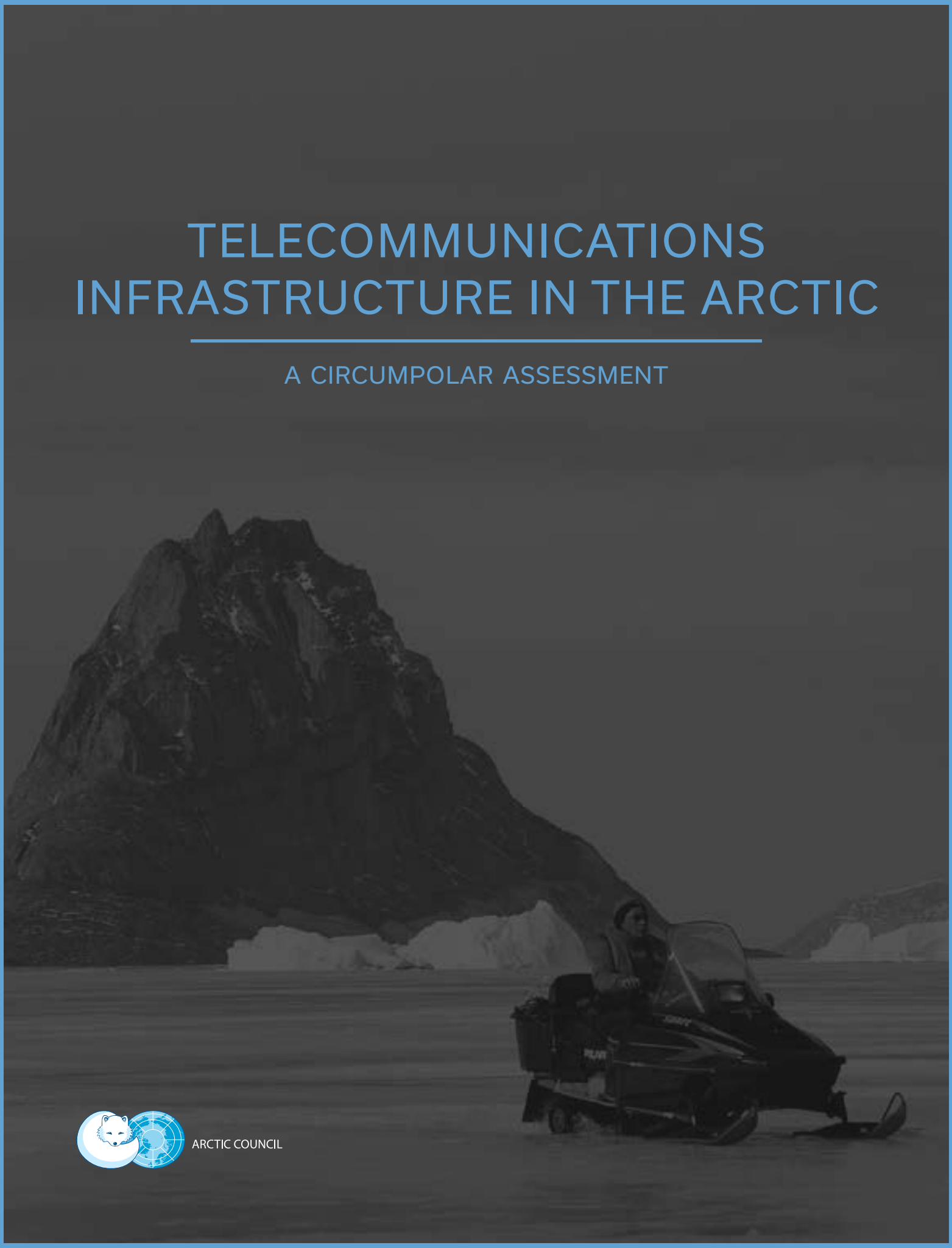
TELECOMMUNICATIONS INFRASTRUCTURE IN THE ARCTIC

A CIRCUMPOLAR ASSESSMENT



ARCTIC COUNCIL

Telecommunications infrastructure in the Arctic: a circumpolar assessment

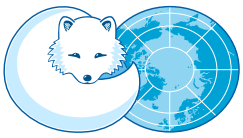


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Table of contents

1. Executive summary (including findings and recommendations) 8

2. Mandate and goals of the Task Force on Telecommunications Infrastructure in the Arctic (TFTIA) 14

3. Local community needs 16
   a. Public use 18
   b. Household and personal use 18
   c. Education 18
   d. Language and culture 19
   e. Telemedicine and social services 19
   f. Economic development 20
   g. Community sustainability 20

4. Inter-regional and pan-Arctic needs 22
   a. Science and environment 23
   b. Maritime 25
   c. Aeronautical 33
   d. Search and rescue (SAR) systems 38

5. Available technologies 40
   a. Satellite services 42
   b. Fixed lines 44
   c. Fixed wireless 45
   d. Mobile wireless 46
   e. Digital HF, VHF, and UHF networks 46

6. Gap analysis (including coverage maps) 48
   a. More densely populated areas 50
   b. Sparsely populated areas 55
   c. Maritime and aeronautical gaps 60

7. National priorities and infrastructure (2017) 62
   a. Canada 64
   b. Kingdom of Denmark 66
   c. Finland 68
   d. Iceland 70
   e. Norway 71
   f. The Russian Federation 72
   g. Sweden 74
   h. United States 76
   i. Common themes 78

8. Implementation options (including case studies) 80

9. Findings and recommendations 86

Terms and abbreviations used in this report

ADS-B: Automatic Dependent Surveillance – Broadcast is a surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked. The information can be received by air traffic control ground stations as a replacement for secondary radar. It can also be received by other aircraft to provide situational awareness and allow self-separation. It can also be received via low-Earth orbit satellites.

ADSL: asymmetric digital subscriber line

AIS: automatic identification system

ARCC: Aeronautical Rescue Coordination Center

Argos system: a satellite-based system which collects, processes, and disseminates very narrow-band environmental data from fixed and mobile platforms worldwide.

AWI Hausgarten: deep-sea observatory in the eastern Fram Strait established by the Alfred Wegener Institute.

C band: the 4-8 GHz portion of the electromagnetic spectrum in the microwave range of frequencies. (Up until the time of publication of this report, this is the most frequently used distribution band for satellite services.)

CASSIOPE: Cascade, Smallsat and Ionospheric Polar Explorer (CASSIOPE) is a Canadian Space Agency multi-mission satellite operated by MacDonald, Dettwiler and Associates (MDA).

CNS / ATM: communications, navigation, and surveillance systems / Air Traffic Management

Cospas-Sarsat: an international satellite system for search and rescue (SAR) distress alerting that was established in 1979 by Canada, France, the U.S. and the former USSR.

CPWG: The Cross Polar Work Group (in full, Cross Polar Trans-East Air Traffic Management Providers' Working Group) is a forum where air navigation service providers (ANSPs) and operators meet to address operational issues and develop solutions related to the provision or use of air traffic services for the Cross Polar and Russian Trans-East (RTE) traffic flows.

DASS: Distress Alerting Satellite System

DSL: Digital Subscriber Line

DSLAM: Digital subscriber line access multiplexer

FDR: Flight data recorder

FSS: fixed satellite services

FTTH: Fiber to the home

GEO: geostationary Earth orbit

GEOSAR: geostationary Earth orbit search and rescue system

GLONASS: global navigation satellite system (Russian: Глобальная навигационная спутниковая система)

GMDSS: Global Maritime Distress and Safety System

GPS: global positioning system

GPRS: General Packet Radio Service

GSM: Global System for Mobile communication

GW: ground wave

HEO: highly elliptical orbit

HF: High frequency, 3-30 MHz radio waves

HFC: hybrid fiber-coaxial

HSPA+: High Speed Packet Access, also known as 4G or Evolved HSPA

ICAO: International Civil Aviation Organization

ICE: Interactive Connectivity Establishment

ICT / ICTs: information and communications technology (or technologies)

IMO: International Maritime Organization

IP: Internet Protocol

JRCC: Joint Rescue Coordination Center

K_u band: the 12–18 GHz portion of the electromagnetic spectrum in the microwave range of frequencies.

K_a band: the 26.5-40 GHz portion of the electromagnetic spectrum in the microwave range of frequencies.

L band: the 1 to 2 GHz portion of the electromagnetic spectrum in the microwave range of frequencies

LEO: low-Earth orbit

LEOSAR: low-Earth orbit search and rescue system

LF: low frequency, 30 kHz – 300 kHz radio waves

LTE: Long-Term Evolution

M2M: machine-to-machine

MEOSAR: medium-Earth orbit search and rescue system

MF: medium-frequency, 300 kHz to 3 MHz radio waves

MRCC: Maritime Rescue Coordination Center

MSS: mobile satellite services

PPP: public-private partnership

RLS: return link system

SAR: search and rescue

SART: search and rescue transponder

SESAR: Single European Sky ATM Research project

SOLAS: International Convention for the Safety of Life at Sea

Store-and-forward: a telecommunications technique in which information is sent to an intermediate station where it is kept and sent at a later time to the final destination or to another intermediate station.

TFTIA: Task Force on Telecommunications Infrastructure in the Arctic

UAV / RPAS: unmanned aerial vehicles / remotely piloted aerial systems

UHF: ultra-high frequency, 300 MHz – 3GHz radio waves

VDES: VHF Data Exchange System

VDSL: Very-high-bit-rate digital subscriber line

VHF: very high frequency, 30-300 MHz radio waves

VSAT: very small aperture terminal

WiMAX: Worldwide Interoperability for Microwave Access

1. Executive summary

The Task Force on Telecommunications Infrastructure in the Arctic (TFTIA) was established by Ministers of the Arctic States at the 2015 Arctic Council Ministerial meeting in Iqaluit. Ministers noted "the importance of telecommunications to Arctic communities, science, navigation and emergency response" and created the TFTIA to "develop a circumpolar infrastructure assessment as a first step in exploring ways to improve telecommunications in the Arctic, and report to Ministers in 2017" (Iqaluit Declaration, 2015). In establishing the TFTIA, the Arctic Council recognized the importance of telecommunications as a factor for sustainable development in the Arctic. The Council also saw that telecommunications is a truly cross-sectoral issue, and touches the areas of focus of the Council's six Working Groups and other subsidiary bodies.

From 2015-2017, the TFTIA worked to assemble and assess information about the available telecommunications infrastructure in the Arctic and the present-day needs of users living, working, or traveling in the Arctic. It examined the technologies presently available to meet the needs of these users, identified gaps in the infrastructure that is essential in providing acceptable connectivity to users, and examined some measures for the future development of telecommunications infrastructure in the Arctic.

This report presents this investigation and analysis, including maps showing the extent of telecommunications coverage in each of the eight Arctic States. The report also provides an overview of each State's telecommunications priorities. Findings from the report are summarized in chapter 9, which also contains the TFTIA's recommendations for the future work of the Arctic Council on this issue. These findings and recommendations are also listed in full in this executive summary.

Changes in the telecommunications industry occur rapidly, and it is inevitable that some of the information or details contained in this report will quickly become outdated. Readers should view this report as a "snapshot" of the state of telecommunications infrastructure in the Arctic, and should certainly be attentive to ongoing developments.

Findings

Capabilities

No single technology alone will meet all telecommunications needs in the Arctic, and the best technology (or combination of technologies) for any specific case depends on geography, users' needs, and many other factors. In addition, openness to new technologies is important to successful development of telecommunications infrastructure in the Arctic. Independent of bandwidth or technology, dependence upon a single system or provider creates vulnerability for users.

Presently, communication over the northernmost parts of the Arctic is possible, but only with select communications systems with limited bandwidth capabilities. These typically include VHF/HF radio communications and Iridium satellite voice and data services.

There are serious limitations to the connectivity provided by geostationary satellites in the northernmost parts of the Arctic. Nevertheless, the future for satellite-based connectivity in the Arctic looks potentially positive, as there are several companies seeking to deploy new constellations, including constellations of satellites that will provide expanded or nearly-complete coverage in the Arctic. If these developments materialize, they will benefit many users (including maritime and aeronautical ones) throughout the Arctic who will continue to rely solely on satellites to meet their connectivity needs.

Deploying one type of telecommunications technology does not preclude subsequent deployment of additional or alternative technologies as circumstances and technologies change. Therefore, basic telecommunications infrastructure can be deployed to serve Arctic users without in any way hindering future investment in network area coverage and service expansion.

Some of the telecommunications capacity in the Arctic may be delivered by systems that generate their revenue primarily in more southerly latitudes. For example, existing and future fiber-optic cables in the Arctic present opportunities to create connections (both fixed and mobile) that will serve communities and businesses near to the cable route.

More and less densely populated areas

There are enormous variations in the population densities and associated telecommunications infrastructure and services present across the Arctic. Within the Arctic States, the Faroe Islands, Finland, Iceland, Norway, northwestern Russia, and Sweden are more densely-populated, and often have broader availability of telecommunications infrastructure and services. On the other hand, the vast expanses of the Canadian, Greenlandic, Russian, and U.S. Arctic have extremely low population densities often with lesser availability of telecommunications infrastructure and services. This is not an analytically perfect division, but it can help to draw useful conclusions related to current and future telecommunications expansion.

Reliability, accessibility, and affordability

In some parts of the Arctic with low population densities, communities lack reliable, accessible and affordable broadband. The main reasons for this include vast geographical distances between communities, a lack of infrastructure, and few service providers. This lack of connectivity impacts the sustainable development of these Arctic communities.

Needs of indigenous peoples and local communities

Improvement in telecommunications infrastructure in the Arctic supports resilience and sustainable development. Improved connectivity in the Arctic supports better access to education, healthcare, and commerce, as well as enhancing citizens' participation in civic life and improving delivery of services.

Access to telecommunications is important to indigenous peoples in maintaining and preserving their cultures and livelihoods.

Science

Improved connectivity in the Arctic creates better conditions for data collection, data preservation, and data transfer within, and to and from, the Arctic. These improvements may encourage an increase in research activity.

Maritime users

Maritime transportation in the Arctic and associated demand on telecommunications services has increased in recent years and this trend is expected to continue with the extension of the shipping season as a result of ice receding. With the technologies that exist today, expansion of satellite coverage may benefit both local and international maritime users, as well as land populations near to shore. Near-coastal services will benefit from land-based communications technology as well. The overall safety of operations will increase for all vessels and will allow the most modern fleets requiring continuous data links to operate safely at the highest latitudes.

Air traffic

The CPWG estimates the annual future growth of Arctic overflights to be approximately 3.5% (400-500 additional flights per year). Improved connectivity in the Arctic will allow the airspace to accommodate increased traffic, enhance safety, and permit the introduction of new and more efficient routings.

Search and rescue

Telecommunications capacity is essential to the conduct of search and rescue operations in the Arctic.

Increasing human activity in the Arctic, including maritime and aeronautical activity, will place additional demands on search and rescue capabilities, and subsequently require additional telecommunications capacity.

Improved connectivity in the Arctic will support collection and distribution of meteorological and oceanographic information and services, as well as better information on sea ice and icebergs, which will help inform the search and rescue response.

Inmarsat has minimal coverage to provide access to the Global Maritime Distress and Safety System (GMDSS) in much of the Arctic. However, work is ongoing in order to gain recognition by the IMO for an expansion of the GMDSS which may benefit the Arctic.

Government regulation

Streamlining regulatory processes and procedures could enhance investment in, and accelerate deployment of, telecommunications infrastructure and services in the Arctic.

Financing

An increasing fraction of civilian telecommunications infrastructure in the Arctic is financed in a competitive, commercial environment. Grants, low-cost long-term loans to private-sector entities, and/or long-term anchor clients often drive public-private partnerships (PPPs). The PPP may be a model that supports telecommunications infrastructure investments that satisfy the needs of users in the Arctic.

Economic development

Improved connectivity in the Arctic supports local economic development by allowing businesses in remote areas to compete with counterparts in better-served, more developed areas. A vibrant local economy helps to make it more feasible and appealing for individuals to live and work in remote communities. Moreover, economic development will, in turn, provide opportunities to further develop the telecommunications infrastructure and services in these communities.

Improved connectivity in the Arctic will support the growing tourism industry in the Arctic.

International cooperation

The development of telecommunications infrastructure and services in the Arctic can benefit from strong international – and in particular, cross-border – cooperation. The development of any pan-Arctic system would benefit from international collaboration.

Global benefit

Infrastructure that supports connectivity in the Arctic provides global benefits through better connectivity between the Arctic and the rest of the world, and within the Arctic itself.

Recommendations

The Task Force makes the following recommendations to the Arctic Council:

- The Arctic Council should continue a strong and enduring focus on telecommunications infrastructure and services.
- Future research on, or development of, telecommunications infrastructure and services in the Arctic should continue to take into account the needs of indigenous peoples and local communities, and those operating in the Arctic, such as businesses, tourism, and researchers. Emphasis should also be given to developing connectivity that supports maritime and aeronautical users and, in particular, search and rescue efforts.
- Efforts to further develop telecommunications infrastructure and services in the Arctic should continue to include research institutions and private industry (including the Arctic Economic Council). This engagement could, inter alia, further explore the possibility of public-private partnerships as tools for the development of telecommunications infrastructure in the Arctic. Where possible, the Arctic Council should encourage public and private infrastructure development projects to consider the related build-out of telecommunications infrastructure.

Further developing telecommunications infrastructure in the Arctic will require work by, and cooperation among, a constellation of different actors in the public and private sectors. The work of the TFTIA, we hope, will give impetus to all such efforts.

Nome, Alaska, U.S.A. //
Photo by Arctic Council Secretariat / Kseniia Iartceva

2. Mandate and goals of the Task Force on Telecommunications Infrastructure in the Arctic (TFTIA)

"…develop a circumpolar infrastructure assessment as a first step in exploring ways to improve telecommunications in the Arctic, and report to Ministers in 2017". (Iqaluit Declaration 2015)

In the Arctic Council's "Senior Arctic Officials' Report to Ministers" from 2015, Senior Arctic Officials (SAOs) for the Arctic States acknowledged that "the existing telecommunications infrastructure in the Arctic is not sufficient to meet current demands for modern community needs, regional connectivity, human services, scientific observations, navigation, and support for potential emergency [search and rescue] or oil spill response." In response to this perceived shortfall, the Task Force on Telecommunications Infrastructure in the Arctic (TFTIA) was established by Ministers of the Arctic States at the 2015 Arctic Council Ministerial meeting in Iqaluit, Nunavut, Canada. When established, it was mandated to "develop a circumpolar infrastructure assessment as a first step in exploring ways to improve telecommunications in the Arctic, and report to Ministers in 2017."

The TFTIA's initial mandate demands the production of a completed "Arctic Telecommunications Infrastructure Assessment" by the 2017 Ministerial meeting; the TFTIA responded by producing this report. As mandated, the report addresses, among many other topics, "recommendations for public-private partnerships to enhance telecommunications access and service."

SAOs acknowledged in the "Senior Arctic Officials' Report to Ministers" from 2015 that the work of the TFTIA might serve as the start of a longer process, noting that "[a]n eventual build-out of an Arctic-wide telecom infrastructure is a long-term, multi-year endeavour." And indeed, in the long run, the work of the TFTIA (and any successor it might have) is meant to deliver "a strong message from the Arctic States to make the Arctic a top priority for future telecommunications investment." The authors hope that this report serves, in part, to make progress towards that goal.

3. Local community needs

For many people, including for residents and businesses in the Arctic, the use of information and communications technologies (ICTs) has become part of everyday life. Today, ICTs are increasingly important for providing and coordinating government services, for running business operations and logistics, for groups and organizations to coordinate their activities, and for residents to remain connected, informed, educated, and entertained. With the increasing economies of scale and the efficiencies gained from the use of ICTs, government and commercial services are becoming dramatically more digital, requiring businesses and households to keep pace in order to maintain their ability to learn, communicate, transact, seek customer assistance, apply for jobs, and conduct other important tasks.

High-speed Internet, or broadband, is a transformative technology that is improving the lives of its users regardless of location. Broadband helps governments provide public safety and health services more efficiently, for example by providing rural residents with access to high-quality healthcare delivered in the form of telemedicine. Broadband enables a range of life-enhancing technologies and facilitates convenient and cost-effective communication among family and friends.

Broadband, especially affordable broadband, also helps to break down the barriers of distance and time, potentially allowing Arctic residents to more actively participate in economic and civic life far beyond their geographic locations. Communication made possible by broadband technology eliminates some of the logistical constraints of regionally-based business models, even allowing businesses in isolated areas to compete with their big-city counterparts. For example, individuals can reach out to the global community with products they have produced themselves, greatly reducing boundaries between producers and consumers. These kinds of opportunities and activities foster the creation of innovative products and services that can be delivered to users regardless of location and, thus, create a number of economic opportunities and cost savings that have direct and measurable impact on individual users and the wider economy.

Ultimately, the numerous public, economic, and social advantages enabled by the availability of ICTs in rural areas (particularly including broadband) not only benefits these areas specifically, but may also have positive impacts on the Arctic as a whole.

In many parts of the Arctic with low population densities, communities lack reliable, accessible, and affordable broadband. The main reasons for this include vast geographical distances, a lack of infrastructure, and few service providers. The cost for connectivity in these communities is often significantly higher than in less remote, more densely populated communities. There is also less access to high-speed networks in remote communities, and network outages occur more often. The fragile nature of connectivity in parts of the Arctic has been highlighted when unplanned satellite outages or fiber cuts have occurred, disrupting access to basic services (economic, social, and cultural). This lack of connectivity impacts the sustainable development of remote Arctic communities. Future telecommunications infrastructure should be built with a view to enabling sustainable economic development.

3a. Public use

Throughout the Arctic, governments are increasingly relying upon the use of ICTs to support the delivery of essential services, such as education, healthcare, emergency response, search and rescue (SAR), and information services. This reality demonstrates the need for Arctic citizens and businesses to have effective, adequate, and affordable access to ICTs.

3b. Household and personal use

Telecommunications is a fundamental requirement for household and personal needs. It is true in the Arctic, as it is globally, that more and more people are using ICTs in their daily lives. Mobile devices and computers connected to the Internet give users the ability to gain access to news and information, connect with friends and families around the globe, and participate in the global marketplace for goods and services. The Internet also helps users to be active in social networks and to get involved in public debate.

There is also a public safety dimension for personal connectivity in the Arctic. Many Arctic residents harvest wildlife for subsistence purposes, and better connectivity would allow for quicker and safer navigation while performing these activities.

A 2016 survey by the University of the Arctic Thematic Network on Telecommunications [1] found that nearly 50% of respondents from the Arctic States identified access to information, email, and employment as very important personal uses of the Internet. Approximately 40% of those same respondents identified safety, search and rescue, and scientific research as very important community uses of the Internet. It should also be noted that many Arctic residents may have limited or no access to effective and affordable broadband and, thus, have not had the opportunity to determine its potential benefits.

3c. Education

Education is essential for every community, large or small, rural or urban. Advances in ICTs would continue to extend the reach of education, such that education is not confined to a classroom located hundreds of miles away, often inaccessible to inhabitants in remote communities.

New broadband-enabled educational tools allow for remote collaboration among students on projects, videoconferences with teachers, and real-time video exploration of distant places, including Arctic-to-Arctic connections. Lectures from the world's leading educational institutions, when posted on the Internet for anyone to view or download, offer enormous opportunities to broaden and deepen learning while simultaneously lessening the burden on local resources. The educational advantages possible with broadband Internet have become indispensable to students preparing to enter today's workforce.

A study by the Institute of Social and Economic Research at the University of Alaska Anchorage found that, while personal communications and entertainment ranked highest among respondents' expected uses of broadband Internet (e.g., social networking, downloading music and videos, playing online games), 48% of respondents said that they expected to use broadband for education. [2]

Distance learning also provides opportunities for students to remain in their communities while in school, which can increase their sense of community and may encourage them to stay in their communities in later years.

While distance education in some areas may be available via satellite, affordability is a concern and the inherent latency (or delay) of certain satellite technologies can result in a poor user experience for students and educators. To be most effective, broadband solutions are needed to support voice-over-Internet protocol (VOIP), full-motion video at high resolution, and – in many cases – large file transfer, remote control of computer systems, and simultaneous multiple users of media-rich educational web sites and email. Educational providers see challenges in connectivity and bandwidth as the single biggest issue they have in developing and delivering services like these.

1 http://www.uArctic.org/media/1478224/uArctic-telecom-survey-results.pdf

2 Based on a telephone survey of 9,700 households in rural southwest Alaska. (http://www.iser.uaa.alaska.edu/Publications/2012_11-TERRA.pdf)

Robust communications systems that can support videoconferencing-style communications can bridge the educational divide by giving communities access to primary and secondary education, vocational training, adult basic education, and post-secondary education from colleges and universities.

3d. Language and culture

Languages and cultures are essential elements of living in the Arctic, and the preservation of Arctic languages and cultures remains extremely important to the inhabitants living and working there. ICTs can provide excellent opportunities for indigenous voices to be heard and can be effective in helping to strengthen indigenous cultures, languages, and identity.

There is growing interest in using technology in indigenous language revitalization and reclamation efforts. Even in areas where the status of indigenous languages is relatively strong, modern telecommunications serve to reinforce the long-term viability of those languages. One example is the relatively recent efforts in Nunavut to develop online Inuktitut-language tools such as the Tusaalanga online Inuktitut learning site at www.tusaalanga.ca.

Libraries often serve as gathering places that offer access to many services offered within a community. They can also function as local cultural centers. Libraries may also be the only places where the general public can access the Internet, and thus serve as critical gateways to information outside one's own community. In the future, many library patrons may use library-provided broadband to access the Internet and resources such as e-books, government websites, social networking, and other media. In Alaska, for example, the Library Network serves, as a critical gateway of community broadband services, providing multiple telecommunication services to community residents.

3e. Telemedicine and social services

Healthcare has traditionally been delivered face-to-face between doctor and patient. But in remote areas of the Arctic, where patients may have to travel long distances to receive care from a doctor, the potential benefits of telemedicine are enormous. Distance, time, and cost are all dramatically reduced when telemedicine facilities (using broadband connections) are made available where hospitals do not exist. In many cases, a community will have a clinic with one medical staff and a broadband connection to a hospital. This arrangement is often sufficient to serve many basic healthcare needs.

An indigenous person's local language may not be the same as the language spoken by the medical staff at the hospitals. With the use of ICTs and broadband, it may be easier to overcome this language barrier and receive more effective healthcare by simultaneously connecting the patient, interpreters, and medical staff.

Better broadband helping to create jobs in sparsely populated areas

The availability of affordable broadband in remote and sparsely-populated areas of the Arctic may enable the creation of new jobs in the Arctic. This applies to jobs in industries like tourism that depend on natural resources, but it also applies to ICT-enabled jobs that do not require that employees work from a specific location. One example of this is that Norway's national health system has just chosen to build a new central telemedicine office on Svalbard. This draws upon the availability of excellent broadband communication, and responds to the need of Svalbard – a remote archipelago – for telemedicine services.

3f. Economic development

It has become evident that access to ICTs and broadband can generate major economic growth and job creation around the globe. ICTs and broadband accelerate business development by providing new opportunities for innovation, expansion, and e-commerce. Connected communities create wealth and opportunity by attracting businesses that want to locate in areas with a strong broadband presence. For example, Facebook recently constructed a data center in Luleå in northern Sweden due, in part, to the reliably cool environment (which reduces Facebook's cost for climate-controlling the data center), availability of renewable energy, and political stability.

From the perspective of indigenous communities, ICTs can also benefit the development and growth of traditional industries, such as reindeer husbandry in Sámi areas. Indigenous peoples and nomadic peoples often cultivate and harvest natural resources through hunting and herding, making use of the vast areas available. These areas are often devoid of roads or communications infrastructure; increased availability of ICTs might help to foster the economic and social development of these communities.

In Nunavut, there are many sectors – including mining, fisheries, financial services, small businesses, and tourism – that have significant connectivity requirements. These sectors help to stimulate the private sector in small communities. Various government agencies in Nunavut work to support and encourage tourism, the arts industry, film, and businesses. While tourism does contribute to economic development, it also increases demands on local access to ICT and broadband connectivity.

3g. Community sustainability

Access to modern ICTs helps to increase opportunities in every facet of community life, including improved health care, education, social interaction, business opportunities, and governance. ICTs can help northern, remote, and isolated communities become more sustainable, and can aid in their long-term survival. The availability of ICTs and broadband increases the opportunities for communication with family members, friends, neighbors and co-workers. Moreover, as mentioned earlier, modern ICTs are increasingly important for conducting business activities, seeking and performing jobs, and participating in commerce. With this combination of factors, ICTs can significantly contribute to the long-term viability of Arctic communities.

4. Inter-regional and pan-Arctic needs

4a. Science and environment

Introduction

Space-based telecommunications infrastructure is crucial for Arctic science, as well as for environmental monitoring. It has facilitated passive and active Earth observation systems, global satellite navigation systems, and generally-improved connectivity. Data collected from research in the Arctic, however, is difficult to transmit back to the researchers, as the availability of communication systems is limited in the Arctic. This also applies to the satellite transmission of information back to scientists working in the field, where access to reliable geostationary satellite communication is limited.

Sufficient and steady telecommunication is also crucial not only for personal safety but also for avoiding potential data loss during expeditions. For scientists that travel and stay in the Arctic for longer periods, new systems would improve safety and welfare due to availability of information services like weather, ice forecasts, telemedicine services, and general access to the Internet for improved research.

Beyond merely having connectivity, modern scientific research and environmental monitoring require ever-increasing bandwidths to transmit large amounts of data back to the researchers. The distribution of this information is currently done by fiber-optic links or geostationary satellites, but only where those options are available.

Very narrow-band services arrived with the establishment of the Argos system in 1978. The Argos system allows for short (up to 31 bits) machine-to-machine (M2M, described in more detail below) messages to be transmitted to six internationally available polar-orbiting satellites. Two of these satellites allow for identical two-way signal communication. This very limited capability has revolutionized wildlife studies all over the world, particularly in the Arctic. The transmitters are also mounted on buoys, ice floats, and icebergs.

The Iridium satellite system provides the capability of continuous low-data-rate communications (<2.4 Kbps per channel), allowing scientists to accumulate data from expeditions and fixed data platforms. With the soon-to-be launched Iridium Next satellites, users may, over time, gain access to increased data capacity up to approximately 1 Mbps per channel.

These low-data-rate systems have the advantage that they only need small, omnidirectional antennas with little additional infrastructure; this allows for lower investment costs and simplified logistics. These systems also cover all of the Arctic. Other M2M and store-and-forward systems exist, like Orbcomm (based on LEO satellites) and Thuraya (based on geostationary satellites), but few of them have substantial Arctic coverage. The Canadian CASSIOPE satellite has been used to test and demonstrate store-and-forward functionality from an elliptical LEO, which works well for Arctic coverage. Soon there may also be other LEO narrow-band (<200 Kbps) polar-orbiting satellites/systems using VHF for data exchange, as well as new higher-capacity LEO systems, which may improve opportunities for scientific research. Geostationary satellites, however, require bigger directional antennas and more ground infrastructure, thus requiring increased investment and maintenance costs. The capabilities provided by the geostationary satellites are typically used on larger research vessels and manned research stations.

Research vessels

Vessels like Germany's *RV Polarstern* and *RV Heincke* use geostationary satellite links for their telecommunications needs (email, Internet, phone, and fax), currently in C and K_u bands, which provide services in the range from 128 Kbps to 2 Mbps. They use Iridium for operations situated further north.

Oil- and gas-related sub-sea research/surveys have an increasing need for capacity. Companies like Electromagnetic Geoservices ASA (EMGS) conduct surveys in which they deploy receivers (numbering sometimes in the hundreds) in a grid on the sea bottom, and tow a transmitter behind a vessel above the grid for weeks at a time. Each receiver may, during the campaign, collect large amounts of data, even up to several gigabytes.

Aeronautical science

Today, there is limited availability of capacity for transfer of scientific data during flights over the Arctic. Being able to transfer data during measurement flights may be very important for certain scientific campaigns in order to provide for near real-time decision-making. It is furthermore expected that the use of unmanned or remotely piloted aircraft (UAV/RPAS) will increase. Such craft may collect scientific information or conduct environmental monitoring over large remote areas, reducing the cost and risk involved. UAV/RPAS will require access to a certain amount of data communications capacity for safe operation, and this communication link must be stable and secure. The link may also need to be able to communicate in real-time some or all of the sensor data from the aircraft to the ground.

Buoys, gliders, and moorings

The more than 2,000 ARGO floats have increased the knowledge of the global ocean structure enormously through their ability to transmit narrow-band information through satellite links. However, due to ice conditions, these floats only work intermittently in the Arctic.

Several mooring systems for oceanographic and biological information exist in the Arctic, but none of these systems have satellite links as of today. The long-term ecological research observatory "AWI Hausgarten" has 21 permanent stations that are serviced yearly from vessels. Some of the stations are planned, sometime in the future, to have modems connected to Iridium for data transmission of small and basic data packages. The long-term moorings in the Fram Strait and "AWI Hausgarten", for example, could benefit from dedicated connectivity to enable ongoing transmission from underwater measuring systems.

Land-based stations and expeditions

Scientific installations on Svalbard at Longyearbyen and Ny-Ålesund have installed fiber connections, while Barentsburg is connected to fiber via a microwave link. The Polish research station in Hornsund has a geostationary satellite connection operating at 256 Kbps.

In much of the Russian Arctic, Greenland, Alaska, and Canada, scientific stations typically have geostationary satellite links of a few hundred Kbps. For example, at the Russian Samoylov Station on Samoylov Island, bandwidth is 256 Kbps upstream and 512 Kbps downstream.

For land expeditions in the Arctic, local communication in the field is typically provided by VHF radios and Iridium mobile phones, while safety is supported by emergency beacons (Cospas-Sarsat, for example).

Current Arctic research activities involving permanent or long-term collection of large amounts of data generally require that research sites be manned during campaign periods or, alternatively, that data be manually collected and sent back to the research institute for analysis after a campaign has been completed. The placement of personnel at research stations is costly and hazardous for the researchers, while the deferred data retrieval process delays the timeliness of the research. With reliable remote access to scientific measurement systems, Arctic research would gain greater efficiency and deliver data more immediately back to the researchers.

4b. Maritime

Introduction

Increased navigability through Arctic waters due to reduced sea ice coverage is resulting in increased human activity in maritime traffic, trade, and tourism, and an accompanying demand for better communications coverage throughout the Arctic. Arctic maritime communications needs are, in general, satisfied through satellite coverage, the expansion of which will collaterally benefit coastal populations as coverage and performance are improved.

The development of Arctic communication systems is critical to maritime safety and situational awareness. Improving real-time access to, and sharing of, information that is critical for situational awareness is necessary for the safety of vessels sailing through such a dynamic environment. This is particularly the case for route, chart, weather, and ice information, all of which are critical for safe navigation, efficient travel, and regulatory compliance. Of particular importance is the ability to communicate with ships regarding the presence of other vessels in the area and any potential hazards to navigation. In the Arctic, where fishing and subsistence harvesting are regular practices, the need for vessels to communicate positions and other information is critically important. The communication systems available to Arctic maritime users at the time of writing this report do not provide coverage or sufficient bandwidth to support the data-centric services that modern activities require.

Categories of maritime communications users

Maritime communications may be divided into segments or user profiles. Each of the user profiles is distinguished by its bandwidth needs, availability requirements, and mobile or fixed communications demands. While overlaps exist, they can be broadly divided as follows.

- Safety
  - Requires modest bandwidth, high reliability and availability, and mobility
  - Required for planning of safe routes, operations, SAR

- Protection of the environment
  - Requires low bandwidth capacity, periodic but reliable availability, and mobility
  - Required for oil spill preparedness, research, crisis management

- Business-related (including welfare of crew/ passengers and regulatory obligations)
  - Requires high bandwidth, high availability, and mobility
  - Required for integrated operations, logistics systems, seismic data, real-time reporting, fisheries catch reporting, etc.
  - Required for telemedicine for passengers and crew onboard ships and rigs

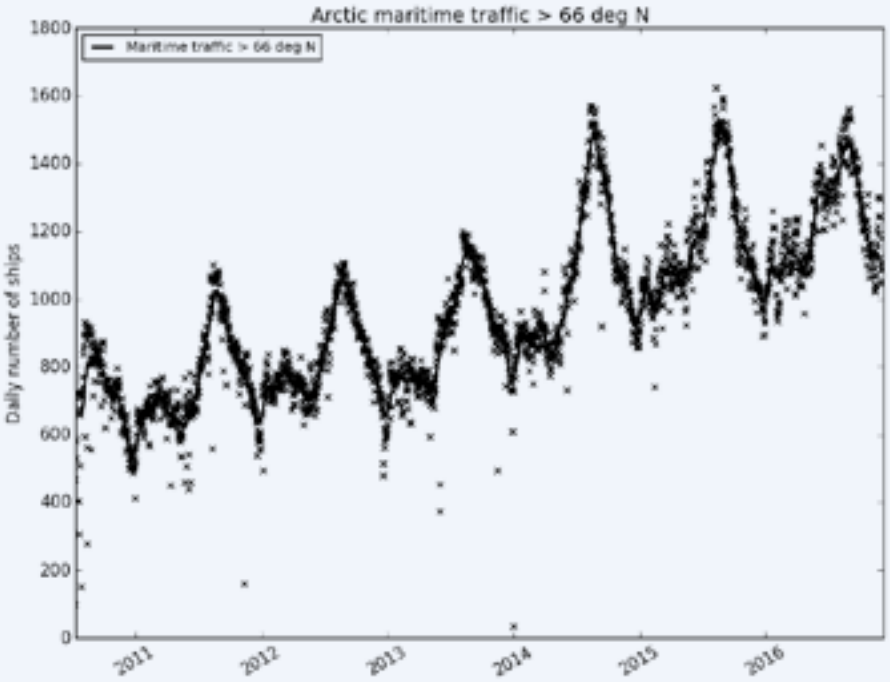
- Security / law enforcement
  - Requires modest bandwidth, high integrity, and mobility
  - Required for border control, fisheries monitoring, regulatory enforcement

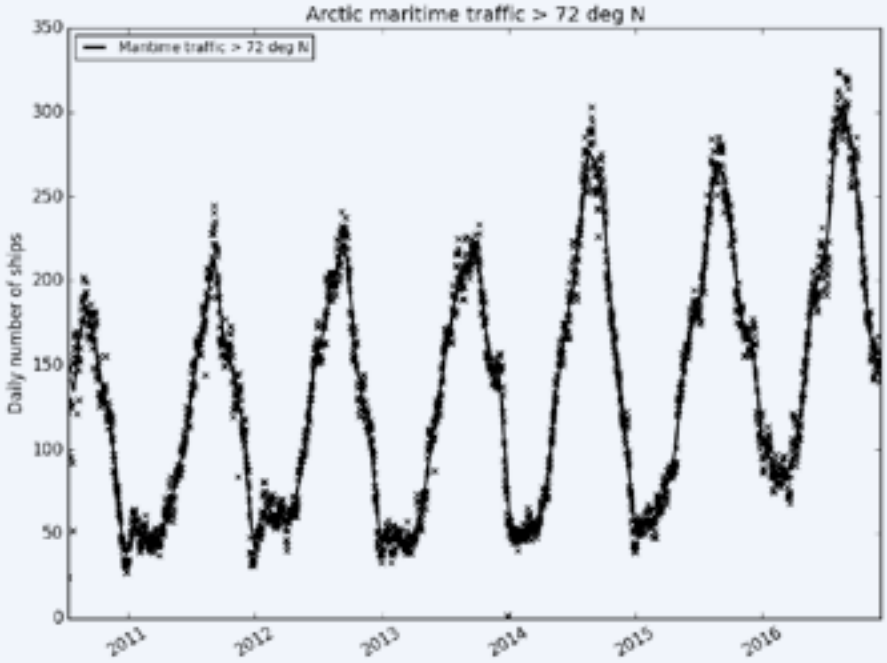
- Leisure (especially tourism)
  - Requires high bandwidth, scalable availability, and mobility
  - Required for general purposes (email and web browsing, streaming etc.)

Increasing maritime activity

Figure 1 and figure 2 demonstrate the increase in maritime traffic that is taking place across the Arctic. As maritime activities increase, demands for connectivity will similarly increase. As demand for connectivity increases, there will be growing incentives to implement technological enhancements and deploy additional infrastructure to overcome coverage and performance gaps.

FIGURE 1 & 2: Arctic maritime traffic above N 66° (figure 1) and N 72° (figure 2). Through the use of information collected by AIS satellites since June 2010[3], it has been possible to map the changes in maritime traffic from year to year in the entire Arctic region. // Reproduced by permission from the Norwegian Space Center and Norwegian Coastal Administration database (data from AISSat-1 & 2)





3 The Norwegian AISSat-1 satellite was launched into polar orbit in July 2010 and was joined by AISSat-2 in 2014.

FIGURE 3: Arctic sea routes // Reproduced by permission from The Arctic Institute

Over the past five years, discussions and projections of the Arctic as a new international trade route have increased. Between 2011 and 2013, transits through the Northern Sea Route increased from 36 to 71 (compared to only four in 2010). Russia's Northern Sea Route Administration granted more than 650 permits to transit the Northern Sea Route in 2015, demonstrating sustained interest in the region. Updated statistics from the Arctic Council Working Group PAME (Protection of the Arctic Marine Environment) however, indicate a reduced number of Northern Sea Route transits conducted in 2014 and 2015, compared with 2013. [4]

Regarding longer trends, the U.S. Coast Guard statistics from district 17 [5] (table 1) show that the total number of unique vessels in the waters around Alaska increased by 250% from 2008 to 2015. More detailed statistics show the following significant increases in Arctic maritime traffic during that time period. Between 2011 and 2013, transits through the Bering Strait increased from 410 to 440 [6]. As stated in a 2016 report by the U.S. Committee on the Marine Transportation System, "transit statistics for the 2015 season support this continued interest with 300 unique vessels and 540 vessel transits through the Bering Strait, an increase over 2012 activity." [7]

4 Pame.is/index.php/projects/Arctic-marine-shipping/northern-sea-route-shipping-statistics

5 The Seventeenth Coast Guard District, with district office in Juneau, Alaska, is comprised of: Alaska; the ocean area that is bounded by a line from the Canadian coast at latitude 54°-40°N, due west to longitude 140°W; thence southwesterly to position 40°N, 150°W; thence due west to position 40°N, 165°E; thence due north to latitude 43°N; thence northwesterly to 51°N, 158°E; thence north and east along the coastline of the continent of Asia to the easternmost point of East Cape; thence north to the Arctic Ocean.

6 U.S. Committee on the Marine Transportation System. http://www.cmts.gov/downloads/CMTS_10-Year_Arctic_Vessel_Projection_Report_1.1.15.pdf

7 U.S. Committee on the Marine Transportation System. http://www.cmts.gov/downloads/NSAR_1.1.2_10-Year_MTS_Investment_Framework_Final_5_4_16.pdf

TABLE 1: Change from 2008 to 2015 in the number of unique vessels in the waters around Alaska

Category	Change 2008-2015
Bulk shipping	No change
Cargo shipping	Increase by 200%
Tugs	Increase by 300%
Research/science	Increase by 400%
Oil and gas research	Increase by 300%
Tankers	Increase by 400%
Cruise ships	No change
Adventurers	Increasing
Government	Increase by 200%
Other/unknown categories are also up 200-300% since 2008.	

Source: U.S. Coast Guard, district 17

The International Code for Ships Operating in Polar Waters[8], commonly known as the "Polar Code," has been developed to supplement existing IMO instruments like SOLAS (1974) in order to increase the safety of ships' operation and mitigate the impact on people and the environment. The Polar Code acknowledges that operating in polar waters imposes additional demands on ships, their systems, and their operations beyond the existing requirements of SOLAS, the International Convention for the Prevention of Pollution from Ships (1973, as modified by the Protocol of 1978 relating thereto as amended by the 1997 Protocol), and other relevant binding IMO instruments. The Polar Code, adopted as chapter XIV to SOLAS, describes additional requirements for vessels, and is applicable from 1 January 2017 for new ships and from 1 January 2018 for existing ships. These requirements pertain to communications and navigations equipment on board, and they take into account the lack of and/or limitations of communications and navigations systems in high latitudes, the anticipated low temperatures, and the vast distances between ships or between ships and SAR resources. The Polar Code also acknowledges the theoretical limit of coverage for GEO systems at N or S 81.3°, but also that instability and signal dropouts can occur at latitudes as low as N or S 70° under certain conditions. The Polar Code also includes separate chapters containing guidance for working around some of these limitations, like the following examples (selected for illustration only).

- Non-GMDSS systems may be available and may be effective for communication in polar waters.
- AIS could also be used for low-data-rate communication, but there are very few base stations, and the satellite-based AIS system is designed for data reception only.
- As the chart coverage of polar waters in many areas may not currently be adequate for coastal navigation, navigational officers should be aware of potential discrepancies between chart data and GNSS positioning.
- A procedure should be developed to ensure that, when survival craft are in close proximity, not more than two alerting or locating devices are activated at the same time. This is to preserve battery life and to enable extended periods of time for the transmission of alerting or locating signals.
- Responding ships and aircraft may not be able to scan/search on 406/121.5 MHz, in which case other locating devices (e.g. AIS-SART) should be considered.

Figure 4 indicates the links between capacity utilized and integrity of certain types of systems needed and employed by maritime users. The vertical capacity scale will be shifted downwards once new satellite systems (maritime high-throughput satellite, or HTS, GEO systems like Inmarsat Global Xpress and Thor 7) are put into use and new services are developed using the available capacity. The figure is provided by the Norwegian Marine Technology Research Institute (Marintek, a part of the Sintef Group of R&D institutes), which has been part of several studies and projects related to Arctic user needs.

8 The Polar Code covers the full range of design, construction, equipment, operational, training, search and rescue and environmental protection matters relevant to ships operating in waters surrounding the two poles. The latitude limit around the Arctic is not uniform, and depends on the longitude.

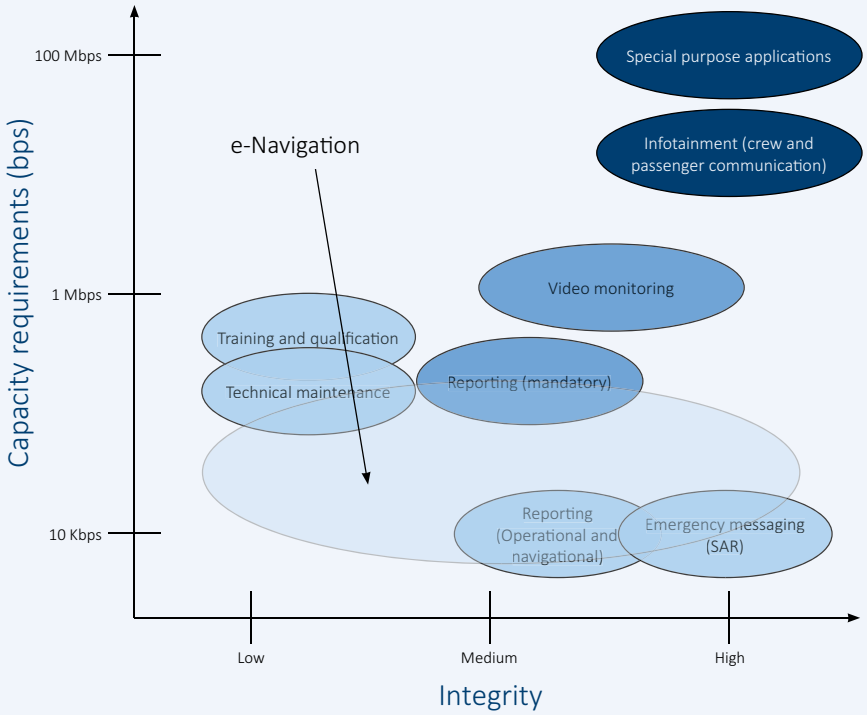


FIGURE 4: Links between capacity requirements and integrity of certain types of systems needed and employed by maritime users. // Used by permission from Marintek

Land-based connectivity for maritime use

Maritime communications users who follow the coastlines closely may, to a great extent, rely on shore-based terrestrial communications infrastructure, such as VHF/HF, which are usually concentrated where vessels operate most frequently. HF signals have a special propagation mode called ground wave (GW) with a propagation range of about 500 km – 1000 km from the shore transmitter. Indeed, HF communication is not particularly restricted near to shore, and HF signals propagate over thousands of kilometers via the ionosphere (via skywave propagation) enabling satellite-like coverage and the potential to offer communications both on the high seas and throughout the Arctic. However, it is important to note that the bandwidth available for HF (and hence the total capacity/throughput such systems may provide) is low. The historical standard for communicating weather, wave, and ice information to ships at sea is by radio facsimile broadcast, which faxes weather and other information via FM radio. While its use is diminishing worldwide as digital communication capabilities increase, analog radio broadcast (VHF and HF) remains an important source of information in the Arctic.

The HF industry and governments have invested significant time and resources in standardizing and developing new ways to use the traditional HF band. Some new digital HF technologies have already been commercialized and are used by some shipping companies and governmental users.

Many maritime communications users make use of cellular networks when they are operating within reach of those networks. WiMAX or directive radio links are used if the user is fixed in a single location or a small area. Other users without mobility requirements, such as oil and gas rigs or wind farms, may use communications via sub-sea fiber cables, if available, or cellular and radio devices if they are close enough to the existing infrastructure.

Users within each profile and some of the communications challenges they have are detailed below.

Safety

Safe operations in the Arctic require the publication of the same meteorological and oceanographic data, products, and services as are provided in regard to oth-

er oceans, plus comprehensive information on sea ice and icebergs. Most modern and larger ships have satellite communications equipment, not only for safety reasons, but for the management and navigation of the ship.

If a maritime communications user is in need of assistance, communications capacity is one important factor. The availability and reliability of the infrastructure necessary to support the alarm, and basic communications with a joint rescue center or with other entities related to the SAR operation, are other important factors. However, the entities that are brought into any SAR operation may need to share and have access to large amounts of information in order to act efficiently and make the best decisions.

Maritime SAR activities are expected to rely largely on satellite communications. However, there are SAR-related vessels stationed around Svalbard, Norway, with access to terrestrial wireless communication networks (3G/4G/ICE/LTE/WiMAX), which they can use for streaming images and pictures. It is also essential to understand that, especially in emergency communications, traditional radio communication has one advantage over satellite or cellular communications; radio communications typically allow multiple users to participate on the same communication network, which can be a distinct advantage over systems that permit only point-to-point communication.

The strategy called e-Navigation (eNav) was developed by the IMO to increase the safety of navigation in commercial shipping. It stipulates that there should be: 1) better organization of data on ships and on shore; and 2) better ship-ship and ship-shore data exchange and communication. The concept was launched when maritime authorities from seven nations requested that the IMO's Maritime Safety Committee begin the development of an e-Navigation strategy in 2005. Sixteen different maritime service portfolios (MSPs) are defined in the strategy. New systems for two-way VHF data communications may be useful for provision of certain eNav applications in the Arctic, but their bandwidth will be limited.

Protection of the environment

Satellites and aerial surveillance systems can improve monitoring capability and serve to improve compliance with regulations, such as those intended for pollution prevention, or with traffic reporting arrangements in place that can help to protect the environment. Remote surveillance and detection technologies (i.e. satellite communications, GPS availability, weather stations) are critical for establishing situational awareness for both preventive and response issues. This overall surveillance capability is limited in the Arctic due to the lack of coverage from GEO satellites and inadequate availability of real-time weather information.

The Arctic Council Working Group EPPR (Emergency Prevention, Preparedness, and Response) has addressed various considerations of prevention, preparedness, and response to environmental emergencies in the Arctic. These considerations include the need for improved communications capabilities and exchange of information between various entities and users involved in pollution prevention or incident response activities.

Proper oil spill preparedness requires stable communications. But in the Barents Sea, for example, the northernmost oil and gas exploration activities have limited satellite bandwidth available. Fiber-based communications from mainland Norway may be an alternative for rigs in the production phase, but distances from shore in excess of 250-350 km introduce a substantial cost issue. However, modern digital HF communication can be seen as a possible solution for narrow-band communication even today.

Commercial activities (including welfare of crew/ passengers and regulatory obligations)

Demand is increasing for the capacity to transfer pictures and video and use streaming applications for a broad range of uses on board ships or rigs. As shipping increases in the Arctic, the need for improved voice and data transmission to and from maritime users becomes acute. Establishing new capabilities with increased capacity would not only improve the current situation, but could function as a driver for increased sustainable maritime activity, thus driving economic growth in the region.

Modern telemedicine (which uses video and advanced health monitoring systems) for the welfare of crew and/or passengers is generally difficult to provide without access to more communications bandwidth than is presently available. Greater detail in reports of catches from fishing vessels (for sustainable management of species and catch areas) also requires additional capacity for vessels operating in the Arctic.

Leisure (especially tourism)

Tourist cruises in particular will create high demand for bandwidth both for operations and for servicing cruise passengers, and cruise activity in the Arctic will typically be in unpopulated areas not served by terrestrial networks.

FIGURE 5: Tourists transiting Longyearbyen harbor, 2000-2015.// Source: Port of Longyearbyen

Cruise ships worldwide are seeing dramatic growth in demand for communications services as travelers increasingly use Internet-connected devices during their vacations. Companies like EMC[9], MTN[10],[11] and Harris Caprock[12] have all reported annual connectivity increases of 25-30%. Cisco and Carnival Cruise lines[13] have reported better communication between ships and their headquarters, increased crew welfare, increased guest/passenger satisfaction, and increased revenues as important drivers of the need for expanded connectivity.

Figure 5 illustrates the development of Arctic cruise tourism as measured by the number of tourists visiting Svalbard every year.

Although the number of overseas cruise *ships* visiting Longyearbyen has been fairly stable since 2005 (similar to the trend seen in data from the U.S. Coast Guard for Alaskan waters), the number of *passengers* on board each ship has increased substantially, growing by nearly 400% compared to the number of passengers in 2000. The number of passengers associated with expedition cruises has remained fairly stable over the last seven years, while the number of passengers involved in day cruises has grown by 50% over the same time period.

9 http://www.marinemec.com/news/view,shipowners-invest-in-multiband-antennas-and-enhanced-wifi_41703.htm

10 http://www.forbes.com/sites/marcwebertobias/2013/03/08/cruise-ship-communications-for-passengers-is-about-to-change/#6a4203eb139c

11 http://www.satellitetoday.com/telecom/2015/03/11/mtn-reports-over-500-percent-increase-in-cruise-line-bandwith-consumption/

12 http://www.harriscaprock.com/downloads/AR_2016_CruiseandFerry.pdf

13 http://www.cisco.com/en/US/prod/collateral/voicesw/ps6788/vcallcon/ps556/_case_study_c36-601472_ps2664_Services_Success_Story.html

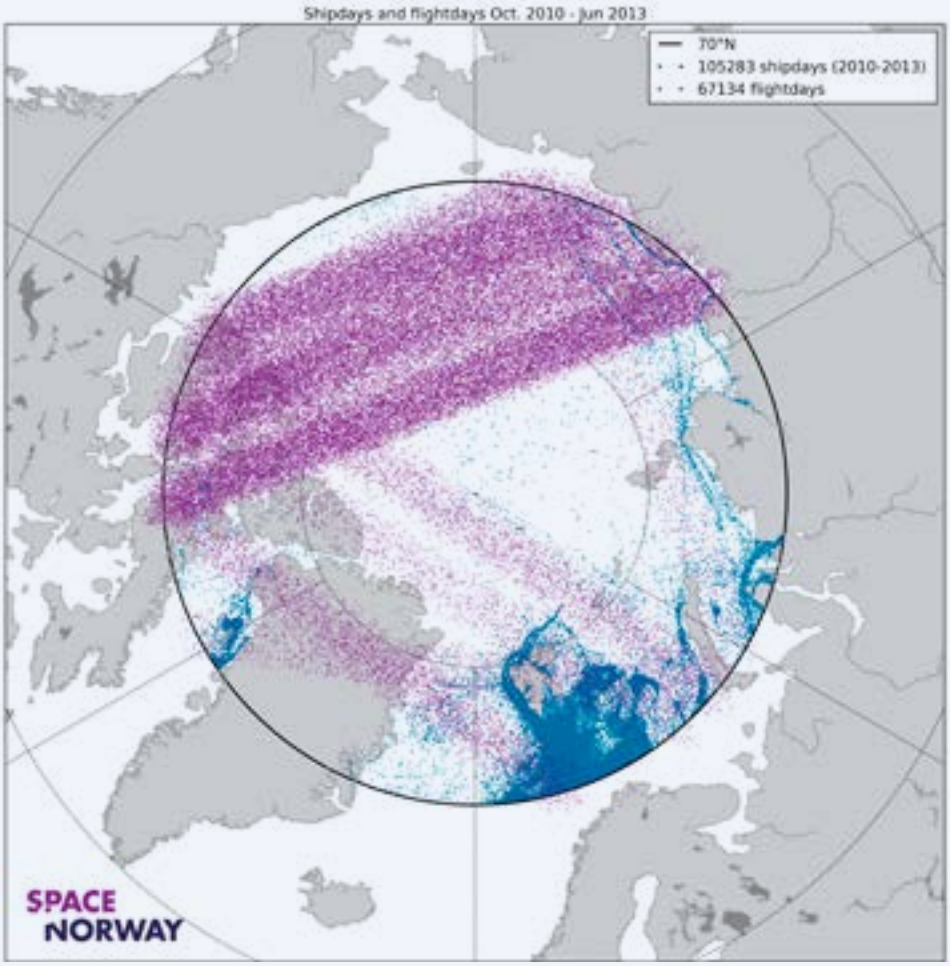


FIGURE 6: A heat map of trans-polar flights from 2010-2013. Purple dots are flights, and blue dots show marine traffic. // Used by permission from Space Norway

4c. Aeronautical

Introduction

According to the International Civil Aviation Organization (ICAO), the number of trans-polar flights is increasing (see figure 6 illustrating routes that airliners often travel over the Arctic). To a large extent, the number of specific flight routes is expected to remain even while the number of airplanes using those routes is expected to continue to increase beyond today's levels. The traffic increase in the overall trans-polar area (which also covers large areas of latitudes below N 80°) has been quite remarkable during the last 15 years. According to statistics presented in the CPWG, the traffic level has grown substantially, from slightly more than 400 flights in 2000 to 12,759 flights in 2014. CPWG estimates that annual future growth will be approximately 3.5% in the Arctic, i.e. slightly less than the ICAO statistics for the world in total.

This traffic growth will have an effect on the magnitude of benefits related to improved flight efficiency. The introduction of new surveillance and communication capabilities will make Arctic airspace more economically attractive to airlines. The new capabilities will allow the airspace to accommodate more traffic, and new and more efficient routings can be introduced.

There are four main categories into which the communications needs of aeronautical users can be sorted.

- Operational needs (for safe flight management)
- SAR operations (with aeronautical resources)
- Machine-to-machine (M2M) data communications
- Commercial needs of cabin passengers (primarily on trans-polar flights)

Operational needs

ICAO is active in infrastructure management, including Communication, Navigation, Surveillance / Air Traffic Management (CNS/ATM) systems, which employ digital technologies (like satellite systems with various levels of automation) in order to maintain a seamless global ATM system-of-systems. There are several elements of modern ATM systems, including air traffic control, air traffic flow management, and a set of aeronautical information services. The last includes exchange of information related to safety, navigation, technical, and administrative or legal matters and their updates.

Globally, the majority of operational communication between an airplane and the ground is provided by VHF/HF radios. These systems do not provide for rapid transfer of large amounts of data. Voice communication over the Arctic is possible, but only with selected communications systems which typically include VHF/HF radios or Iridium satellite services. More recently, the focus of aeronautical communications has shifted to satellite data link communications via Iridium and, to a lesser extent, via HF data links. The standards and guidance for data link options concerning satellite data services are covered by ICAO provisions. North of N 80°, VHF communication services are virtually nonexistent, although some airport locations may provide scattered VHF coverage at latitudes above N 80°.

The European Union is moving towards implementation of the Single European Sky ATM Research (SESAR) project for implementing a new air traffic management administrative, operational, and technical concept. A similar modernization is ongoing in the U.S. (called NextGen). As a complement to terrestrial datalink, satellite communication will have an important role to play in ATM infrastructure both in Europe and in the rest of the world; it will provide additional bandwidth for continental operations, as well as coverage at sea and in remote regions like the Arctic.

The ATM systems used today are regional (U.S., European, or Asian), but because aircraft fly international routes, including trans-polar flights, several parameters are harmonized in order to allow for safe flights from one airspace to another. As an example, the ongoing work related to modernization of the U.S. and European ATM systems through the NextGen and SESAR projects include agreements on harmonization between the systems, including communications. If data communications are to be introduced in 2020 as the primary means of air-to-ground communications, it would allow such a huge volume of data to be exchanged that VHF/HF could no longer be considered as the primary means of communications. Analog voice by VHF/HF would remain as a last resort in emergency situations, but for flights in remote areas, or over the ocean, the systems would have to rely on satellite connections. As of today, satellite systems based on L band (like Iridium and Inmarsat) are used for ATM communications. It is expected that such use will increase globally, with a need for more (and preferably dedicated) bandwidth also over the Arctic. Aeronautical operational use would typically also require high reliability and availability of the data links.

Increased global interest in unmanned aerial vehicles (UAVs) for science, surveillance, situational awareness, and SAR creates a demand both for increased data capacity between the UAV and the ground and for secure communications links to ensure safe operations of the UAV, potentially in non-segregated airspaces. This is true in the Arctic, as it is elsewhere. The growth of civilian use means that the necessary technology and capacity will begin to be available at much lower costs than those that military/governmental users have been used to. This could include, for example, new antenna systems for increased data throughput on smaller UAVs.

FIGURE 7: Areas of responsibility – Arctic SAR agreement (Arctic Council, 2011) // Used by permission from The Arctic Institute

Search and rescue (aeronautical)

The joint rescue coordination centers (JRCCs), maritime rescue coordination centers (MRCCs), and aeronautical rescue coordination centers (ARCCs) listed by the Arctic Council's SAR treaty (2011, "Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic") (figure 7) are located in the Arctic States as follows (from West to East):

- Canada – JRCC Trenton
- Kingdom of Denmark - JRCC Nuuk, Greenland
- Finland – MRCC Turku and ARCC Finland
- Iceland – JRCC Iceland (in Reykjavik)
- Norway – JRCC Northern Norway (in Bodø)
- Russian Federation – State Maritime Rescue Coordination Center (SMRCC) and the Main Aviation Coordination Center for Search and Rescue (MACC). The more specific centers for Arctic operations (not listed in the treaty) are in Murmansk, Tiksi, Pevek, and Dikson.
- Sweden – JRCC Gothenburg
- United States of America – JRCC Juneau and ARCC Elmendorf (outside Anchorage)

Successful SAR in the Arctic depends in large measure on the proximity of the necessary assets to the site of an incident. The closer these units are to the site of the incident, the quicker the response. Trans-polar flights between Asia and North America spend most of their time transiting the airspace of the three biggest countries in the Arctic: Russia, Canada, and the U.S., yet the majority of the assets that can be deployed for SAR in the region are located in northern Norway, Sweden, and Finland, and on Russia's Kola Peninsula. That is to say, the majority of available SAR assets are far from where the majority of aeronautical activity takes place (figure 8). The lack of telecommunications capacity in these areas compounds the challenge of responding to an aeronautical incident.

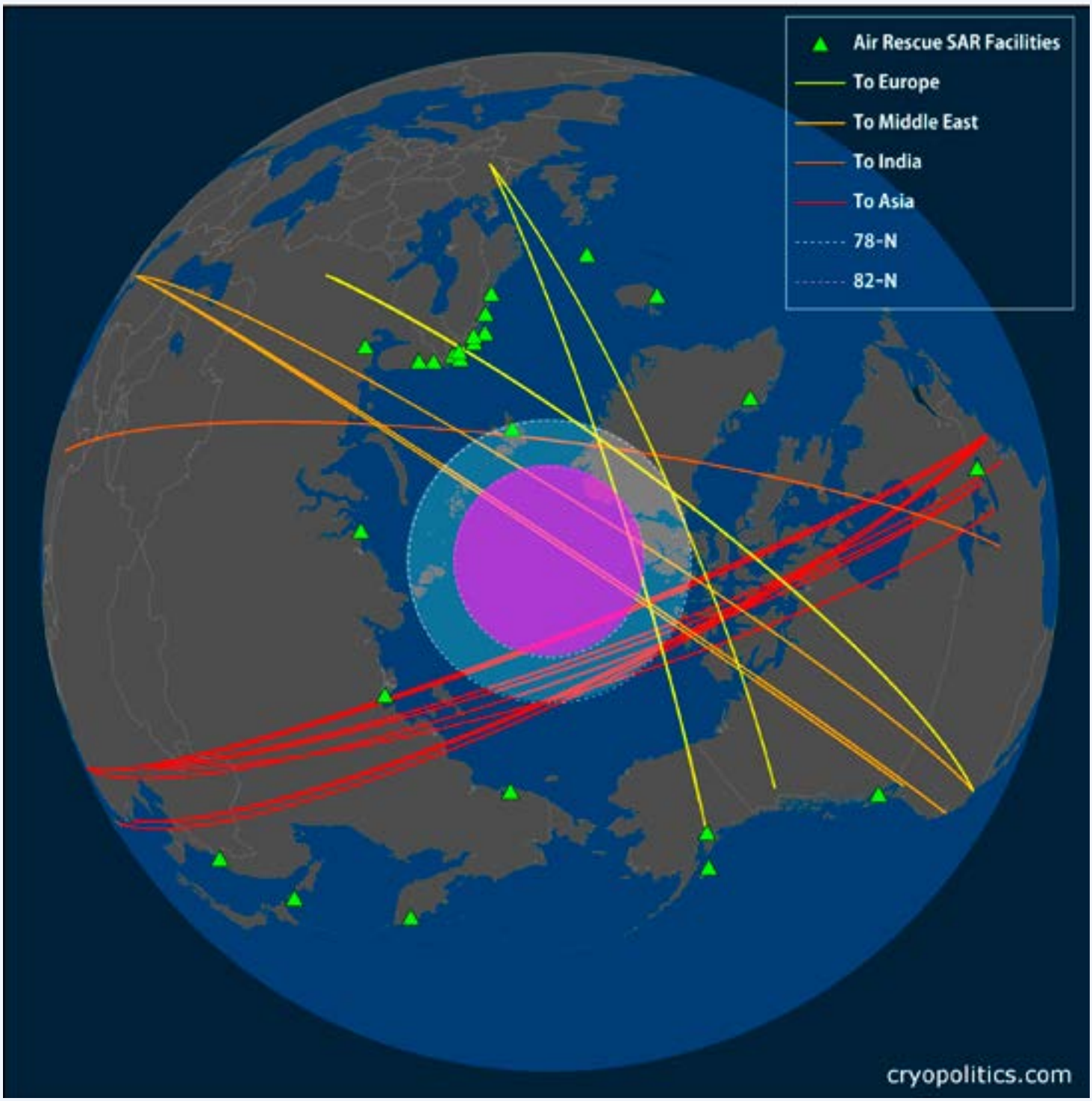


FIGURE 8: Trans-polar airline routes and locations of rescue coordination centers around the Arctic. // Used by permission from Mia Bennett / cryopolitics.com

Aeronautical resources communicating with RCCs and other involved resources must use either air-to-ground wireless communications (like VHF/HF) or satellite-based systems, depending on the availability or type of data/information to be exchanged.

The initial call for assistance will typically be based on either voice communication or through the activation of a Cospas-Sarsat beacon/transmitter to initially report and locate the SAR event (see section 4d for a fuller explanation of Cospas-Sarsat). Developments undertaken by the U.S. in relation to NextGen bring ADS-B receivers on board LEO-satellites in order to collect the position of planes in near real-time worldwide. As SAR events develop, the demand for telecommunications resources typically increases and changes. For the immediate messaging at the beginning of a SAR event, the bandwidth needs are small, but the availability and integrity of the communications options are critical to life saving. This could typically be served through L band satellite terminals and VHF/HF voice radios to guide first responders to the event. GNSS devices will typically be used for positioning and navigation. The initial low-bandwidth distress messaging systems are based on satellite infrastructure. Some of the latest technologies (found on Galileo GNSS satellites) have the ability to respond to the sender, confirming that the distress signal has been received (requiring the use of a two way SART-unit).

As a SAR event evolves, the bandwidth needs may increase significantly, while the requirement for integrity may go down for the higher bandwidths. Video, data, and voice communications will begin to focus on rescue and recovery, and these activities will require the use of wireless technologies due to the likely unavailability of terrestrial infrastructure.

Machine-to-machine (M2M) communications

The evolution of the "Internet of Things" (or M2M) has reached the aeronautical domain. M2M communications is a broad term, but it refers to direct communication between devices using any communications channel, including wired and wireless means, and hence excludes voice communications.

The increasing interest in UAVs has already been mentioned earlier in this chapter, where communications must be secured to provide safe operations of the UAV, while at the same time the equipment on board must often be able to stream large amounts of data back to the user on ground. As users could be commercial or governmental, the preferred communications systems may be commercial or governmental as well.

There is also a growing interest to allow for live streaming of information from flight data recorders (FDR) aboard aircraft to ground infrastructure, possibly reducing the need for an FDR search after an incident in which an FDR might be destroyed or permanently lost. This would only be possible through a broadband channel with available connectivity, and it would result in a cost to the aircraft operator (Inquiries on this topic should be directed to ICAO).

Commercial needs of cabin passengers

People want to be connected at home, at work, and while traveling. The longer the travel is, the more we need to be connected, whether for entertainment or for work. The onboard capacity involved in connecting users while they are on board a flight is usually commercial and asymmetrical (providing more bandwidth toward the user on the plane than away from the user). Airlines are adding in-flight connectivity options on more and more of their planes, and systems tend to use either direct-to-ground wireless communications or satellite-based systems. It is expected that, by 2024, nearly all long-haul aircraft will have antennas installed to provide passenger connectivity.

4d: Search and rescue (SAR) systems

Introduction

SAR activities in the Arctic require the use and availability of multiple systems in order to respond to the variety of emergencies that can and do occur in the Arctic. Given the vast areas in the Arctic, wireless systems (including those formed by intergovernmental organizations) provide the connectivity between those in need of rescue and the first responders who will come to their aid. The systems currently in use are introduced below.

Cospas-Sarsat

The International Cospas-Sarsat Programme [14] is a treaty-based, nonprofit, intergovernmental humanitarian cooperative of 43 nations and agencies dedicated to detecting and locating radio beacons activated by persons (e.g., backcountry hikers), aircraft, or vessels in distress, and forwarding this alert information to authorities that can take action for rescue. The system utilizes a network of satellites that provide coverage anywhere on Earth. Distress alerts are detected, located, and forwarded to over 200 countries and territories at no cost to the receiving government agencies. Cospas-Sarsat was conceived and initiated by the founding Party States of Canada, France, the United States, and the former Soviet Union in 1979 (The Russian Federation succeeded the Soviet Union as a Party to the organization). The other 39 States and agencies are associated in a non-Party "Participant" status. Between September 1982 and December 2015 the Cospas-Sarsat System provided assistance in rescuing at least 41,750 persons in 11,788 SAR events.

The Cospas-Sarsat system space segment consists of receivers aboard:

- Five satellites in polar low-altitude Earth orbit called LEOSARs,
- Nine satellites in geostationary Earth orbit called GEOSARs, and
- Over 30 satellites in medium-altitude Earth orbit called MEOSARs.

The most recent space segment augmentation for Cospas-Sarsat is MEOSAR, which blends the advantages of the older LEOSAR and GEOSAR systems, while avoiding the drawbacks. Over time there will be more than 70 MEOSAR satellites, and the MEOSAR system will become the dominant space-segment capability of Cospas-Sarsat. In addition to the large number of satellites, the MEOSAR system benefits from relatively large satellite footprints. MEOSAR consists of receivers aboard the following navigation-satellite constellations: the European Union's Galileo, the Russian Federation's Glonass, and the United States' Global Positioning System (GPS). The current payloads aboard GPS satellites also are known as the Distress Alerting Satellite System (DASS). Ultimately, the MEOSAR system will be able to provide near-instantaneous detection, identification, and location-determination of 406-MHz beacons.

The Cospas-Sarsat system is the only satellite distress-alerting system that is capable of dual, redundant means of locating an activated distress beacon; both from location data included in the distress message that have been derived from a local navigation source, and through "independent" mathematical analysis in near-real-time of the received signal characteristics.

GMDSS

The Global Maritime Distress and Safety System (GMDSS) is an international system which uses terrestrial and satellite technology and ship-board radio systems. It ensures rapid alerting of shore-based rescue and communications authorities in the event of an emergency. In addition, the system alerts vessels in the immediate vicinity and provides improved means of locating survivors. [15]

14 The text for the Cospas-Sarsat section was provided by Mr. Steven Lett, Head of Secretariat for the International Cospas-Sarsat Programme.

15 http://www.ccg-gcc.gc.ca/eng/CCG/SAR_Gmdss

There are four "Sea Areas" defined internationally in the GMDSS:

- A1: Within range of shore-based VHF coast station (40 nautical miles)
- A2: Within range of shore-based MF coast station (excluding sea areas A1)(150 nautical miles)
- A3: Within the coverage of an Inmarsat geostationary satellite (approximately N 70° to S 70°) (excluding sea areas A1 & A2)
- A4: The remaining areas outside sea areas A1, A2, and A3 (polar regions)

Inmarsat, Ltd. maintains the public service obligation to provide the GMDSS satellite services. Equipment to operate with the GMDSS network is required on all maritime vessels in excess of 2,000 tons. Today, around 100,000 vessels also rely on Inmarsat to provide vital communications.

As noted earlier in the report, communication via geostationary satellites is difficult in the northernmost parts of the Arctic. Therefore, Inmarsat cannot be relied upon for the provision of GMDSS in much of the Arctic. However, work is ongoing in order to gain recognition by IMO for an expansion of the GMDSS to include Iridium satellites. The Iridium satellite communications system, if included, would help to augment the GMDSS, with operations possibly beginning as early as 2018.

It should be noted that, although the GMDSS is a maritime-oriented framework, the Inmarsat satellites that provide this service also provide services that can be used by other user groups on land and in the air.

Iridium satellite network

The Iridium satellite network provides complete pole-to-pole satellite coverage for voice and data services. Portable handsets allow for immediate access to the network in order to communicate any emergency event. Iridium provides communications services beyond where existing wireless or wireline networks exist, including remote land areas, open ocean, and polar regions.

Iridium is currently launching a new satellite constellation, called the Iridium NEXT system, which will allow Iridium to evolve its bandwidth and offer data-centric services with greater performance.

Global Navigation Satellite Services (GNSS)

Global Navigation Satellite Services, such as GPS and GLONASS, provide ubiquitous positioning data to allow for accurate navigation for SAR events and other uses. The European Union has developed a third system, called Galileo, which is expected to be fully operational by 2020.

Each of these systems provides (or will provide) independent continuous global coverage, but the on-ground user equipment (even commercial low-cost user equipment like mobile phones) may also use data from a combination of these satellites to perform calculations. The fusion of multiple GNSSs will significantly increase the number of observed satellites, optimize the spatial geometry, and improve continuity and reliability of positioning, including in the Arctic.

On the Galileo GNSS space segment, there will be a two-way capability called Return Link Service (RLS) related to the SAR distress beacon location service (MEOSAR). This will provide an option for limited two-way communication.

HF, VHF, and UHF radio

HF, VHF, and UHF radio systems are essential communications technologies for SAR in the Arctic, as they are in the rest of the world. They are used particularly for voice communication and transmission of short messages. For more information on these technologies, see the section in chapter 5 on HF, VHF, and UHF radio.

5. Available technologies

This chapter presents an overview of the different technologies currently in use in the Arctic and discusses the relationships of those technologies to the needs of the users living and working there. Each technology described below has certain benefits that make it an appropriate choice for the Arctic in certain situations today. However, it is important to note that no single communications technology is the right choice for every circumstance. For example, while geostationary satellites are used for many Arctic connectivity requirements, physical limitations associated with currently available satellites undermine the viability of this technology for serving higher latitudes of the Arctic (this is discussed in more detail later in this chapter). Where latitudes do allow, however, satellite technology is well-suited to support, for example, offshore maritime activity, given the need for mobility and the absence of land upon which to deploy terrestrial infrastructure.

All of the technologies described in this chapter will continue to be used to provide telecommunications services in the Arctic for the foreseeable future. Fortunately, communications technologies are designed to be interoperable. That is to say, new infrastructure using the latest technologies can be deployed in the same region as a legacy network using older technologies and, after these two networks are interconnected, both networks can be used to seamlessly deliver services to end users. Therefore, for future consideration, broader strategies for expanding the telecommunications infrastructure that will make up the emerging pan-Arctic "network of networks" can be developed without the need to specify which particular technologies must be used to satisfy the connectivity requirements in the Arctic.

Whatever technology is used, redundancy and reliability are key principles for assessing network deployment, as is sustainability. Dependency on a single provider or technology creates vulnerability for users. Service providers must also take into account a number of additional variables when designing networks, including the type of communication need, current and anticipated bandwidth demands, revenue opportunity, density, topography, foliage, climate, regulatory requirements, and existence of and access to rights-of-way. For submarine cables, underwater terrain, currents, and maritime activity are also analyzed. In Arctic areas in particular, permafrost conditions, unimpeded access to the network facilities in challenging weather and environmental conditions, and (in the case of submarine cables) the risk of ice scour, are also important factors.

It is important to note that initial deployment of one type of telecommunications technology does not preclude subsequent deployment of additional or alternative technologies as circumstances change. Therefore, less expensive or easier-to-deploy telecommunications infrastructure can be deployed initially to provide adequate communications service to Arctic users until economic development has progressed sufficiently to justify additional investment in network and service expansion. From a user perspective, this can mean that initial connectivity may provide for voice communications and a relatively lower-bandwidth broadband connection to the Internet. This connectivity can help power the economic growth that helps justify additional investments. After sufficient demand supports the deployment of additional telecommunications infrastructure, end users can be expected to benefit from access to broader services and applications.

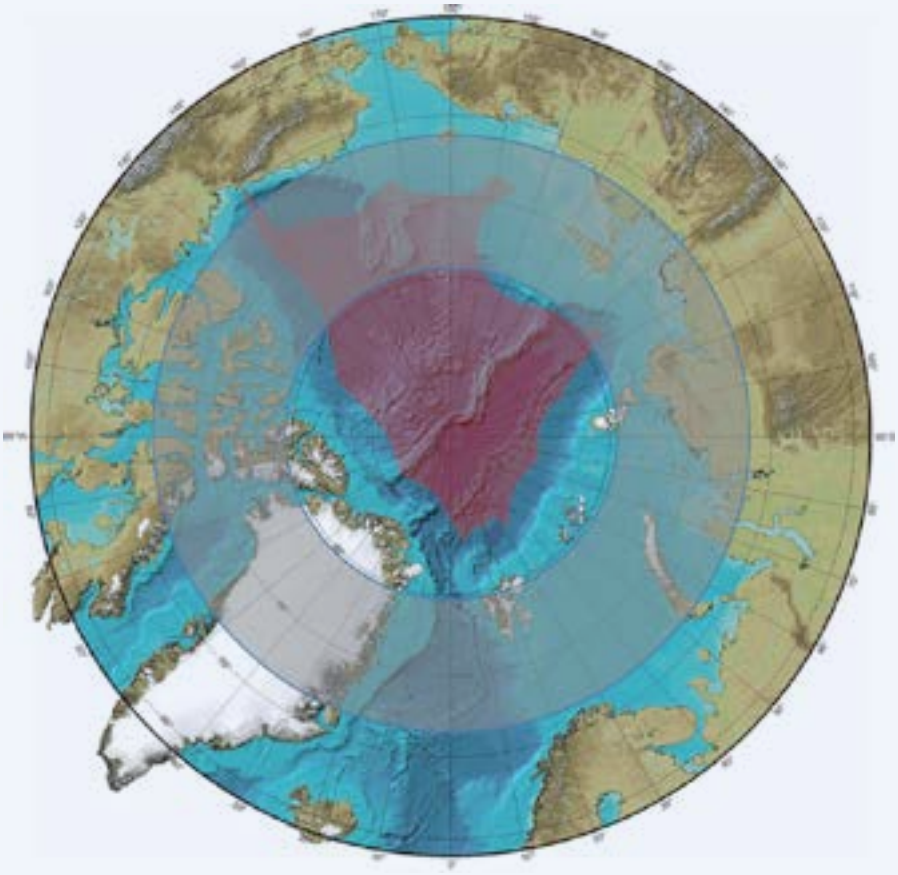


FIGURE 9: In the shaded area from about N 72°-79°, geostationary satellite broadband coverage diminishes towards zero. The rate of loss with latitude depends on weather, horizon, and the size of communication antennas. // Used by permission from the Norwegian Space Center

5a. Satellite services

Fixed satellite services (FSS) provided by geostationary (GEO) satellites are frequently used to provide network connections between communities (sometimes referred to as "middle mile") or between a community and a distribution point ("backhaul") in a larger communications network. In this implementation, the network provider often aggregates traffic in a location – for example, all of a provider's mobile wireless traffic in an Arctic village – and uses the satellite to relay that aggregated local traffic to its network where voice calls are connected or where links to the Internet backbone are provided. In other applications, FSS providers also offer services directly to end users for – as two examples – television distribution and Internet access.

Satellite technology has intrinsic benefits in certain circumstances, including providing service in remote Arctic areas far from population centers. Improvements in technology have increased satellite bandwidth availability and utility, thereby strengthening the viability of satellite services for multiple purposes, including meeting Arctic residents' needs for distance learning and telemedicine.

GEO satellites are deployed in orbit at an altitude of 35,786 kilometers above the equator, where they remain in a fixed orbital location. As a result of their placement above the equator, one unique physical limitation in the latitudes above approximately N 70° is that it becomes increasingly challenging to use these satellite services because of the low "look angle" to the satellite from the Earth stations on the ground (figure 9). With such low look angles, the Earth station's connection to a satellite becomes limited or impossible due to the curvature of the Earth.

As a result, for those areas in the higher latitudes, non-geostationary satellite services are the only option (such as low-Earth orbit (LEO) satellites, or highly elliptical orbit (HEO) satellites, for example). With such limited options available today, the leading choice of connectivity in these high latitudes has been voice radios based on lower frequencies (where feasible) and satellite services on LEO satellites (e.g., Iridium).

Satellite networks have a distinct advantage over terrestrial systems, in that they cover a very large area (whether land or high seas) without the same need for distributed ground-based infrastructure (like fiber and copper lines or transmission towers) that can be vulnerable to damage caused by weather, etc., and which can also be more expensive on a per-destination basis to expand and maintain over time. The challenge in the Arctic is finding satellite capacity that can serve the northern latitudes with sufficient bandwidth to meet the evolving demands. The good news is that satellite technology continues to improve, and satellites – due to their broad reach over vast areas – are likely to be an important part of the telecommunications infrastructure used to deliver connectivity services to the Arctic for the foreseeable future.

In addition to geostationary satellites – which provide network connections, bulk capacity, and some direct-to-home services – other mobile satellite service (MSS) providers operate in low-Earth orbit and provide voice and data services. These services are used for a variety of purposes, from connecting two individuals who are speaking to one another on satellite phones, to tracking cargo on land or at sea, to providing shipboard communications services. With regard to the Arctic, these LEO MSS systems have a distinct advantage over GEO satellite systems because their orbits traverse the North Pole and allow these satellites to offer services throughout the northern latitudes.

The satellite future looks bright for the Arctic. There are several companies seeking to deploy new constellations, including constellations of satellites that will provide expanded or ubiquitous coverage of the Arctic.

It is important to note that, because LEO satellite constellations are located closer to Earth (altitudes are around 1,500 kilometers), latency is significantly lower than that of GEO satellites and can be comparable to fiber-based service depending on the specific implementation and distance. The future development of these projects and other technological improvements are exciting, as satellite coverage provides the broadest single reach across unserved and underserved Arctic areas.

Commercial satellite broadband in the Arctic

Among LEO satellite constellations planned for the near-term (i.e. 2017-2018), OneWeb is one potential provider of broadband (up to 50 Mbps) in the Arctic. Launch of test satellites is planned for 2017, and OneWeb projects that its full constellation of nearly 650 satellites will be operational by 2022. Once the constellation grows above the number of 60 satellites, it may provide full broadband coverage of the Arctic. The satellites may be a potential commercial competitor to planned HEO systems. Other LEO constellations are also under development. Telesat, for example, is launching two satellite prototypes in 2017 to test and validate designs for a planned global constellation with a minimum of 117 satellites.

5b. Fixed lines

Fixed line (also called "wireline") infrastructure forms the core of most large telecommunications networks and, especially in urban areas, also connects end-users to those networks. Fiber-optic cables, coaxial cable, and traditional copper telephone wires are all examples of fixed lines.

The use of fixed lines to serve Arctic communities largely depends on the specific circumstances of individual communities. It is logistically easier to deploy fixed lines where there are roads, existing conduits, telephone/utility poles, railway lines, or other public rights-of-way – all characteristics that are usually found in and near population centers. However, where the distances between communities are vast and where populations are low, the cost to install and maintain fixed lines may outweigh the economic benefit, especially if the combined demand for services in the community does not exceed the capacity of existing telecommunications infrastructure alternatives. In some areas of the Arctic, regulatory requirements may also be a significant barrier where government land-use policies restrict cable burial, such as in Alaska where the federal government owns, controls, or administers approximately 62% of Alaska's land mass.

Fiber-optic cables

Telecommunications providers have used fiber-optic cables in their middle-mile and long-haul networks globally for decades, including in submarine cables, because of the vast amounts of data that a single fiber can carry. Increasingly, fiber-optic cables are also being deployed to enterprise customers, apartment buildings, mobile wireless towers, and the neighborhood nodes to which individual subscribers' access lines are connected. In large areas of the Nordic countries, for example, the standard copper communication connections are being replaced by fiber-optic cables.

Submarine fiber-optic cable is the primary way Internet and other traffic is transmitted between continents or countries separated by the high seas (such as connecting certain European Arctic nations, or connecting Alaska with western portions of the United States where Internet traffic is exchanged). In the Arctic, providers need to select their submarine fiber routes carefully, given the risk of ice scour in some areas, and to ensure reliable service backup plans to carry end-users' traffic if a submarine cable breaks during the winter months when weather conditions can make repair infeasible.

Submarine fiber-optic cables in the Arctic

New submarine cables are planned in the Arctic, including a cable that would connect six coastal communities in northern Alaska, with in-service scheduled for 2017 and longer-term intentions of eventually linking Tokyo to London.

Until 2004, the telecommunication and broadband connections to and from Svalbard were provided by GEO satellite networks. A 1,350 km submarine cable pair was then installed by the Norwegian Space Centre and Space Norway to significantly increase bandwidth while lowering the long-term costs. This cable connectivity has made Svalbard the showcase of Norwegian authorities in providing fiber connections to the individual housing entities in Longyearbyen. In 2016, another submarine fiber connection between Longyearbyen and Ny Ålesund became operational. All of the mobile networks on Svalbard use the fiber cable to the mainland as backhaul.

Another example is the Mackenzie Valley Fibre Link in Canada, which is a high-speed fiber-optic project extending over 1,000 kilometers from McGill Lake in southern Northwest Territories to Inuvik in the north. In the Russian Federation, fiber networks may be built up in connection with the development of oil and gas infrastructure. Where there other driving reasons for building a fiber-optic network, this infrastructure will also be to the benefit of the general population and other stakeholders.

Coaxial cable

Cable systems typically use copper coaxial cable to connect network equipment to the end user to deliver cable television, Internet, and voice services. Cable operators typically then use fiber-optic cable to connect the neighborhood node to the core network, which is why cable operators' networks are often referred to as "hybrid fiber coaxial (HFC)" networks.

The copper wire used in coaxial cable infrastructure is capable of carrying a significant amount of data. Coaxial cable initially deployed to deliver cable television service today also supports broadband and voice services in Arctic communities. By continuing to upgrade their equipment, cable operators have been able to offer very high-capacity broadband service to residential customers, including gigabit speeds in urban areas.

Copper telephone wires

Classical copper-based telecommunications infrastructure is still used to deliver communications services in large parts of the Arctic. Legacy copper access lines are twisted pairs of thin copper wires which carry information as electric signals. While originally designed for voice traffic, newer technologies have enabled broadband services to be delivered to residential and small business customers in the Arctic over legacy copper networks.

Digital Subscriber Line (DSL) service is the most common such technology. The bandwidth provided by DSL technology depends on the distance between the service provider's network and the end user's location. While the details depend on a number of factors, certain DSL protocols can sustain bandwidths of 10 to 20 Mbps over distances of one to two kilometers, with service generally falling to 1 Mbps or less as distance increases to approximately five to nine kilometers. Because of this distance sensitivity, DSL technology is generally not used as a middle-mile (or long haul) technology.

5c. Fixed wireless

Fixed wireless service uses radio transmissions to send information between stationary locations. It is used to provide both middle-mile and last-mile services in the Arctic. Depending on the radio spectrum used, fixed wireless service may require a clear line of sight between the antennas used to transmit and receive wireless signals. The propagation characteristics of radio spectrum vary according to the frequency of the signals transmitted. In practical terms, propagation relates to how well a radio frequency band will penetrate foliage, buildings, and other obstacles, and thus how necessary it is to have a clear line of sight between the transmitting and receiving antennas.

Microwave transmissions, which have been used as middle-mile fixed wireless infrastructure (e.g., in Alaska and Greenland), require clear lines of sight for good performance. Service providers, therefore, tend to mount fixed wireless microwave antennas on mountain tops, radio towers, buildings, and other high structures.

Some providers have begun using mobile wireless spectrum (which propagates well through buildings and foliage) for last-mile fixed wireless services. In such cases, the provider will often mount an antenna that can support voice and Internet service on the outside of a home or building; this eliminates the need to run access lines to the home or business.

Although wireless technologies do not have the same overall capacity as some wireline middle-mile alternatives, multiple gigabits of capacity per second can be transmitted over a single microwave link with a resulting latency that is approximately the same as fiber over the same distance. In sparsely populated areas of the Arctic where the total aggregate demand is within the capacity limits of the network, terrestrial fixed microwave technology has proven to be an effective option.

Because fixed wireless service travels through the air between the sending and receiving antennas, the deployment costs of fixed wireless networks can be significantly lower than those of wireline infrastructure, especially in areas with low population and difficult terrain. It can also be easier to obtain regulatory approvals for fixed wireless infrastructure than for fiber- or copper-based technologies in environmentally sensitive areas.

5d. Mobile wireless

Mobile wireless service is another important alternative for Arctic residents. Mobile wireless infrastructure also uses radio spectrum to deliver last-mile voice and broadband services. A customer subscribing to mobile wireless service can move a wireless device anywhere covered by the wireless signal without losing connectivity. While the service is mobile, most of the infrastructure used to deliver mobile wireless service is fixed terrestrial infrastructure.

Mobile cellular coverage requires base stations, which are the antennas, radio equipment, and power supply that send and receive the wireless signal to and from the end users. The base station is connected to the core network (and the world) through some type of backhaul transmission capability (as described above). In urban areas, base stations are frequently connected to the network with fixed-line connections – usually fiber. In more rural areas, fixed wireless connections and – in some cases – satellite connections are used to connect base stations to the network.

The signal range and capacity provided by a base station is heavily dependent on how much spectrum is available and what type of spectrum is used. In general, lower frequencies (e.g. the 800 MHz and 900 MHz bands) support good area coverage. However, for these bands, the available capacity is spread across a larger area, resulting in lower data speeds for each user within the coverage area. In higher bands (e.g. 1800 MHz and 2600 MHz), the range is shorter. Therefore, a denser grid of base stations is required for continuous coverage. At the same time, the increased capacity will result in higher data speeds for each user. Often a combination of higher and lower frequencies is used, and developing small-cell technology may help overcome frequency-based performance variances.

5e. Digital HF, VHF, and UHF networks

New technologies are enabling data communications (in addition to voice) via terrestrial radios at high frequency (HF), very high frequency (VHF) and ultrahigh frequency (UHF). These radios and antennas are generally fairly inexpensive, lighter, and smaller, but the data transmission rates are fairly low, thus limiting the types of services they can provide.

The maritime community has been one of the most traditional users of HF radio. HF communication on board vessels has typically consisted of analog voice or telegraphy. For several reasons relating particularly to the HF channel characteristics, HF channels have not, historically, been widely used for data transfer. However, with some improvements, there is some potential to make more use of HF for data transfer.

New, state-of-the-art signal processing capabilities have enabled communication capacities by using the HF band between 1.5-30 MHz. Currently, it is possible to offer data connection speeds up to 153 Kbps, which supports IP services like email, chat, and file transfer. New HF modems are showing increased robustness of data rates. One advantage of HF is its very wide range when the radio waves are reflected by ionospheric layers. But radio communications in the Arctic are prone to challenging and rapidly-changing transmission conditions, and realistic data rates and ranges are therefore significantly lower.

Radio communication with VHF generally uses more bandwidth and achieves significantly higher data rates (bandwidth and rates are even higher for UHF). Telenor Maritime Radio VHF-data today offers speeds of up to 133 Kbps. Terrestrial radio systems without stabilized or fixed mounted directional antennas (as in radio links) are limited to significantly less than 100 km distance with VHF, and even shorter distances with UHF. Where those services do exist, new modulation and coding techniques can be used to increase data rates and robustness.

Satellite VDES (VHF Data Exchange System) enables two-way data VHF communication via LEO satellites with a bandwidth of less than 200 Kbps. Transmission conditions between the ground and the satellite are usually better than for terrestrial systems, and even fairly low-cost user terminals are sufficient. Satellite VDES may be an important service for Global Maritime Distress and Safety System (GMDSS) and for other narrow-band data needs.

Although these digital HF/VHF/UHF technologies exist as options, none of these systems is likely to be a significant contributor to delivering broadband communication widely in the Arctic.

6. Gap analysis

This chapter seeks to provide an overview of the identified gaps in Arctic telecommunications infrastructure. It uses information from the Arctic States that is based on input from relevant national authorities and communications providers, as well as on publicly-available information. Changes in the ICT industry occur rapidly, so this overview should be understood as a snapshot in time.

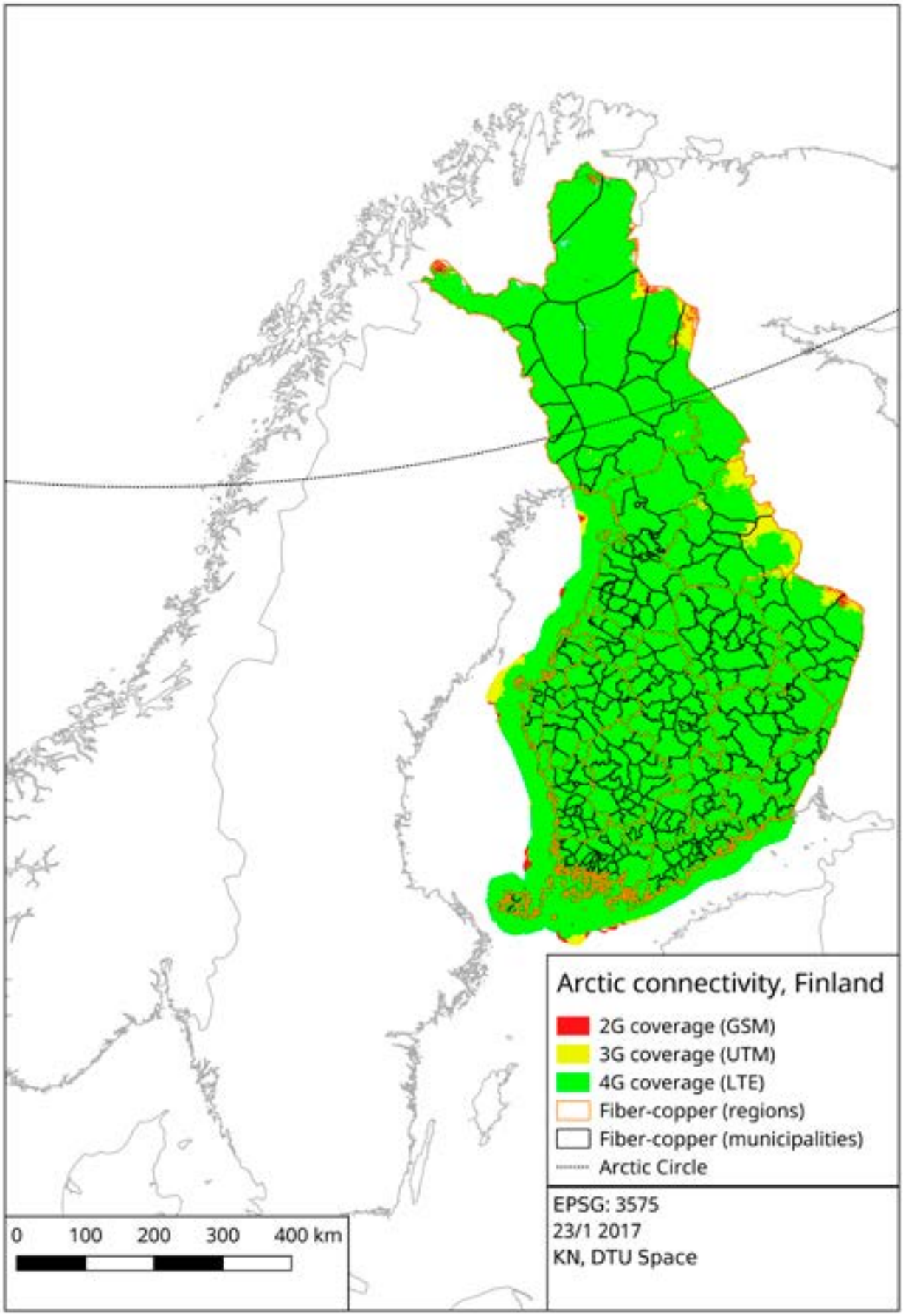
Seeing that there are enormous variations in the population densities and associated telecommunications infrastructure and services present across the Arctic, it may be helpful to assess the Arctic as being divided along this conceptual line. Within the Arctic States, the Faroe Islands, Finland, Iceland, Norway, northwestern Russia, and Sweden are more densely-populated, and often have broader availability of telecommunications infrastructure and services. On the other hand, the vast expanses of the Canadian, Greenlandic, Russian, and U.S. Arctic have extremely low population densities often with lesser availability of telecommunications infrastructure and services. This is not an analytically perfect division, but it can help to draw useful conclusions related to current and future telecommunications expansion.

The following analysis, in addition to addressing more- and less-densely populated areas, will also address gaps that are particularly relevant to maritime and aeronautical users.

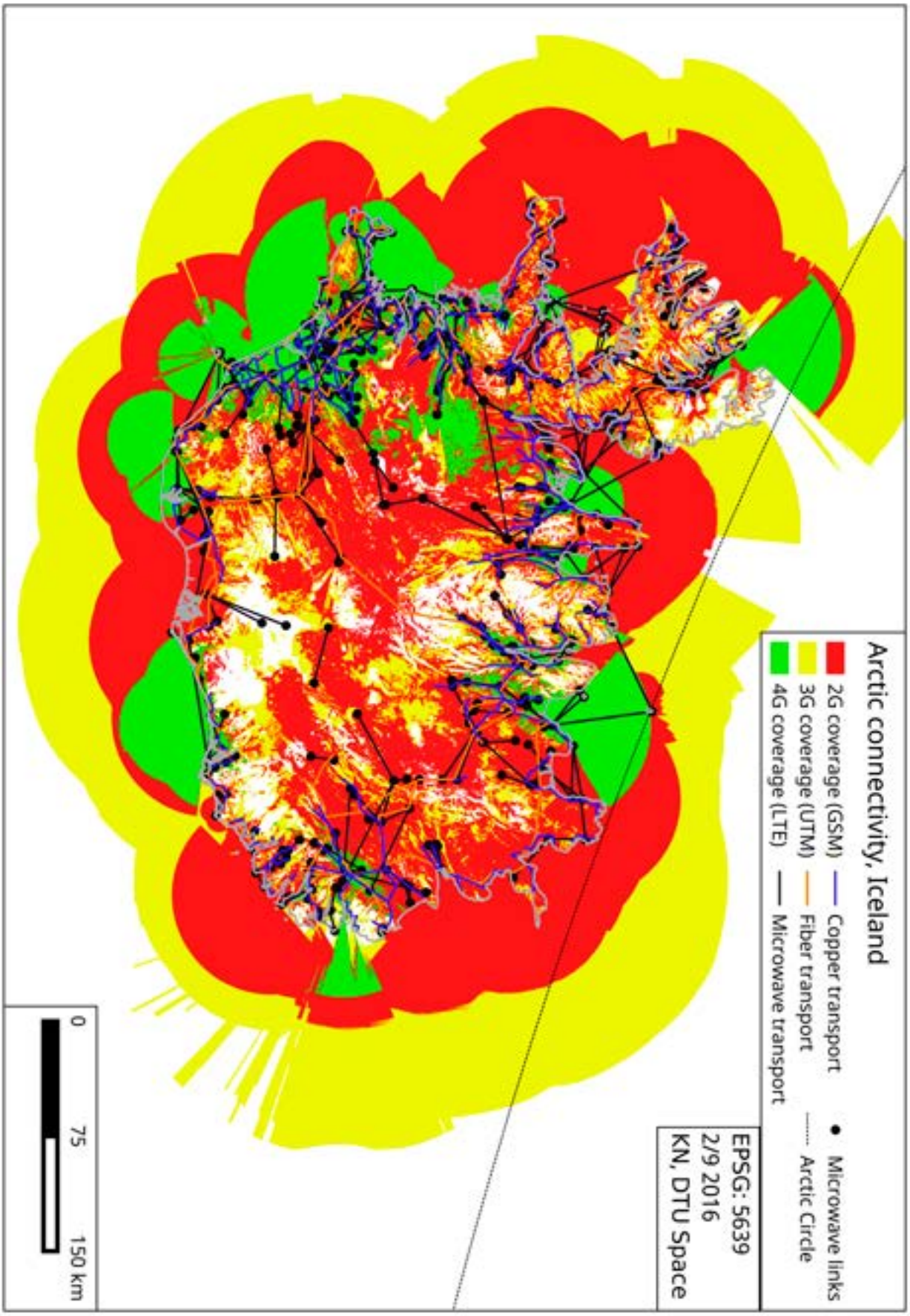
6a. More densely populated areas

In the more densely populated areas described above, the availability of fixed broadband lines (often with mixed technologies), mobile voice, and mobile Internet is very high (>98%) (or will be so in the near future). Coverage in these areas by mobile networks and other forms of communications technology (e.g. microwave transport and fiber cables) is shown in the following "heat maps" (maps 1-4) built on the information provided by the individual Arctic States.

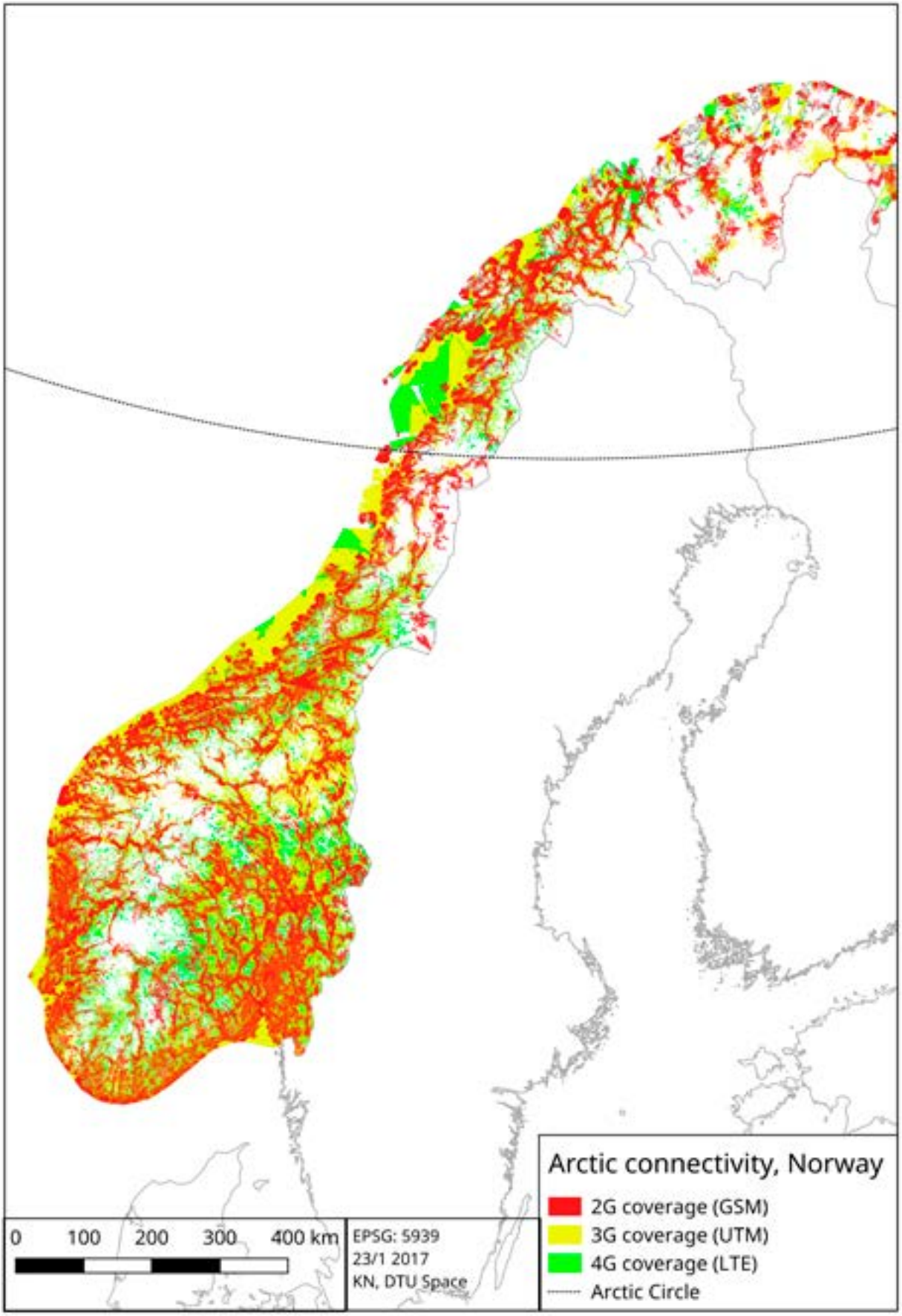
MAP 1: Mobile and fiber-copper coverage in Finland.



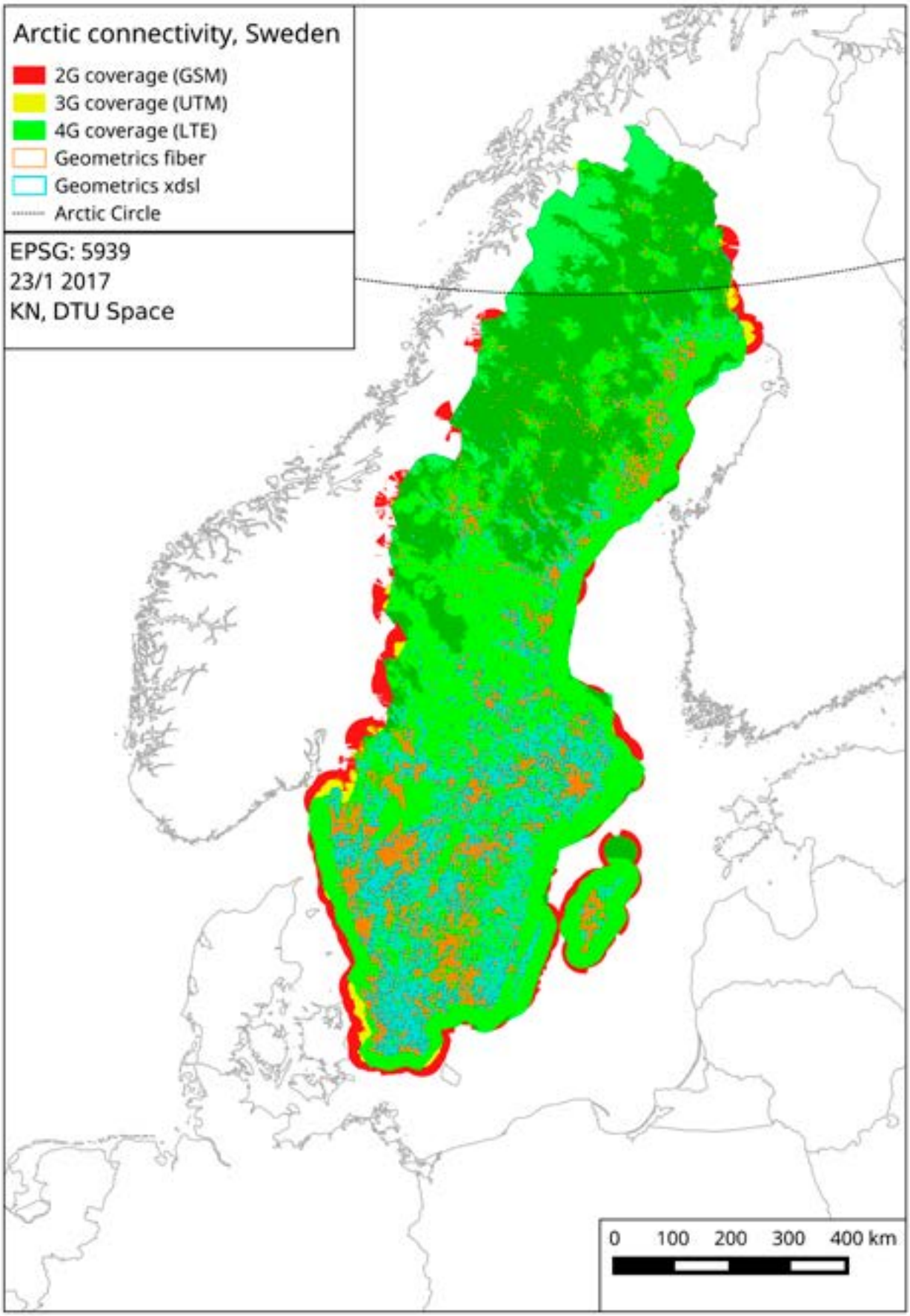
MAP 2: Mobile, fiber-copper and microwave transport coverage in Iceland.



MAP 3: Mobile coverage in Norway.



MAP 4: Mobile coverage in Sweden.



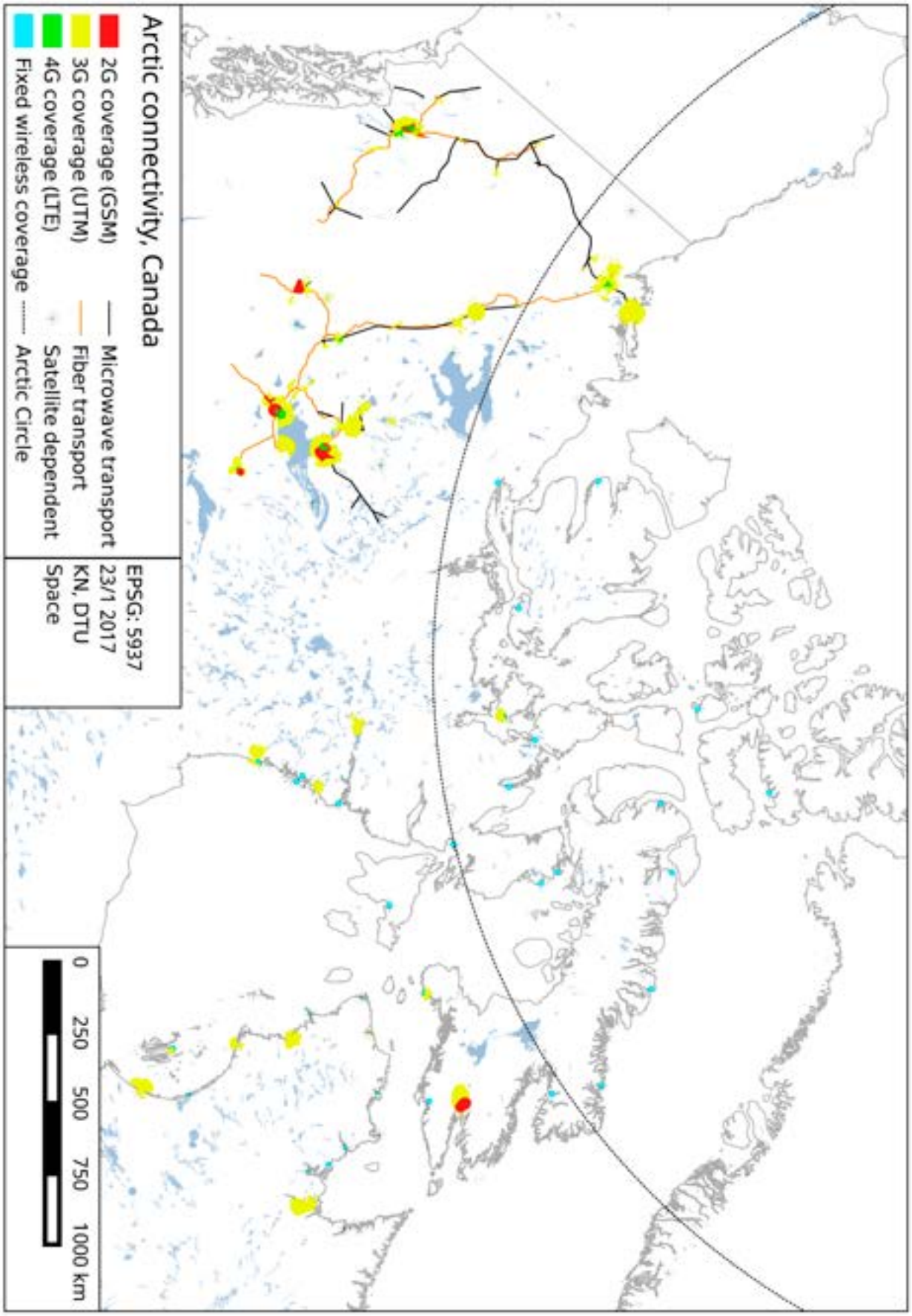
6b. Sparsely populated areas

Even in the sparsely populated areas that characterize much of the Arctic, where basic infrastructure is in place, there is – in general – access to some form of communications technology. Few areas are entirely without access to any form of communications technology. Access to mobile telephone, fixed broadband, and mobile broadband is quite limited, but – in and around local communities – mobile and fixed-line telephone availability for the inhabitants is better. Access to mobile broadband (3G, 4G) remains quite low (ranging from 0%-20%), and network solutions often use several technologies in combination (such as a mix of land lines, wireless towers, and satellite networks).

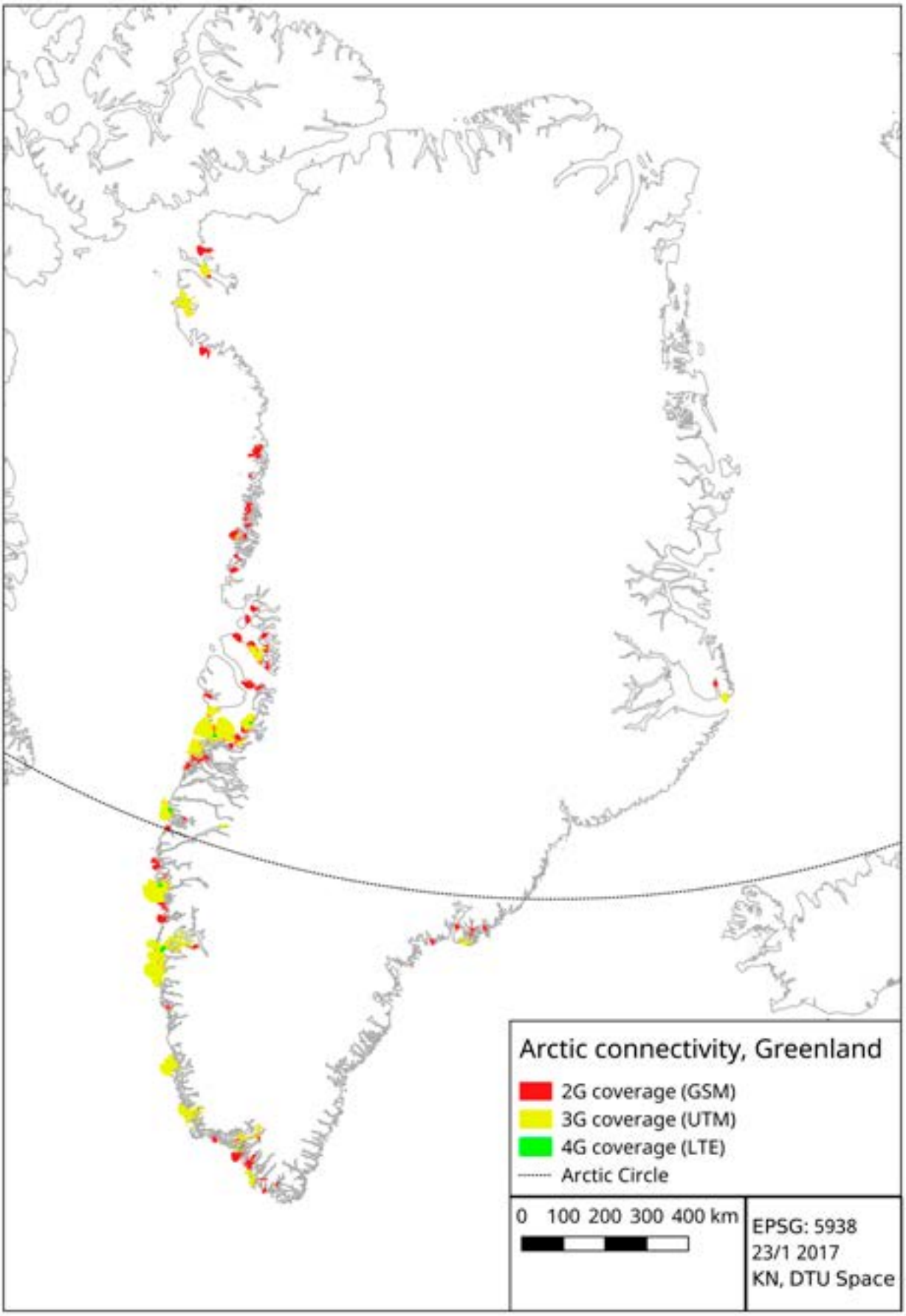
In sparsely populated areas, local mobile providers rely heavily on geostationary satellites for connectivity back to the core network, but there are a few exceptions where fiber cables and/or terrestrial microwave towers are used to access the core network.

Coverage in these areas by mobile networks and other forms of communications technology (e.g. microwave transport and fiber cables) is shown in the following "heat maps" (maps 5-8) built on the information provided by the individual Arctic States.

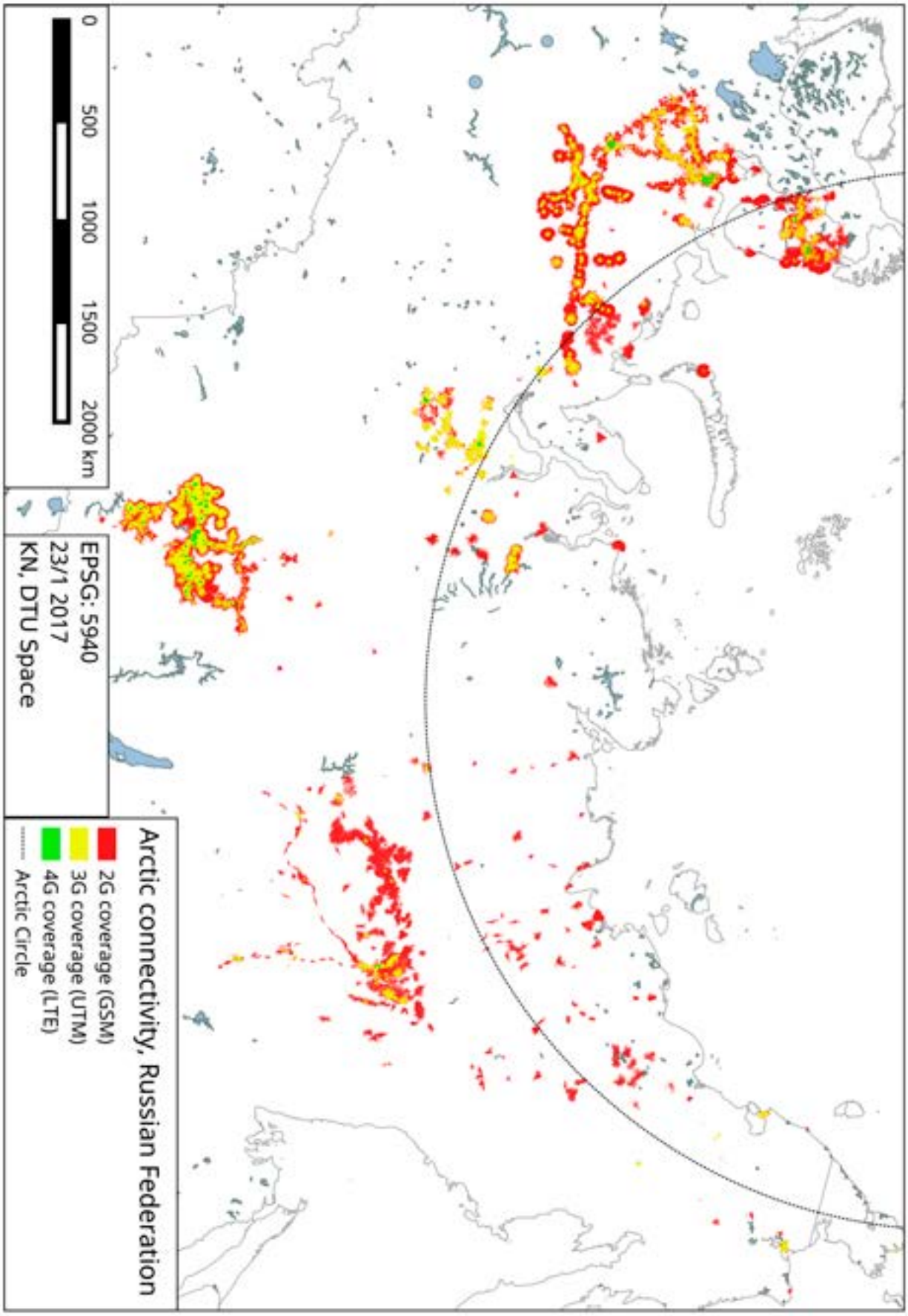
MAP 5: Mobile, fiber and microwave transport coverage and satellite dependent areas in Canada.



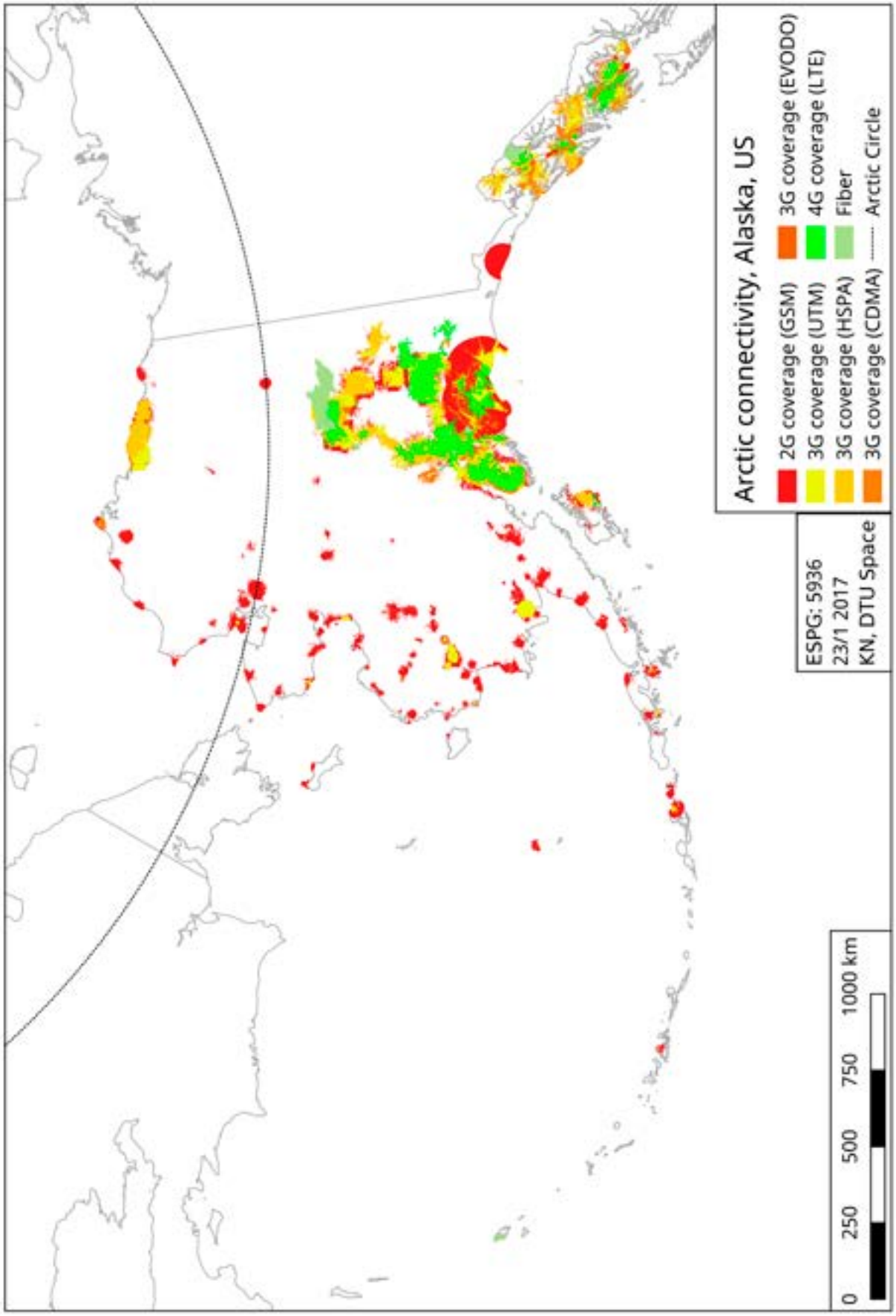
MAP 6: Mobile coverage in Greenland (Kingdom of Denmark).



MAP 7: Mobile coverage in the Russian Federation.



MAP 8: Mobile, fiber and incumbent telephone coverage in Alaska (United States of America).



6c. Maritime and aeronautical gaps

For maritime and aeronautical users, satellites provide the only full-time infrastructure for communications. This is with the notable exception of some coastal areas, in which coverage is very good, essentially equivalent to coverage on-shore. Currently, Iridium provides relatively low-data-rate services throughout the Arctic, but does not provide broadband connectivity. While fixed satellite services provided by geostationary satellites can provide broadband and other services, their ability to serve the Arctic varies as one approaches N 80°. (Figure 9 illustrates the physical limitations of geostationary satellites over the Arctic.)

Maritime users in general have good visibility for satellite connectivity, but poor weather conditions may create large waves resulting in the effective horizon being substantially worsened, thus severely reducing their ability to use fixed satellite services.

As it stands today, there is no ability for maritime and aeronautical users to use broadband services above N 80°, and the ability to acquire broadband services above N 72° is very limited. The ability to use broadband services in the northernmost parts of the Arctic will depend on the successful development and deployment of new satellite systems, as well as on the improvement of existing systems. Until that happens, maritime and aeronautical communications in the Arctic will continue to rely on radios and low-data-rate satellite services.

Yellowknife, Northwest Territories, Canada //
Photo by Arctic Council Secretariat / Jesper Stig Andersen

7. National priorities and infrastructure (2017)

The following submissions addressing the national priorities and infrastructure of each of the Arctic States have been provided by each Arctic State on its own behalf. These submissions are not jointly-written products of the TFTIA.

The TFTIA reviewed the national priorities and compiled a list of common themes. These common themes can be found in section 7i.

7a. Canada

Introduction

In Canada, investment in telecommunications networks is largely driven by the private sector. Facilities-based competition between telephone and cable providers has resulted in the deployment of faster speeds, and more advanced services, particularly in urban areas. Faster broadband speeds of 30 Mbps are available to 83% of Canadian households, while 75% have access to 100 Mbps or above. For mobile networks, LTE coverage reaches over 97% of the population, while HSPA+ is available to over 99% of the population. Government initiatives have focused on expanding service where there is a lack of business case for the private sector. The Canadian Arctic is particularly challenging. The three northern territories in Canada, combined, comprise 40% of Canada's landmass, but account for less than 0.5% of the total population.

Federal Initiatives

On December 15, 2016, the Minister of Innovation, Science and Economic Development launched the CAD 500 million Connect to Innovate (CTI) program. CTI is focused on expanding high-capacity backbone to underserved rural and remote communities and also connecting anchor institutions such as schools, medical facilities, and Indigenous government buildings. More broadly, access to community backbone will support fixed and mobile services to local homes and businesses. Limited backbone access is currently an important bottleneck for northern communities. CTI builds on the ongoing progress of the Connecting Canadians program launched in 2014. Connecting Canadians is augmenting shorter-term satellite capacity leases for satellite-dependent communities in each of the territories and in Northern Quebec. The projects in Nunavut and Northern Quebec are also supporting expansion of 4G wireless in each of those communities.

On December 21, 2016, Canada's telecommunications regulator, the Canadian Radio-television and Telecommunications Commission (CRTC), announced a new regulatory framework. Fixed and mobile broadband were defined as basic telecommunications services and targets were set to provide universal fixed access to 50 Mbps download/10 Mbps upload and mobile LTE service coverage for homes and businesses as well as along major roads. A new fund will provide up to CAD 750 million over its first five years from a levy on telecommunications revenues. It is intended to complement current and future funding from the private sector and levels of government. The existing fund for voice services will be transitioned to the new fund. Consultations will be launched in 2017 to determine implementation details.

The CRTC is also overseeing the implementation of a

network modernization plan for Northwestel, the incumbent telecommunications provider in the territories. Northwestel was required to develop this plan in response to concerns that it was not adequately investing in its network. The plan runs to 2017 and includes investments to expand 3G/4G wireless and broadband upgrades where economical in the Western Arctic. Separately, in October 2016, the CRTC ordered Northwestel to re-evaluate pricing of its wholesale data services. Northwestel is to file new wholesale tariffs in January 2017 for CRTC approval that are expected to decrease the rates for competitor access over Northwestel's terrestrial fibre and microwave backbone networks.

The Department of National Defence is leading the Enhanced Satellite Communication Project - Polar (ESCP-P) which aims to provide communications for tactical operations and highly-mobile platforms. The project is looking to augment communications capability in UHF, X, and K_a bands.

With details to be announced in the 2017 federal budget, the Investing in Canada plan proposes CAD 81 billion of investments in infrastructure over 11 years, starting in 2017–18. Recognizing the distinct needs of Canada's rural and northern regions, the plan includes CAD 2 billion of funding for these regions with broad eligibility criteria that respects wide-ranging nature of infrastructure needs, including the need to expand Internet connectivity.

Provincial/Territorial Government Initiatives

Territorial and provincial governments also have connectivity initiatives underway or at the planning stages. The Northwest Territories is building a 1,100 km fibre optic line from Fort Simpson in the southern Northwest Territories to Inuvik. This line is expected to subsequently be expanded to Tuktoyaktuk on the shores of the Arctic Ocean. Further detail on this project is provided later in this report in the section on public-private partnerships.

The priority actions of the Québec Government in the Plan Nord in 2015-2020 in the field of telecommunications are to complete a master plan for a fibre optic-based telecommunications network serving the whole of the area covered by the Plan Nord area (namely all of Québec located north of the 49th parallel and north of the St. Lawrence River and Gulf of St. Lawrence) through integrated planning for the following projects:

- Nunavik project (Inuit): complete a feasibility study and prepare technical specifications for the creation of a fibre optic and satellite network.
- Eeyou communications network project (Crees): add the communities of Eastmain, Waskaganish and possibly Whapmagoostui to the fibre optic network.
- Schefferville regional project (Naskapis): design, plan and implement a fibre optic project from Labrador City to Schefferville.

The Québec Government is also working to improve the high-speed Internet network on the Basse-Côte-Nord.

In Yukon where there is already considerable fibre presence, there is interest in building a redundant fibre optic ring, to create a fail-safe network. Yukon is planning to build close to 800 km of fibre between Dawson City (Yukon) and Inuvik (Northwest Territories). This would mitigate outages in the event of a cut on the existing fibre line connecting Yukon to British Columbia.

7b. Kingdom of Denmark

The Kingdom of Denmark is centrally located in the Arctic. The three parts of the Realm – Denmark, Greenland and the Faroe Islands – share a number of values and interests and all have a responsibility in and for the Arctic region.

With respect to the subject matter, telecommunication for civil use is a domestic matter of the governments of the self-governing countries of the Faroe Islands and Greenland, while Arctic telecommunication in general is a priority for the Kingdom of Denmark as a whole.

The Faroe Islands

Broadband based on ADSL2+ is available to 100% of the Faroese population (June 2016). The speed is up to 20 Mbps Download/2 Mbps Upload.

High Speed Broadband based on VDSL2 is implemented geographically in all parts of the islands. The speed is typically 40 or 50 Mbps Download and 4 or 5 Mbps Upload respectively. However, due to the distance constraint of 900 meters between DSLAM and house, only some 60% of the population have access to those speeds at present (June 2016). FTTH is delivered to businesses. Speed is typically 100+ Mbps.

There were 19,366 broadband subscriptions in the Faroe Islands at year end 2015. Of those, 11,795 subscriptions (i.e. 61%) were 10 Mbps or more (ITU indicator 21c 4213_G10).

At year end 2015 only 4.6% did have a speed of 30 Mbps up to but not including 50 Mbps, while 3.1% had a speed of 50 Mbps up to but not including 100 Mbps. The relatively few high-speed broadband subscriptions at year end 2015 probably reflect the fact that the VDSL2 technology was introduced to the market in October/November 2015. In addition, 98% of the population has access to LTE 4G which includes high speed Internet access, often above 30 Mbps.

Greenland

The Government of Greenland has adopted the strategy "Digitization as a driver for Growth"[16] which aims for ambitious goals on broadband speeds in all populated areas of Greenland by 2018. The strategy has five pillars: Modernization of Basic Data, Effective digital Government Administration, E-learning, E-health and Innovation. The pillars all stand on the foundation of the national telecom infrastructure.

The strategy on telecom infrastructure is technology neutral and sets targets for the availability of broadband services in all towns and settlements. By 2018 all populated areas should have access to 10 Mbps and 80% of the population shall have access to at least 30 Mbps by 2018.

Broadband services have a household penetration of 45% with the majority of the connections being provided between 2 and 10 Mbps. Demand has yet to develop in order to reach speeds above 10 Mbps.

TABLE 2. Fixed line Broadband in Greenland

	2015	Household penetration
Below 2 Mbps	1,112	5%
2 to 10 Mbps	8,728	39.5%
Above 10 Mbps	102	0.5%
Total	9,942	45%

Source: The Greenlandic Telecom Authority

The usage of 2G/3G/4G mobile services is high in Greenland with 1.05 active SIM cards per inhabitant. The focus has been on talk and text services with a rising demand for data.

TABLE 3. Mobile telephone use in Greenland

	2015	Line per inhabitants
Talk and data	56,135	1.01
Data only	2,535	0.05
Total	58,670	1.05

Source: The Greenlandic Telecom Authority

16 Digitalisering som drivkraft, National digitaliseringsstrategi 2014-2017

Current telecom infrastructure

Broadband is currently supplied in all towns and settlements through DSL and 3G/4G services. To meet the goals, the access infrastructure needs to be upgraded in most towns.

With the long distances between towns and settlements in Greenland the transportation network that carries traffic from the towns and settlements to the capital Nuuk, the main hub, is the main barrier for delivering high speed broadband in Greenland. The southwestern coast of Greenland is connected though a submarine cable to Iceland and Canada with connections further on to New York and Denmark. The towns from Nanortalik in the south to Uumannaaq in the north are connected to the submarine cable through a series of microwave links.

The eastern coast and north of Upernavik the connection is provided through GEO satellites.

Investments in telecom infrastructure

The Northwest project

During 2017 the government owned Tele Greenland will expand the capacity to all communities from Nuuk to the Upernavik district. The build which is dubbed the "Northwest project" will improve the communications to around 20,000 inhabitants and allow for speed and cost of service improvements for broadband Internet services.

The towns north of Nuuk, Maniitsoq, Sisimiut Aasiaat, Qassigianguit and Ilulissat will get bandwidth availability comparable to that of other towns connected to the international submarine cables.

The Upernavik district will experience the bandwidth and latency advantages of being served by terrestrial infrastructure instead of satellite.

The settlements in the area will experience improved quality of services as the current microwave system will remain in place with all its capacity available for them.

Future Satellite

Tele Greenland is currently evaluating the options for satellite capacity in the years to come. Current satellite contracts expire in 2019 and 2021.

More efficient satellites will replace the Intelsat 903 and 907 and disruptive satellite concepts will appear. These will be of benefit to the northern communities in Greenland.

Amongst the concepts that might prove their viability is low-Earth orbit constellations such as Iridium Next, OneWeb and LeoSat. Other emerging options are geostationary high throughput satellites including satellites with Arctic K_a band coverage. Some of these concepts are also likely to improve the communication options north of the reach of current GEO satellites and provide improved services for the maritime sector.

4G upgrade

As the current GSM/GPRS technology becomes outdated, Tele Greenland is likely to replace the current 2G base stations with 4G base stations, allowing for great improvements on mobile broadband services. The migration is likely to start within 2-3 years.

7c. Finland

In Finland, consumers and businesses are entitled to access to a reasonably priced and smoothly functioning telephone subscription and 2 Mbps broadband service in their permanent place of residence or business location. The right does not apply to summer houses. The subscriber connection under universal service obligations must allow the user to have access to emergency services, to make and receive national and international calls and to have access to other ordinary telephone services.

A broadband connection with a download speed of 2 Mbps has been defined as a universal service, and telecom operators designated as universal service providers must provide every permanent residence and business location with access to such a service with a reasonable price. The subscription may be implemented as a fixed or wireless connection. The 2 Mbps connection speed enables the use of basic online services, such as banking services and online newspaper and magazine browsing. In addition, the government has taken a goal to increase the minimum speed of broadband connection to 10 Mbps by year 2021 to every permanent residence and business location.

Broadband coverage and investments

Fast fixed broadband means a connection that enables data transfer rate of at least 100 Mbps and that has been delivered to the user's home or building over fixed ground or aerial cabling. A fast fixed broadband connection may be delivered over optical fibre, cable TV network or a short copper local loop. In the mobile network, a speed of 100 Mbps may be delivered using the LTE technology. Approximately 76% of Finns have access to a 100 Mbps mobile broadband connection at the end of 2015. The mobile broadband network is rapidly expanding and shortly it will cover more than 99% of population in the end of year 2017.

Finland has been implementing a state aid project since 2010 to improve the availability of ultra-fast broadband in rural areas. The aggregate state aid from the municipalities and the government is approximately 130 million euros. The targeted area covers the most sparsely populated areas of the country, which equals only 5% of the population, but over 75% of the geographical area. As of the end of 2015 high speed fiber broadband has been made available for over 70,000 inhabitants in these areas. The project is still ongoing, currently until the end of 2019.

In the beginning of June 2016 the Government issued a new plan called "Towards the Internet of Things: broadband implementation plan." [17] This plan entails several initiatives aiming at improving the availability and use of both fixed and wireless high speed broadband. The measures include:

1. The consumer demand for optical fibre will be promoted. Ways to digitalize public services will be prioritized and the delivery of digital media content via mobile Internet will be encouraged.
2. The private sector will proactively focus on constructing fixed lines. Promoting broadband access mainly relies on market-based solutions.
3. Permit structure and processes will be renewed and the processes will be digitalized.
4. The principle of shared construction will be implemented in order to reduce the building costs of infrastructure. A service point will be developed so that the information of all major infrastructure construction projects can be accessed by all constructors.
5. Conditions will be created for the introduction of 5G technology in the 2020s. Decisions on the spectrum to be allocated for 5G will be made in the World Radiocommunication Conference in 2019 (WRC-19).
6. Wireless broadband will be promoted by means of spectrum allocation. The aim is that also in the future as many frequencies as possible will be allocated to the wireless broadband.

17 http://www.lvm.fi/lvm-site62-mahti-portlet/download?did=206741

Finland has four commercial wireless broadband service providers. One of them offers only wireless broadband service without voice and messaging service. All four operators are expanding their network coverage and capacity. Most of countryside and sparsely populated areas are covered by wireless networks where LTE 800 frequency has a major role and in special cases LTE 450 network.

An important aspect of spectrum policy in Finland has been to allocate as many frequencies as possible for wireless broadband use. The 700 MHz frequencies are a good example of that since Finland is the first country in Europe to transfer the band from TV use to nationwide LTE use from 1.1.2017. The high penetration rate, high quality and inexpensive prices of mobile broadband are, to a large extent, a result of our successful national spectrum policy. In Finland, the 4G networks cover more than 97% of the population and, according to our telecommunications operators, in the next few years the coverage will even exceed the licence term requirement of 99%. In addition to the 700 MHz band, Finland promotes the flexible future use of the lower UHF TV-band (470-694 MHz) for mobile broadband and early introduction of 5G networks in new bands and also to the existing mobile broadband frequencies, especially in the 3400-3800 MHz band.

7d. Iceland

National priorities and infrastructure

In general Iceland has good mobile coverage and communication options on land and sea up to 50 nautical miles. Telecommunication infrastructure and services have been built up over the last decades both under government owned and funded initiatives as well as by private companies. Now the telecommunication services industry is comprised of a number of competing private companies that focus on providing telecommunications services to business, public sector and private customers. The legal framework for telecommunications is largely in line with the EU legal framework when it comes to among other things spectrum allocation and rules about state aid and competition guidelines in the telecommunication industry.

From Iceland´s perspective the challenge is to provide more robust communication infrastructure and connectivity to maritime areas within the Icelandic exclusive economic zone and beyond. Better connectivity at sea will increase maritime security and safety at sea as well as general well-being of the crews of the fleet.

The need for better communication infrastructure and connectivity at sea has increased with more demand for services to meet the needs of vessels at sea. There is a need to consider how increased cruise traffic also requires more connectivity and better connections for ocean going vessels. Furthermore, better telecommunications infrastructure is crucial for search and rescue operations in the maritime areas around Iceland and in the north eastern Atlantic.

The airspace is controlled by the air navigation services division of ISAVIA, the state-owned company that operates all airports and air navigation services in Iceland. The Icelandic Air Traffic Zone is among the largest in the world, approximately 5.4 km^2.

Iceland has already good broadband coverage, both on the fixed and mobile side. However, the sparsely populated areas do not have the same coverage of the higher speed broadband as in the more densely populated areas, especially with regards to fixed line broadband services. Mobile broadband coverage is approximately 99% (3G) and 98.3% (4G) of the population.

The Icelandic government has issued the following plan for broadband services:

Fixed line broadband services

The government has issued a five-year plan to ensure (near) 100% coverage of 100 Mbps fixed line broadband services by 2020.

The plan will be reached by state aid where the government, municipalities, infrastructure stakeholders and the end users will be involved in the co-financing.

Mobile broadband services

99.9% of homes and businesses to be ensured access to high speed mobile broadband services by 2022.

80% of the landmass (including glacial areas) and the ocean around Iceland to be ensured access to high speed mobile broadband services by 2018.

The coverage of the ocean is extremely important to Iceland due to the fishing industry and the security at sea. Large areas of the main fishing territories are already today covered by mobile broadband (3G/4G) on market prerequisites.

The Post- and Telecom Administration (PFS) held an auction in 2013 for the 800 MHz spectrum where one of the licenses requires a coverage of 99.5% for a network offering 30 Mbps by 2020. PFS has issued a plan to auction the 700 MHz frequency by the fourth quarter of 2016 to ensure further coverage plans and higher speeds of the mobile broadband services.

By these plans Iceland exceeds the goals set at the European level (30 Mbps and 50% of the households should have access to at least 100 Mbps by 2020).

7e. Norway

National priorities and infrastructure

Norwegian priorities concerning telecommunication/ broadband should be divided into three areas:

1. Mainland Norway, public goal of full coverage by commercial actors independent of latitude
2. Svalbard with very high bandwidth in Longyearbyen and Ny-Ålesund. Wireless 4G coverage near Longyearbyen
3. Maritime sector up to latitude N 74-75° with commercial actors, public study for possible PPP or other solutions further north.

The land-based users (private, public and business) in Norway and at Svalbard are well covered with access to broadband, and there are financial support schemes available in order to cover costs of "last mile" [18] infrastructure in rural areas. Such co-funding can be used to cover excessive costs of miscellaneous communications technologies like broadband via satellite or via microwave links to people living in the most rural areas.

Maritime users north of approx. N 72° suffer from lack of bandwidth and unstable communications at sea, even for voice based and narrow-band communications. Modern telemedicine (utilizing video and more advanced health monitoring systems) and crew welfare is generally difficult without access to more communications bandwidth. Increasing reporting of catch from fisheries for sustainable management require more capacity as well.

Licenses for oil and gas exploration in the Norwegian part of the Barents Sea is limited to approx. N 75°. Fiber based communications from mainland Norway may be an alternative for rigs in the production phase but the distances from shore are in excess of 200-300 km, and hence this is also a substantial cost issue.

For Arctic aeronautical users, both safety related communications like ATM [19] between the cockpit/airplane and ground infrastructure/systems as well as passenger related communications suffer with increasing latitude due to GEO satellite limitations and no availability of terrestrial infrastructure.

Norway is studying the need and possible solutions for satellite communications systems with capacity to serve maritime and aeronautical users with broadband should be established. Such systems should provide both commercial and governmental users with sufficient capacity and data volumes similar to GEO-based systems further south. Preferences include ability to roam between new systems and existing GEO systems in order to limit the number of communication systems onboard each vessel.

18 Last mile - The last mile is the common colloquialism referring to the telecommunications network chain that physically reaches the end-user's premises (currently <10 000 households have <4 Mbps broadband).

19 ATM - Air Traffic Management is an aviation term encompassing all systems that assist aircraft to depart from an airport, transit airspace, and land at a destination airport.

7f. The Russian Federation

The Strategy for development of the Arctic Zone of the Russian Federation (AZ RF) and provision of the national security for the period up to 2020 (2013), developed pursuant to the Fundamentals of the State Policy of the Russian Federation in the Arctic for the period till 2020 and Beyond (2008), formulates national interests, priorities and key objectives. The Action Plan on the implementation of the Strategy and the State program of social-economic development of the Arctic zone of the Russian Federation for the period up to 2020 direct efforts of the state bodies in line with the following prioritized directions of development of the Arctic zone: comprehensive social-economic development of the region, development of science and technology, establishment of modern information and telecommunication infrastructure, environmental security, international cooperation in the Arctic, military security, protection of the state border of the Russian Federation in the Arctic.

1. The priorities of the state policy of the Russian Federation in the field of telecommunications also relevant for the Arctic Zone of the Russian Federation are:

- Formation of modern information and telecommunications infrastructure, providing high quality services in the field of information technology;
- Ensuring access of citizens and organizations to services based on modern information technology, including conditions for growth up to 70% in 2018 of the share of people who use the mechanism for obtaining public and municipal services in electronic form;
- Development of technical and technological foundations of the information society;
- Creation of own ground and space infrastructure for transmission of all types of information;
- Development of regional informatisation;
- Ensuring the rights of citizens and organizations to access to the information.

Improvement of the quality, accessibility and expansion of services, including by increasing the level of communication in small and remote communities, including those located on the territory of the AZ RF, is one of the main tasks in the field of telecommunications. Formation of a highly developed information-telecommunication infrastructure in the AZ RF including in the area of the indigenous people of the North makes it possible for the population living there to find work, to get access to education and medical services, to establish social ties, to participate in cultural life of the country, to get access to public services provided in electronic form.

Among the goals – providing mobile radio telephone communication on the territory of small settlements, improving the quality and cover of space communications services.

The use of satellites in high elliptical orbits allows to expand the service areas, including areas with difficult terrain (mountains and forests), high-latitude areas and neighboring countries, as well as providing the possibility of new types of services, including provision of communication and broadcasting to all mobile transport facilities, the establishment of the communication system along the Northern sea route for ships, scientific expeditions, oil and gas companies. This would increase the coverage of the AZ RF by space communication services from the current 45% to 100%.

2. The following work is carried out according to established priorities.

The list of the universal services in the field of telecommunications is enlarged (Federal Law of 02.03.2014), in particular with the use of access points to the Internet; the threshold criteria for setting points of collective access to the Internet is lowered from 500 to 250 people. This will ensure that by 2020 access to the Internet to be provided for about 14 thousands settlements of the Russian Federation with a population above 5 million people, including those located on the territory of the AZ RF. In addition, in settlements with a population of 250-500 people access points to the Internet will be set allowing residents independently connect to the Internet at speeds of at least 10 Mbps using available and widely used devices.

By 2017 in the settlements with a population above 10,000 people 100% availability of mobile broadband Internet services should be installed.

Up to 2018 in 86 localities of the AZ RF it is planned to provide the beginning of provision of universal telecom services using the access points by means of 186 multiple access (CAS) to the Internet (without the use of user equipment) and 848 payphones.

Agreement between the Ministry of Telecom and Mass Communications of the Russian Federation and the Government of Chukotka Autonomous Okrug (District) of 12.18.2015 provides for the possibilities of increasing of telecommunications services capacity (spacecraft "Express-AM5» (140° E)) which allows to improve the quality and increase the speed of Internet access as well as of creating the backbone of underwater fiber-optic communication lines along the route Petropavlovsk-Kamchatsky-Anadary.

One of the objectives of the Ministry of Telecom and Mass Communications of the Russian Federation is by 2018 to ensure the availability of broadband Internet access services to 90% of the population.

In order to minimize the negative factors, significantly slowing down the development of modern communication services and the creation of environment for efficient development of their accessibility efforts are being made to improve the legal and regulatory mechanisms, to reduce the administrative barriers and to create favorable conditions for the effective development of the telecom operators in the small and remote areas.

The principles of technological neutrality apply for using the radio spectrum for radio frequency bands in the ranges of 450/900/1800 MHz, as well as for the networks of mobile radio telephone communication and the sharing of communications infrastructure.

Changes in the calculation method for the use of radio spectrum in the Russian Federation allow further reduce the size of transaction costs and, as a consequence, to expand the coverage area of mobile radio communication services.

The Ministry of Transport is working on creation of the secure information system of the transport complex of the AZ RF on the basis of the satellite, cable and tropospheric systems.

In order to ensure 100% coverage of the AZ RF with space communications services the project "Express-RV" is designed. It involves the creation by 2025 of the orbital satellites constellation of communication and broadcasting on high elliptical orbits.

Work on the further development of a multifunctional personal satellite communication system and data transmission (MPSCS) "Messenger-D1M" (Gonets-D1m) including by placing the dual-band.

7g. Sweden

Objectives and priorities

A new broadband strategy for Sweden was presented by the Government in December 2016 with the vision that Sweden is completely connected in 2025. To implement the vision a number of targets are set, aiming at both fixed and mobile connectivity.

By 2020, 95% of all households and businesses should have access to broadband at a minimum speed of 100 Mbps and by 2025 the entire Sweden should have access to high speed broadband. The target is set for households and businesses and by 2025, 98% should have access to 1 Gbps, 1.9% should have access to 100 Mbps and 0.1% should have access to 30 Mbps.

The broadband strategy also sets a target for mobile broadband coverage outside of homes and places of business. *By 2023 the entire Sweden should have access to stable mobile services of good quality.* This means that in areas where people normally find themselves they should be able to use the mobile applications and services they require. This applies correspondingly to connected things. The connection should be stable and of such quality that the user does not experience limitations.

To focus on the specific needs and challenges of different regions and municipalities, broadband strategies are also to a large extent adopted at regional and local levels.

The Swedish priorities for the Arctic are presented in Sweden's strategy for the Arctic region and focus on three areas: Climate and the environment, Economic development, and The human dimension. In relation to telecom, the strategic objective is to give the population and commercial actors in the Arctic access to cost-effective and leading IT and telecom technology. Infrastructure that supports telecom solutions in the fields of, for example, eHealth, eEducation, eGovernment, etc. are important for the population and businesses in Sweden as a whole, as well as in sparsely populated areas including the Arctic.

Other focus areas in the strategy for the Arctic region related to telecom are improved infrastructure for sea and air rescue, development of technology and communications that facilitate ice-breaking operations, and climate and environmental research. The government is committed to socially and culturally sustainable development for Arctic indigenous peoples, including through technological development.

Broadband coverage and investments

Overall, Sweden has good broadband coverage. In October 2015, less than 130 households and workplaces lacked access to any kind of broadband. The coverage of mobile broadband has expanded rapidly and the coverage of LTE (4G) has increased from 0% in 2010 to cover 99.95% of all households in 2015. The LTE coverage for households in the Swedish Arctic is currently 99.98%.

There is however a difference in coverage between more densely populated areas such as cities and small towns and more rural and sparsely populated areas when it comes to broadband of higher speeds. The difference in coverage is however not greater in the Swedish Arctic than in other parts of the country. About 67% of the households in total have access to broadband of at least 100 Mbps, while the coverage in rural and more sparsely populated areas is 21%. The corresponding numbers for the Swedish Arctic are 65% and 18% respectively.

There is a demand for broadband coverage also when you move outside your place of work or residence. Surface coverage in parts of northern Sweden, including the Swedish Arctic, is lower than in the rest of the country. The coverage of mobile broadband of up to 10 Mbps has however increased significantly over the last year and 77% of the Swedish surface in total is now covered. Surface coverage of 10 Mbps in the Swedish Arctic is 56%.

The main role of the government is to strive for well-functioning markets and to remove obstacles for development. The market is doing the absolute majority of the investments in broadband infrastructure, but high deployment costs and lower population density often lead to a lack of commercial investments of especially high-speed networks in more remote areas.

There is an ongoing expansion of both fixed and mobile networks in Sweden, primarily by commercial actors but also by projects receiving state aid for deployment of infrastructure in areas where there is a lack of commercial investments. The selected projects are not allowed to crowd out commercial investments and have to be carried out in accordance with the regulatory framework for state aid to broadband deployment.

The state aid is currently channeled through the European Agricultural Fund for Regional Development (EAFRD) and the European Regional Development Fund (ERDF). The programs are open to applicants from for example regions, municipalities, companies or small local village-projects and to apply for aid, the applicants need to co-finance approx. half the cost of the project.

In order to further facilitate deployment of broadband infrastructure the Government has set up a Broadband Forum to help identify and solve issues that can hamper broadband deployment. The forum is headed by the Minister of Digitalisation. At the regional level, the Government has appointed regional broadband coordinators throughout Sweden to act as the link between the regional and municipal level and the market actors deploying broadband-infrastructure.

Spectrum policy is also an important tool in creating greater broadband coverage – especially in remote areas where fixed solutions are difficult to provide. When the Post and Telecom Agency held an auction of the 800-MHz band in Sweden in 2011, one of the licenses had a coverage requirement attached to it that entails that the Post- and Telecom Agency points out unique households that lack any kind of broadband and the license holder have to provide broadband coverage in that specific location. Currently around 130 households and work places are on that list as lacking any kind of broadband.

7h. United States

Arctic Priorities

A priority of the United States is to align and focus federal efforts in the Arctic region. In May 2013, the "National Strategy for the Arctic Region" [20] was issued which builds upon existing initiatives by federal, state, local, and tribal authorities, the private sector, and international partners. Among other things, the strategy seeks responsible Arctic Region stewardship as well as stronger international cooperation to promote shared interests in the Arctic. To achieve these goals, the strategy is driven by the following principles: a) safeguard peace and stability; b) make decisions using the best available information; c) pursue innovative arrangements including public-private partnerships; and d) consult and coordinate with Alaska Natives.

In January 2014, the "Implementation Plan for the National Strategy for the Arctic Region" [21] was issued, and it designated the methodology, process, and approach to execute the strategy. Under the plan, federal agencies must "assess the telecommunication infrastructure in the Arctic and use new technology to support improved communications in the region, including in areas of sparse population to facilitate emergency response." The plan directs multiple federal agencies to collaboratively assess current technologies in the Arctic, develop a framework listing and prioritizing opportunities for investments and public-private partnerships in Arctic Alaska, and, in collaboration with the Arctic Council, evaluate the feasibility of an Arctic-wide telecommunications network.

In January 2015, an Executive Order [22] was issued to enhance coordinated federal efforts in the Arctic. The U.S. also established three complementary overarching priorities for its two-year Arctic Council Chairmanship [23] (2015-2017): a) improving economic and living conditions in Arctic communities; b) ensuring Arctic Ocean safety, security, and stewardship; and c) addressing the impacts of climate change.

National Telecommunications Policies

Since 2009, the United States Government has been delivering on a comprehensive plan to provide high-speed Internet access across America – including in Arctic Alaska. Specific program priorities under the "Connecting America" [24] umbrella include the following initiatives:

A. In January 2011, the "Wireless Innovation and Infrastructure Initiative" [25] was issued to encourage public and private sectors to work together to provide high-speed wireless services to at least 98% of Americans within five years – in March 2015, the Administration announced [26] that the U.S. had reached that goal;
B. In June 2013, "ConnectED" [27] was introduced which aims to connect 99% of America's students to next-generation broadband and high-speed wireless in their schools and libraries by 2018;
C. In July 2015, "ConnectHome" [28] was introduced to build on the ConnectED initiative to ensure that students also have access to high-speed Internet in the home;
D. In his State of the Union Address in January 2015, President Obama announced his plan, *"to protect a free and open Internet, extend its reach to every classroom, and every community, and help folks build the fastest networks… to keep reshaping our*

20 https://obamawhitehouse.archives.gov/sites/default/files/docs/nat_arctic_strategy.pdf

21 https://obamawhitehouse.archives.gov/sites/default/files/docs/implementation_plan_for_the_national_strategy_for_the_arctic_region_-_fi....pdf

22 https://obamawhitehouse.archives.gov/the-press-office/2015/01/21/executive-order-enhancing-coordination-national-efforts-arctic

23 https://www.state.gov/e/oes/ocns/opa/arc/uschair/index.htm

24 https://obamawhitehouse.archives.gov/blog/2010/03/16/connecting-america

25 https://obamawhitehouse.archives.gov/the-press-office/2011/02/10/president-obama-details-plan-win-future-through-expanded-wireless-access

26 https://obamawhitehouse.archives.gov/the-press-office/2015/03/23/fact-sheet-next-steps-delivering-fast-affordable-broadband

27 https://obamawhitehouse.archives.gov/the-press-office/2015/06/25/fact-sheet-connected-two-years-delivering-opportunity-k-12-schools

28 https://obamawhitehouse.archives.gov/the-press-office/2015/07/15/fact-sheet-connecthome-coming-together-ensure-digital-opportunity-all

world." To achieve these goals, the Administration has promoted "Broadband That Works," [29] a public-private effort to help more Americans get access to fast and affordable broadband. This effort includes:

- Ending laws that harm broadband service competition;
- Expanding the national movement of local leaders for better broadband;
- Introducing the "BroadbandUSA" [30] program to support community broadband projects;
- Unveiling new grant and loan opportunities for rural providers; and
- Removing regulatory barriers and improving investment incentives.

In March 2016, the United States unveiled "ConnectALL", an initiative helping Americans from across the country, at every income level, get online and have the tools to take full advantage of the Internet. ConnectALL aims to connect 20 million more Americans to broadband by 2020.

Ongoing efforts of the Federal Communications Commission (FCC) complement these national priorities. In 2010, the FCC released "Connecting America: The National Broadband Plan" [31], which fulfills a congressional mandate to develop a plan ensuring every American has "access to broadband capability." The plan recommends: a) ensuring robust competition; b) ensuring efficient allocation and management of spectrum, poles, rights of way, etc. to expedite service deployment; c) supporting broadband deployment through universal service reform; and d) maximizing benefits of broadband in public education, health care, government operations, and other areas in which federal agencies have significant influence. Benchmark metrics were set to achieve these goals by 2020.

The FCC's work is also guided by the goals set out in its Strategic Plan 2015-2018 [32]:

A. Promote economic growth and national leadership through the expansion of competitive telecommunications networks;
B. Protect public interest goals by promoting the Network Compact, the interrelationship between the rights of network users and the responsibilities of network providers that includes consumer protection, competition, universal service, public safety and national security; and
C. Make networks work for everyone by ensuring that all Americans can take advantage of the services they provide without artificial impediments.

29 https://obamawhitehouse.archives.gov/the-press-office/2015/01/13/fact-sheet-broadband-works-promoting-competition-local-choice-next-gener

30 http://www2.ntia.doc.gov/new_BroadbandUSA

31 https://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf

32 https://apps.fcc.gov/edocs_public/attachmatch/DOC-331866A1.pdf

7i. Common themes

This report includes information on the state of telecommunications infrastructure on land, at sea, and in the air in the Arctic region. It addresses both densely populated and sparsely populated areas of the Arctic. And, in this chapter, it contains national contributions from each of the eight Arctic States, summarizing their individual national priorities and infrastructure – both today and tomorrow. What common themes can be drawn out of this "raw material"?

Perhaps the single most important theme is the value of collaboration and information-sharing between the Arctic States, and between the private sector and the public sector, in the development of telecommunications infrastructure in the Arctic. This can entail cooperation among national and subnational levels of governments, the private sector, non-profit organizations, and between Arctic States. It is visible, for example, in:

- the ways in which States can learn from one another's successful local, regional, and/or national initiatives;
- the similarity between the types of service providers and technologies used in different regions of the Arctic;
- the prevalence of cross-sectoral collaboration on projects for local/regional infrastructure,
- the potential for individual Arctic States (or groups of States) to develop interoperable basic infrastructure;
- the potential for collaborative projects crossing borders; and
- the potential for development of integrated projects covering the full Arctic.

In their national strategies, no Arctic State addresses development of telecommunications infrastructure as a goal in and of itself. Instead, in each of the Arctic States, national plans for the development of telecommunications infrastructure are focused on the benefits that such development will provide to their citizens. In all cases, goals, milestones, directives, and plans for development are placed in the context of the needs of individuals for (as examples) education, employment, interpersonal connection, access to services, and – often – interaction with governments. In addition, the plans and priorities of many Arctic States explicitly address improvement of telecommunications services both on land and at sea.

In general, the Arctic States have an overarching vision or goal for the bandwidth connectivity available to their citizens. In many cases, this reflects a view that citizens require a certain degree of "connectedness" with their fellow citizens and with the world at large. The specific bandwidth goals set by each State vary, and in some cases there are differences between the established goals for users in larger vs. smaller communities, or for users in the Arctic region specifically vs. those elsewhere. But, putting these differences aside, all States have established goals and milestones for the development of connectivity for their citizens. This represents a common understanding that connectivity is an important component of their citizens' lives, and that it will become more so in the future.

Beyond the simple establishment of goals, many Arctic States have established plans (or portions of larger plans) addressing connectivity in their Arctic regions specifically. Although this is not true for every State, it demonstrates that, in many cases, the Arctic region is – in part or in whole – understood to warrant special attention on the part of governments and businesses. In some cases, while the Arctic is not specifically targeted, national plans address rural users as a specific user group; this approach would naturally address the needs of many users in the Arctic as well, particularly those in sparsely populated areas. Connected to this is the need identified by many States for state support (in one way or another) for infrastructure development in sparsely populated areas. Private-sector entities are identified explicitly by many States as the necessary "hands" that will undertake the work of developing telecommunications infrastructure in the Arctic. But no State appears to base its policies on an assumption that private-sector actors will be willing and able to make substantial improvements in Arctic telecommunications infrastructure without support from, and partnership with, governmental entities.

The support that the governments of the Arctic States see as necessary for development of telecommunications infrastructure in the Arctic may ultimately take many forms. These might include public-private partnerships with commercial entities, models of co-financing, or agreements for long-term contracts with governmental entities.

Several of the Arctic States identify a need to improve or alter regulations, policies, and permitting processes that affect the development of telecommunications infrastructure.

Barrow, Alaska //
Photo by Arctic Council Secretariat / Kseniia Iartceva

8. Implementation options

The options for investment in telecommunications infrastructure in the Arctic vary between the Arctic States, as well as within them. Generally speaking, however, the options can be categorized in three ways:

- Funding by private industry
- Funding by government(s)
- A combination of government and industry funding, often labeled public-private partnerships, or PPPs

The global trend is that civilian telecommunication infrastructure is increasingly financed through commercial competition. However, this approach relies on a customer base that is sufficient to justify the investment (i.e., recover costs and make a profit). In sparsely populated areas of the Arctic, however, achieving the necessary return on investment strictly from the local user communities is difficult at best.

Historically in the Arctic, investments in telecommunications infrastructure have been made with government funding. This generally applies to military or government communications infrastructure (including for the purpose of scientific research) and to some specific civilian users that require service in areas where no commercial interests exist. In sparsely populated areas of the Arctic, government funding may continue to be a necessity for any initiative to expand telecommunications infrastructure.

Private initiatives can be another source of expanded Arctic telecommunications infrastructure. For example, the construction of new undersea cables to connect Europe to Asia via the Arctic (as a shorter route between these continents) will provide an opportunity for Arctic communities to connect to those cables. Additionally, new satellite networks with polar orbits will be able to offer connectivity throughout the Arctic. Even though these constellations build their business cases on projections of revenue from users outside the Arctic, the polar orbits may provide additional income from Arctic users, and thus become an opportunity to expand connectivity in the Arctic.

Public-private partnerships

Public-private partnerships (PPP) are being implemented in many different ways in many of the Arctic States. Reasons for using PPPs to develop telecommunications infrastructure in the Arctic are many, but among the most important of those reasons are the following:

- The private-sector expectation - that revenue cover the investment while also returning a profit - will not be achieved, thus government funding will be required for the initial investments.
- The responsible government agency does not have the required capital for investment, so a private entity makes the investment based on a long-term agreement with the government for a return on that investment.

In the telecommunication sector, it is most often the first of these scenarios that drives PPPs, and that will probably be the model that supports any large scale ground- or space-based telecommunications infrastructure investments that are specifically developed to satisfy users' needs in Arctic. The public support can come as grants, long-term low-interest loans, or direct investment support.

In some cases, it is also possible for government entities or very large private-sector clients to act as "anchor tenants" or "anchor customers" for new telecommunications infrastructure, and thus incentivize the expansion of existing systems or the build-out of new ones. For example, a large new installation by an energy company, or a major new scientific research station, may reach an agreement with a telecommunications company for the installation of new telecommunications infrastructure to satisfy the needs of that facility. The installation of this new infrastructure will likely bring additional opportunities for the telecommunications company to build or expand the infrastructure to serve other connectivity needs in nearby areas. While these nearby communities may not have the economic means to fully fund communications infrastructure themselves, an anchor tenant may provide the impetus necessary to connect these communities.

The direct implementations of PPPs will vary with each project, and will have to relate to the policies and laws of the individual country.

Public-private partnerships: case studies

GCI's TERRA network

In 2010, an affiliate of General Communication, Inc. ("GCI") was awarded a USD 44.2 million loan and a USD 44.0 million grant as part of the Broadband Initiatives Program ("BIP")[33] to construct GCI's TERRA network ("Terrestrial for Every Rural Region in Alaska"). GCI's own investment in the TERRA network stands at ~USD 178 million. TERRA utilizes a combination of fiber-optic cables and mountaintop microwave repeaters to bring high-capacity, low-latency broadband services to southwestern Alaska. The initial phase connected nearly 10,000 users to terrestrial broadband for the first time. To date, the TERRA network has provided terrestrial broadband connectivity to more than 43,000 residents whose only prior option to access the Internet was via satellite.

The U.S. Department of Agriculture's Rural Utilities Service, or "RUS", structured BIP in accordance with several important principles that promoted the efficient use of scarce public resources. The public-private partnerships created under the program were awarded in an open and transparent process with particular eligibility criteria to ensure participation by experienced participants willing to share in the risk of the project. In addition, BIP rules sought to ensure that the public funding did not interfere with basic market forces, inhibit private investment, duplicate existing government-supported projects, or risk scarce societal resources on projects that would ultimately prove financially or technically unsustainable.

The U. S. government has also fostered other public-private partnerships that indirectly support the deployment of telecommunications infrastructure and help provide the business case for "middle-mile" networks like TERRA. As of this writing, school districts and rural health care providers are the primary anchor tenants for broadband services in the U.S. Arctic. Both of these types of clients receive support from the Federal Communication Commission's Universal Service Fund. Like the BIP program, the FCC's support programs are structured to ensure the benefits of competition notwithstanding federal support.

33 The U.S. Congress created BIP as an economic stimulus in response to the financial collapse of 2007-2008, with a goal of supporting deployment of infrastructure that would provide long-term economic benefits. The State of Alaska also provided a USD 6 million grant in support of expanding the TERRA network beyond the initial phase.

The Mackenzie Valley Fibre Link (MVFL) Project

The Mackenzie Valley Fibre Link (MVFL) is a project of the Government of the Northwest Territories (GNWT), Canada, to provide state-of-the-art fiber-optic telecommunications for communities in the Mackenzie Valley and Beaufort Delta regions. The MVFL project involves the installation of 1,154km (717 miles) of high-speed fiber-optic telecommunications cable from McGill Lake in the South to Inuvik in the North.

When completed, the telecommunication system will facilitate improved delivery of health, education, and social services to remote communities in the Northwest Territories. Seven communities will be served directly by the MVFL project, with possible future access to an additional five communities in the region using microwave systems to connect with the MVFL system.

Additionally, the MVFL project will support the further expansion of the Inuvik Satellite Station Facility (ISSF) by its international partners, positioning the facility as one of the leading sites for tracking and receiving real-time data from polar-orbiting satellites used for science, mapping, weather surveillance, and other purposes.

After installation is complete, Northern Lights General Partnership, a consortium comprised of Ledcor Developments Ltd., Ledcor Technical Services, and Northwestel Inc., will maintain and operate the system for 20 years.

The project is scheduled to be completed by June 2017. To date, the project has employed about 160 NWT residents, involved sixty local businesses and organizations across the territory, and contributed CAD 32 million to the local and NWT economy.

Extending the Mackenzie Valley Fibre Link

An extension of the MVFL to Tuktoyaktuk is planned following the completion of the all-weather highway extension from Inuvik. This is just one example of how the build-out of telecommunications infrastructure can be accomplished alongside the construction of other unrelated infrastructure projects.

Baltic Sea cable

The Baltic Sea cable that connects Finland with central Europe is an example of successful PPP funding. The project was originally initiated by the government and funded by Governia, a 100% state-owned company. The name of the company was changed to Cinia after the Finnish private insurance and pension companies OP and Ilmarinen became shareholders. The cable was built by Cinia, which currently sells the fiber and its capacity. Cinia chose Alcatel-Lucent to lay down and operate the cable. In December 2016, a private company (C-Fiber Hanko) signed a contract with Cinia to build a connection from the submarine cable to the town Hanko on-shore. C-Fiber Hanko is a joint company owned by local cities and businesses. The aim of the investment is to establish a world class ICT-hub in the region, attract data centers, create jobs, and stimulate new business in the region.

The Baltic Sea cable offers a good example of how a public project can be widened to attract investments from different private-sector actors according to their needs. The Finnish government has also initiated a similar project stretching from Finland to Asia along the Northern Sea Route for which PPP funding and a PPP business model are sought.

Barrow, Alaska //
Photo by Arctic Council Secretariat / Kseniia Iartceva

9. Findings and recommendations

Findings

Capabilities

No single technology alone will meet all telecommunications needs in the Arctic, and the best technology (or combination of technologies) for any specific case depends on geography, users' needs, and many other factors. In addition, openness to new technologies is important to successful development of telecommunications infrastructure in the Arctic. Independent of bandwidth or technology, dependence upon a single system or provider creates vulnerability for users.

Presently, communication over the northernmost parts of the Arctic is possible, but only with select communications systems with limited bandwidth capabilities. These typically include VHF/HF radio communications and Iridium satellite voice and data services.

There are serious limitations to the connectivity provided by geostationary satellites in the northernmost parts of the Arctic. Nevertheless, the future for satellite-based connectivity in the Arctic looks potentially positive, as there are several companies seeking to deploy new constellations, including constellations of satellites that will provide expanded or nearly-complete coverage in the Arctic. If these developments materialize, they will benefit many users (including maritime and aeronautical ones) throughout the Arctic who will continue to rely solely on satellites to meet their connectivity needs.

Deploying one type of telecommunications technology does not preclude subsequent deployment of additional or alternative technologies as circumstances and technologies change. Therefore, basic telecommunications infrastructure can be deployed to serve Arctic users without in any way hindering future investment in network area coverage and service expansion.

Some of the telecommunications capacity in the Arctic may be delivered by systems that generate their revenue primarily in more southerly latitudes. For example, existing and future fiber-optic cables in the Arctic present opportunities to create connections (both fixed and mobile) that will serve communities and businesses near to the cable route.

More and less densely populated areas

There are enormous variations in the population densities and associated telecommunications infrastructure and services present across the Arctic. Within the Arctic States, the Faroe Islands, Finland, Iceland, Norway, northwestern Russia, and Sweden are more densely-populated, and often have broader availability of telecommunications infrastructure and services. On the other hand, the vast expanses of the Canadian, Greenlandic, Russian, and U.S. Arctic have extremely low population densities often with lesser availability of telecommunications infrastructure and services. This is not an analytically perfect division, but it can help to draw useful conclusions related to current and future telecommunications expansion.

Reliability, accessibility, and affordability

In some parts of the Arctic with low population densities, communities lack reliable, accessible and affordable broadband. The main reasons for this include vast geographical distances between communities, a lack of infrastructure, and few service providers. This lack of connectivity impacts the sustainable development of these Arctic communities.

Needs of indigenous peoples and local communities

Improvement in telecommunications infrastructure in the Arctic supports resilience and sustainable development. Improved connectivity in the Arctic supports better access to education, healthcare, and commerce, as well as enhancing citizens' participation in civic life and improving delivery of services.

Access to telecommunications is important to indigenous peoples in maintaining and preserving their cultures and livelihoods.

Science

Improved connectivity in the Arctic creates better conditions for data collection, data preservation, and data transfer within, and to and from, the Arctic. These improvements may encourage an increase in research activity.

Maritime users

Maritime transportation in the Arctic and associated demand on telecommunications services has increased in recent years and this trend is expected to continue with the extension of the shipping season as a result of ice receding. With the technologies that exist today, expansion of satellite coverage may benefit both local and international maritime users, as well as land populations near to shore. Near-coastal services will benefit from land-based communications technology as well. The overall safety of operations will increase for all vessels and will allow the most modern fleets requiring continuous data links to operate safely at the highest latitudes.

Air traffic

The CPWG estimates the annual future growth of Arctic overflights to be approximately 3.5% (400-500 additional flights per year). Improved connectivity in the Arctic will allow the airspace to accommodate increased traffic, enhance safety, and permit the introduction of new and more efficient routings.

Search and rescue

Telecommunications capacity is essential to the conduct of search and rescue operations in the Arctic.

Increasing human activity in the Arctic, including maritime and aeronautical activity, will place additional demands on search and rescue capabilities, and subsequently require additional telecommunications capacity.

Improved connectivity in the Arctic will support collection and distribution of meteorological and oceanographic information and services, as well as better information on sea ice and icebergs, which will help inform the search and rescue response.

Inmarsat has minimal coverage to provide access to the Global Maritime Distress and Safety System (GMDSS) in much of the Arctic. However, work is ongoing in order to gain recognition by the IMO for an expansion of the GMDSS which may benefit the Arctic.

Government regulation

Streamlining regulatory processes and procedures could enhance investment in, and accelerate deployment of, telecommunications infrastructure and services in the Arctic.

Financing

An increasing fraction of civilian telecommunications infrastructure in the Arctic is financed in a competitive, commercial environment. Grants, low-cost long-term loans to private-sector entities, and/or long-term anchor clients often drive PPPs. The PPP may be a model that supports telecommunications infrastructure investments that satisfy the needs of users in the Arctic.

Economic development

Improved connectivity in the Arctic supports local economic development by allowing businesses in remote areas to compete with counterparts in better-served, more developed areas. A vibrant local economy helps to make it more feasible and appealing for individuals to live and work in remote communities. Moreover, economic development will, in turn, provide opportunities to further develop the telecommunications infrastructure and services in these communities.

Improved connectivity in the Arctic will support the growing tourism industry in the Arctic.

International cooperation

The development of telecommunications infrastructure and services in the Arctic can benefit from strong international – and in particular, cross-border – cooperation. The development of any pan-Arctic system would benefit from international collaboration.

Global benefit

Infrastructure that supports connectivity in the Arctic provides global benefits through better connectivity between the Arctic and the rest of the world, and within the Arctic itself.

Recommendations

The Task Force makes the following recommendations to the Arctic Council:

- The Arctic Council should continue a strong and enduring focus on telecommunications infrastructure and services.
- Future research on, or development of, telecommunications infrastructure and services in the Arctic should continue to take into account the needs of indigenous peoples and local communities, and those operating in the Arctic, such as businesses, tourism, and researchers. Emphasis should also be given to developing connectivity that supports maritime and aeronautical users and, in particular, search and rescue efforts.
- Efforts to further develop telecommunications infrastructure and services in the Arctic should continue to include research institutions and private industry (including the Arctic Economic Council). This engagement could, inter alia, further explore the possibility of public-private partnerships (PPPs) as tools for the development of telecommunications infrastructure in the Arctic. Where possible, the Arctic Council should encourage public and private infrastructure development projects to consider the related build-out of telecommunications infrastructure.

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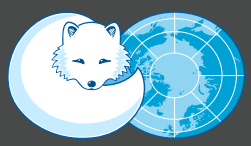

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