL connections for residential use, potentially distorting DSL results. As expected, when Inuvik data is removed the deviation of the data is reduced and more truly reflects predictable DSL data results. Documented speeds fall below the ranges identified in literature of 5–35 Mbps and 1–10 Mbps, respectively.

Analysis of Fibre-optic/Coaxial Community Data

All fibre-optic connected communities have road access and access to developed fibre-optic cable infrastructure. Fibre-optic average speeds for fibre/coaxial NWT communities are on the low range compared to the documented range of download speeds ranging from 10-500 Mbps for cable and 250-1,000 Mbps for fibre-optic speeds. Upload speeds for fibre-optic/coaxial communities are also consistently low, compared to 5-50 Mbps for cable and 250-1,000 Mbps for fibre-optic connection speeds recorded in literature. Heavy reliance on cable connections at the user end of the connection distorts the upstream speeds of the fibre-optic connections. Territorial decision makers and providers of broadband service providers must also consider where and when cable connects to the data stream. Because of the placement of the connections to Yellowknife, the fibre-optic download data speeds are skewed compared to communities of Fort Smith, Hay River, and Norman Wells. Upload speeds are consistent across the four communities, resulting in a normal distribution for the four communities (DigitalNWT, 2021).

Meaning of Data for NWT Communities and Residents

What this data means for the community members of the NWT is that students are not able to access postsecondary or higher education from most communities. In fact, students are required to move to three of the larger centres of Inuvik, Fort Smith, and Yellowknife to attend classes on campus. As identified above, Internet speeds, data usage fees, and upload and download speeds make online learning in remote communities almost impossible. Current efforts, such as the DNWT Nimble project, are exploring the possibility of developing locally managed mesh wireless intranet systems as one solution to reducing the digital divide. Another initiative includes discussions with remote mining companies to explore cloud-based solutions to address these access divides.

Considerations for Future Development

Spatial analysis combined with broadband usage allows us to explain and understand how and why there is inequitable access to remote education. The differences that exist between communities are related to infrastructure development (road systems), the location of each community, and the telecommunication options available. The geographical dispersion of remote populations negatively influences business decisions and restrict further development of equitable access to education at a distance for communities and students. Analysis of upload and download speeds further validates and confirms these conclusions. Further development of remote GIS data is necessary to promote a deeper understanding of the challenges and potential solutions of NWT remote education at a distance. Systemic quantitative analysis can be used to validate the current reality and advocate for further development of remote populations.

This discussion of future developments has prompted several questions related to remote education. Do broadband types influence the development (or lack thereof) of educational opportunities available in remote communities? How responsive are institutions at improving equitable access to remote education options? Are national standards in broadband capacity actually universal? To what extent is the reduced responsiveness to educational requests due to smaller community populations? Is

capital development restricted because low populations in remote communities do not result in profitability and return on investment for corporate service providers? Is this fair; is this equitable? If there are no business models to support broadband development, what alternative political and social justification is necessary to extend national broadband standards to remote regions? Who should pay for these developments? Finally, would the availability of stable broadband and access to the Internet encourage distance learning in remote communities as opposed to an outward migration of young community members to larger urban centres? Would this benefit communities and improve or detract from the quality of remote living?

Conclusion

Although the variability of broadband connectivity is an everyday reality in the Northwest Territories, in Canada, the type of access deeply influences the speed and reliability of community connections. Much of what is done in education now relies on technological use, limiting accessibility to the most remote students in the NWT. The remotest communities are the most disadvantaged, due in part to infrastructure development, low population density, broadband options, and a lack of profitability in further telecommunications development. An examination of broadband data speeds further validates the claims that inequitable access to broadband exists between communities (DigitalNWT, 2021). Download and upload speeds make heavy data files impossible to access at the community level. Inequities are further complicated due to caps placed on data use and time at the community levels. Finally, as networked learning relies heavily on video files, many students are not able to even retrieve videos or data dense files for learning. The five largest communities within the North have access to exponentially larger download and upload speeds in comparison to DSL, or satellite connected communities, creating larger inequities for smaller, more remote communities.

Plans and development of fibre-optic cable connections continue to expand faster connections; however, this does not resolve the short-term issues of the most remote communities or for students studying at a distance. Infrastructure development costs per location are approximately \$250,000 that may or may not reduce the current operational costs of enhanced services. Although the impact of broadband enhancements would create a paradigm shift for remote learners and education at a distance, many communities do not have the time, skills, or money for further development at this time. More work is necessary to support and develop community initiatives and improve infrastructure. In actuality, the ongoing evolution of broadband connectivity and Internet access is becoming even more stratified, as larger road-access communities receive exponentially faster speeds than remote satellite-based communities that continue to rely on high-orbiting satellites at slower speeds. Plans for NorthwTel telecommunications development by 2023 will not bring fairness to the most remote communities in the NWT (see Figure 2). Eight communities will still require satellite feeds to ensure broadband access for those community members. Communities relying on satellite connections still receive exponentially slower connections, monthly usage caps, and unacceptable usage fees. As a result, they are hit with low broadband access and imposed restrictions on upload and download costs,

thereby disadvantaging these communities from an ever-increasing need for telecommunications standards, necessary in today's world.

Variability of broadband connectivity continues to challenge educators in remote communities, making fair and equitable access a constant challenge in postsecondary education. Networked learning relies heavily on data-dense files that are downloaded quickly, reliably, and are easily accessible for learning which is impossible to access at remote sites using slow Internet infrastructure. These are the reasons innovative solutions are beginning to emerge.

Two main constraints of transmission and application will continue to challenge educators for the foreseeable future. Some viable solutions that are currently being pursued include the use of LEOs, mesh networks, and cloud-based solutions. Other options under consideration include the development of a northern-shared data centre, the development and creation of load servers, and the use of innovative data security solutions. The DNWT Nimble project (e.g., locally managed, mesh wireless intranet systems) is another example of an innovative solution to close the broadband access divide (DigitalNWT, 2021).

These challenges, however, have not eliminated educational opportunities. Not surprisingly, all levels of education have been confronted with these limitations and have risen above these challenges to find creative solutions to develop, enhance, and extend learning. Examples of current solutions include shared instructors across remote communities, the use of data sticks, loanable computers, and the use of low bandwidth applications. These global issues have found resolutions in remote spaces around the world and remote educators are leading the way in augmenting and advancing education within these constraints. It is through this continued work that real time solutions are found and connections continue to be made.

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