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# GEOGRAPHY OF THE GLOBAL SUBMARINE FIBER-OPTIC CABLE NETWORK: THE CASE FOR ARCTIC OCEAN SOLUTIONS

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# GEOGRAPHY OF THE GLOBAL SUBMARINE FIBER-OPTIC CABLE NETWORK: THE CASE FOR ARCTIC OCEAN SOLUTIONS

**JUHA SAUNAVAARA and MIRVA SALMINEN**

ABSTRACT. The world is becoming ever more digitally connected. The submarine fiber-optic cable network is crucial for maintaining and developing this connectivity. This article first introduces the key characteristics of and required changes in the network. It then clarifies the network's importance in generating and relaying meanings and practices that sustain contemporary, networked societies globally. Next, it focuses on the challenges of slowness or lack of faster connections and of concentration in critical communications infrastructure. By analyzing the reasons restraining long-awaited changes to the network, the article concludes that neither technological development nor laying of new submarine cables along existing cable routes resolves these challenges. However, recent submarine communications cable projects planning to utilize the seabed of the Arctic Ocean offer potential solutions by suggesting new routes and landings and shortening the cables that carry digital communications between Europe, North America, and East Asia. *Keywords: Arctic, communications infrastructure, development, network, submarine fiber-optic cables.*

The world is not wireless. The internet is not located in "clouds," nor does it rely on the increasing number of satellites placed into orbit. On the contrary, the functioning of internet and all transoceanic digital communications is based on fiber-optic cables—20 to 50 millimeters in diameter (Figure 1) —lying at the bottom of the oceans and seas. The global cable network consists of approximately of 450 submarine cable systems and 1.2 million kilometers of submarine cable (Nagpal 2019) and handles 99 percent of international data traffic (including international internet). Yet this critically important infrastructure escapes our eyes and minds and remains almost invisible. Meanwhile, Artificial Intelligence (AI), Internet of Things (IoT), 5G, and Software as a Service (SaaS)—to name only a few examples—are omnipresent buzzwords used to describe how lives will change globally. Should future scenarios referring to the tremendous increase in daily data generation per capita be realized (Huawei estimation quoted by the Nordic Council of Ministers report refers to an increase from approximately 4 GB in 2008 to 72 GB in 2025 (Nordic Council of Ministers 2018)) even partially, a demand for new cable capacity is evident as the current communications infrastructure cannot satisfy the needs and demands of advancing digitalization.

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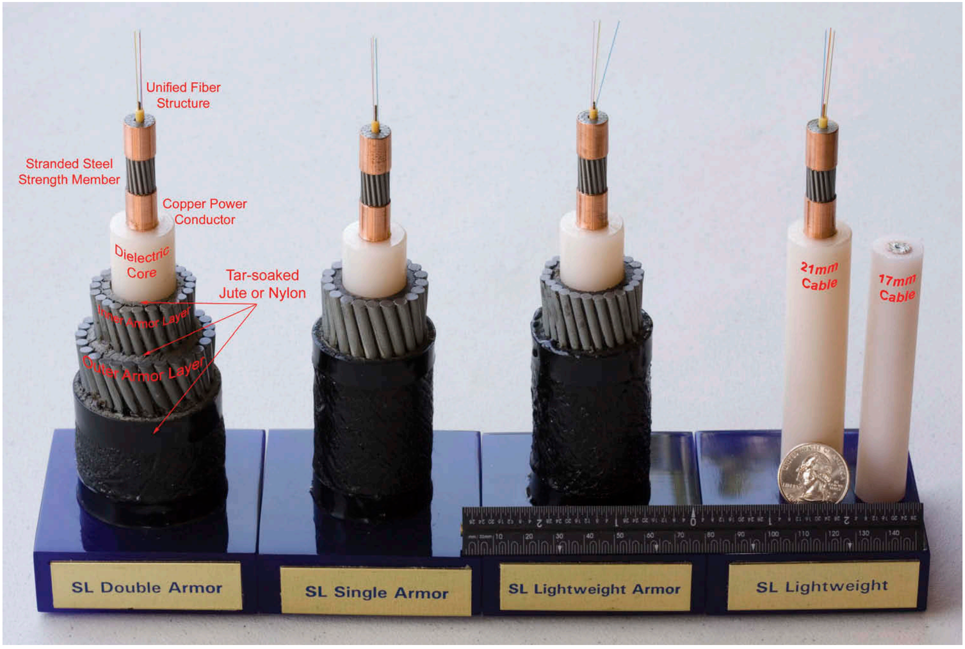


FIG. 1—Samples of submarine telecommunication cables. (Wikimedia Commons, File: Submarine Optical Cables.jpg. This file is licensed under the Creative Commons Attribution-Share Alike 4.0 International license.)

In the article, the network is understood in a two-fold manner. First, it refers to the very physical, technical infrastructure consisting of the landing stations as well as the fiber-optic cables, repeaters, equalizer units, and branching units that lie on the seabed and transmit packets of digital communication. This structure develops when communication needs increase, political and geographical circumstances allow, and strong enough economic and business incentives exist for its supplementation. Second, it refers to network as a metaphor to explain societal evolution: reason political, economic, religious, judicial, and cultural decision making, and describe events taking place around the world. The network metaphor can be used to describe a long historical process defined by the increasing interaction and thickening links between people locally, regionally, and then globally (e.g. McNeill and McNeill 2003). In addition, it may refer to an organizing, including self-organization, principle that currently seems globally dominant. The evolvement of this open, agile, and to an extent borderless network that generates new links and cuts out old ones when useful is much faster and less predictable than evolvement of the physical infrastructure—or the historical process (Eriksson 2009).

According to John R. McNeill and William H. McNeill (2003, 269), the physical construction of a global communications network enabled the connection of areal political, economic, religious, judicial, and cultural webs into a global network—alongside the development of railroads, shipping routes, and navigation enabled by technical innovations. Simultaneously, the network construction formed a conceptual model for understanding societal events (Eriksson 2009, 7). Towards the end of the twentieth century, this network extended and its tightening accelerated, which was largely facilitated by innovations in information and communications technologies (ICTs). The global intertwinement of (national) economies and the emergence of novel social spaces enabled by (close to) global connectivity of individuals and groupings, is transforming societies significantly (see e.g. Castells 2010). Digitalization of societal practices and structures, again, is requesting further innovations in ICTs, increased communication transmission capacity, conversion of a number of different technological fields, and learning processes to sustain these societal practices and structures (Castells 2010, 51–53; 54–61).

The fiber-optic submarine cable network is thus not only a neutral, technical construction that operates as a connector of flows through links and nodes. Instead, it generates interactions and transmits ideas and practices that shape societies around the world. Links, nodes, and choke points of the network gain their meaning as parts of the entity and its operations, which also politicizes them. Locations (and businesses and communities) gain identity through their position and function as part of the network rather than because of their local importance (Eriksson 2009, 8). For example, the location of a landing station entails the promises of economic development and intensified information exchange for the local community. However, where the submarine communications cable lands is not decided on the basis of local needs, but cost- and time-efficiency calculations for and structural setting of the entire cable network. At the same time, landing stations raise environmental concerns and experiences of loss or rejection in the communities that interpret their situation as outsiders or excluded from the network.

Besides explaining what the submarine communications cables are and why they are so important, this article introduces key characteristics of the existing global cable network and describes the changes it is undergoing at present. It pays attention to two present and future challenges: namely, the slowness or lack of faster connections and concentration of critical communications infrastructure. Both of these problems contribute to the emergence of choke points that decrease trust in the reliability of the infrastructure on which the smooth functioning of contemporary societies and networked lifestyles depend.

The article finally analyzes recent Arctic submarine communications cable projects as a potential solution to both limitations. These projects, such as the Arctic Connect project or the project of Quintillion Subsea Holdings, would introduce new routes, bringing network diversity and lowering latency, but they have not materialized—at least, they have been postponed to this point. Therefore, these projects can be considered as useful case studies when analyzing the reasons that politicize and restrain the long-awaited changes in the global submarine fiber-optic cable network. Alongside research literature, this article is based on the analysis of recent texts in professional journals and newspapers. Additional data has been collected through semistructured interviews and participatory observation (see Table 1 at the end of the article) since early 2017 in meetings of cable-industry experts.

TABLE 1—INTERVIEWS, DISCUSSIONS, AND PARTICIPATORY OBSERVATION

| DATE | EVENT | INFORMANT(S) | TYPE OF INTERACTION |
|---|---|---|---|
| 27.1.2017 | | Japanese scholar/businessman | Semistructured interview |
| 9.3.2017 | | Representative of Quintillion | Semistructured phone interview |
| 23.5.2017 | | Representative of NxtVn | Semistructured interview |
| 14-15.6.2017 | Arctic Economic Council: 2nd Top of the World Arctic Broadband summit | Representatives of Cinia and Quintillion | Free discussion and participatory observation |
| 6.6.2017 | | Representative of the Regional Council of Lapland | Semistructured interview |
| 17.10.2017 | Arctic Data Cables, Digitalization and Regional Development seminar | Japanese cable industry expert and representatives of Cinia and NxtVn | Free discussion and participatory observation |
| 12.10.2017 | | Representatives of Hokkaido Government | Semistructured interview |
| 22-24.1.2018 | Arctic Frontiers conference 2018 | Representative of Cinia | Free discussion and participatory observation |
| 5.3.2018 | | Representative of the Council of Oulu Region | Semistructured interview |
| 27-28.6.2018 | Arctic Economic Council: 3rd Top of the World Arctic Broadband summit | Representatives of Cinia, Quintillion, NxtVn, Alcatel Submarine Networks | Free discussion and participatory observation |
| 28.8.2018 | | Representative of Cinia | Semistructured phone interview |
| 29.11.2018 | | Representative of Borealis project | Free discussion |
| 5.12.2018 | | Representative of Cinia | Free discussion |

## The Origin and Characteristics of the Submarine Communications Cable Network

Submarine fiber-optic cables contain one or more optical fibers; they are laid on the seabed to carry telecommunications signals between land-based stations. The importance of these cables is based on their capacity to transmit large amounts of data across stretches of ocean and sea (Burnett, Davenport, and Beckman 2014, 1–3). The existing submarine fiber-optic cable network structure has emerged in an uncontrolled process. A large number of actors have been involved in the installation of submarine cables, in a history that goes back to the mid-1850s when copper cables carrying telegraphs first crossed the English Channel and then the Atlantic. While the era of submarine telephone cables began in the 1950s through the introduction of then-new technology, the first international submarine fiber-optic cable between Great Britain and Belgium was laid in 1986. The first transoceanic fiber-optic cable connecting the United States, Great Britain, and France was installed two years later (Ash 2014).

The current fiber-optic network is an outcome of decisions made by private profit-making businesses in different parts of the world; even today, no international governing body oversees the overall development of the cable network. The International Cable Protection Committee (ICPC), which acts as a forum for international cooperation and provides technical, legal, and environmental information about submarine cables, has had a consultative status with the United Nations (UN) since April 2018. While a few national governments have applied and been granted membership in the ICPC, the latter does not have actual authority to govern or control the development of the submarine fiber-optic cable network (Rauscher 2010; Davenport 2018; ICPC 2018).

The emergence of the global submarine communications cable network has not, however, been entirely unregulated. The first international treaty governing submarine telegraph cables (the 1884 Convention for the Protection of Submarine Telegraph Cables) came into force at the end of the nineteenth century. This international agreement contained provisions relating to the breakage or injury of cables, as well as protection of cable ships engaged in laying and repair activities; these provisions, in turn, gave an impetus to the creation of national legislation. While the regulatory framework affecting submarine cables was altered through the adoption of the 1958 Geneva Conventions on the High Seas and the Continental Shelf, it is the United Nations Convention on the Law of Sea (UNCLOS) and its provisions on submarine cables that form the foundation for the current international legal regime. This legal framework concerns the following issues: surveying of cable routes, laying of cables, and the repair and maintenance of cables. It defines the rights and obligations of coastal and other states in situations where cable operations take place in territorial seas, maritime zones within the national jurisdiction of coastal states (Exclusive Economic Zone (EEZ) and the continental shelf), or in maritime zones beyond national jurisdiction. Besides international law, the submarine fiber-optic cables—and actors planning, constructing and preparing these cables—are subject to national legislation, which often introduces regulations and procedures not required by the UNCLOS (Burnett, Davenport, and Beckman 2014; Shvets 2017; Davenport 2018; Shvets forthcoming). Both national and international judicial networks that govern the physical network construction hence strive to maintain the importance of the state, and of the corporation, in global communication and exchange (see Castells 2010, 61).

While modern societies have relied for a long time on the flawless functioning of a small number of cables, the consequences of digitalization, which now ranges from business to leisure and social services to national security domains, have further consolidated our reliance on submarine communications infrastructure. The development of Low and Very Low Earth Orbit (LEO and VLEO) satellites has inspired various projects involving thousands of small-scale satellites at the altitude of little more than 1000 kilometers (VLEO operating even below 350 kilometers). Such projects offer the promise either to revolutionize global connectivity or, more modestly, to offer tailor-made solutions to areas not covered well by fixed lines or GEO satellites (Dakka 2018; Schneiderman 2019). However, the truth is that only a small portion of current global data traffic volume could be transmitted by such means if the submarine fiber-optic cables were to suddenly stop working.

The existing submarine communications cables, of which routes are described in Figure 2 produced by TeleGeography, form a heavily concentrated structure. Although the cable routes on the map are stylized and do not reflect the actual cable paths in detail, the map shows that the routes of various cables are similar; they often land in the same areas and may even utilize the same landing stations. When the cable companies have planned and installed new cables, they have tended to follow the routes that had been used earlier. While a large number of similar decisions made by different actors have eventually created the problem of overconcentration, the decision of each individual actor is understandable—the actors behind a new cable wish to connect it to the existing global network. The value of a node in the network is higher the better linked it is (Eriksson 2009, 41, 44). In addition, when using an old route, data about the environmental conditions, ranging from the seabed topography and sediment types to the possibility of natural hazards and their recorded effects on infrastructure, is already available. Similarly, if a company lands in a place where it or another company has already landed, issues concerning no-anchor zones and other fishery-related issues have most likely been solved and questions concerning the environmental impacts on the shoreline have been discussed. The maintenance of untested routes may also be more expensive. Only a handful

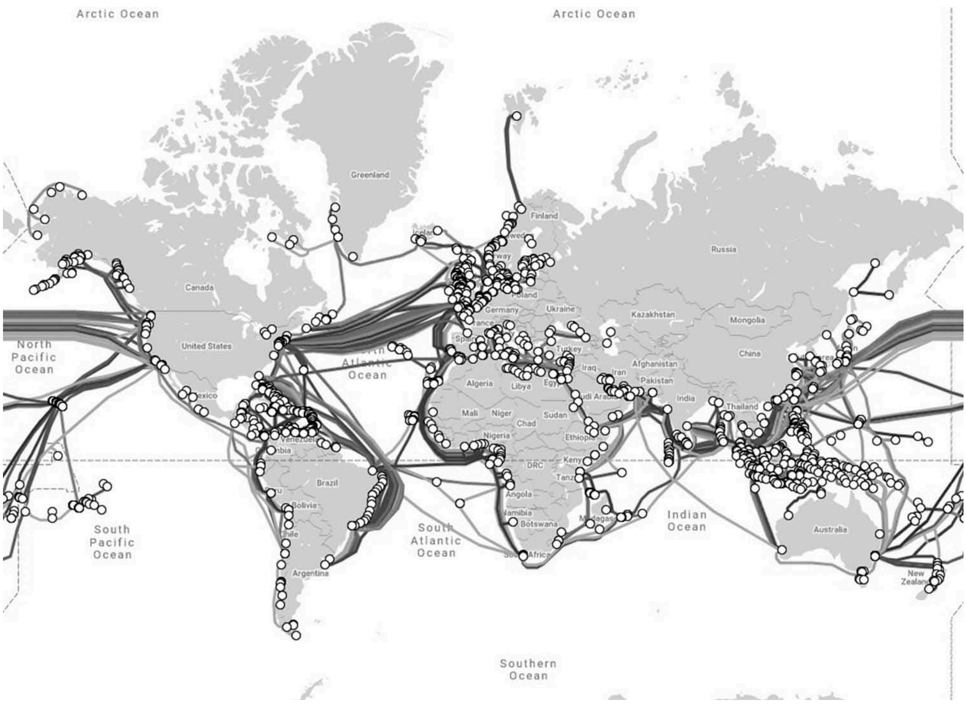


FIG. 2—Global submarine fiber-optic cable network with landing points (https://creativecommons.org/licenses/by-nc-sa/3.0/). Modified from TeleGeography Submarine Cable Map (https://www.submarinecablemap.com/#/).

of cable ships exist that are capable of correcting damage to the system, and they may be located far from the new routes. Next to that, uncertainties concerning market demand may be greater when creating new connections (Starosielski 2015). Thus, the value of a link for the network is relative: it may be defined by its centrality, its ability to relay one- or two-directionally, or its criticality (e.g. existing (non)redundancy in the network or the link's capacity to either include or exclude locations, like in the case of one-cable connections).

Furthermore, it should be noted that while the claim that new routes are needed to increase diversity might be generally agreeable to commercial actors, they are not keen to invest in systems that could be characterized as a "backup" infrastructure. Finally, commercial actors who have invested in the development of the existing routes may hesitate to cooperate with actors who are searching for partners to develop new routes. Concentration inevitably means that this critical infrastructure is vulnerable to both natural and man-made hazards, especially in the so-called choke points where various submarine cable paths meet and that can be identified in different parts of the world (Rauscher 2010). Although the existence of choke points and the risks bound to the lack of robustness were recognized years ago, these problems remain unresolved.

## Recent Trends in the Submarine Fiber-Optic Cable Industry and Regulatory Framework

If one measures newly installed cables in kilometers, the global submarine cable network has been expanding in recent years much faster than during the first half of the 2010s. The increase in global carrying capacity has been even greater, as the average capacity of a submarine fiber-optic cable system has risen from 25 to 60 terabits per second (Tbps) between 2014 and 2019. In other words, due to the development of technology, a new fiber-optic cable can transmit much more data than various old cables it may be replacing. There is no expected end to the current construction boom. Rather than facing the kind of a slump that followed the cable boom around the turn of the millennium, forecasts say that global submarine cable capacity will increase up to 143 percent between 2017 and 2022 (Ash 2014; Clark 2019a; Holiday 2019). The metaphorical network's ability to generate, process, transmit, and destroy information (and goods) at an accelerating speed has been described as one of its defining characteristics (McNeill and McNeill 2003; Eriksson 2009; Castells 2010). The global telecommunications network based on submarine fiber-optic cables is able to do the aforementioned ever faster and while so doing, it ties people and their life environments ever closer together. The network keeps thickening and its criticality for everyone increases, which also increases the perceived needs of and calls for intensified regulation.

International consortia were in charge of the large-scale submarine fiber-optic cable projects for a long time, but recently a shift toward single ownership has occurred. Much of the recent growth in the number of installed cables has been spurred on by the changing dynamic in cable-system ownership observed since 2016—companies such as Facebook, Google, Microsoft, and Amazon have begun to move from the role of capacity purchasers to that of cable developers. First, the technology giants that used to buy a large part of the carrying capacity of submarine cables owned by telecom companies joined international partnerships as coowners, to meet their own bandwidth requirements. Subsequently, they became involved in the building of their own cables. Google has already completed its first cable project and thus became the first major nontelecom company to build a private international cable (Capacity media 2018; Clark 2019a; Garret 2019; Holiday 2019; Nagpal 2019; Palmer-Felgate and others 2019; Sawers 2019). While the consortium structure reduced risks to individual owners, the single ownership and internal consumption model may provide greater flexibility and speed to the process of cable development and installation (Clark 2019b). However, recent developments in the legal and regulatory framework do not necessarily point in this direction.

Even as the steps toward regulatory harmonization in the European Union (EU) may have given hope for simpler regulatory environment, for example, for trans-Atlantic submarine cables, political tensions and turbulence in international relations, as well as the shift toward protectionism and economic nationalism, have affected the cable industry. Furthermore, submarine fiber-optic cables have increasingly become identified as potential targets of sabotage or acts of terrorism (Clark 2019b). Besides affecting operations at sea, these trends have taken form, for example, in the complex national security reviews that have slowed down the necessary license and permission application processes for new cables. The Federal Communications Commission (FCC) regulates submarine cable landings in the United States. While the application process of the FCC license should be relatively fast in principle, the practice has shown that the handling of a landing license may take more than a year. This is largely due to national security reviews that involve a great number of actors through organizations such as Team Telecom (consisting of, for example, the departments of Defense, Homeland Security, and Justice, as well as the FBI) and the Committee on Foreign Investment in the United States (involving the Secretary of Treasury, eight other departments and offices, and observer agencies). At the same time, many European countries are investigating the acquisitions of telecommunications network assets by non-EU nationals; the review processes related to critical infrastructure, such as submarine cables and their landings, are delayed because of national security concerns (Lipman, Pin, and Klos 2019).

The situation in Russia is no less complicated. If a corporation wishes to lay a submarine cable on the continental shelf of the Russian Federation, permission is required from the competent authority, the Federal Service for Supervision of Use of Natural Resources. This entails approvals from the total of nine dedicated federal executive authorities, ranging from the Ministry of Defense to the Federal Agency for Fishery and from the Ministry of Education and Science to the Federal Service for Supervision of Communications, Information Technologies, and Mass Media. The large number of state bodies, all of which have their own internal procedures for considering the application, explains why the process of obtaining a permission takes such a long time (Shvets 2017, 171).

The recent revitalization of the cable industry has also accelerated discussion on SMART (Sensor Enabled Scientific Monitoring and Reliable Telecommunications) or dual-purpose cables. As Howe and others (2019) have pointed out, these concepts bring together two key themes of the twenty-first century: the market-based demand for greater connectivity and the need for a global effort on climate change and ocean management. The basic idea of dual-purpose cables is to integrate different types of environmental sensors into commercial submarine telecommunications cables. Cooperation between the cable industry and the scientific community could benefit both parties. The latter could cover a portion of the installation costs, but the financial burden carried by the academic community would be significantly less than the price of the monitoring system used only for scientific purposes. Usually repeaters—devices regenerating the fiber-optic signal every 50-100 kilometers—are envisioned as the parts of the submarine cable system that could host the sensors, which measure ocean temperature, ocean circulation, sea-level rise, and tides of various origins and contribute to tsunami monitoring and warning as well as to seismology (Carter and Soons 2014; Starosielski 2015, 217–221; Howe and others 2019; Webster and Dawe 2019).

The SMART cables have been studied, for example, under the auspices of the International Telecommunications Union (ITU), World Meteorological Organization (WMO), UNESCO, and the International Oceanographic Commission (IOC) Joint Task Force established in 2012. Despite the promise of this initiative, the advance of SMART cable projects has remained slow, because of a number of factors. The cable companies worry about the loss of commercial traffic if part of their cable system is dedicated to sensor data transmission. A concern has arisen that the combination of science and telecommunications into a single cable make a poor fit with international legal frameworks. Similarly, a concern over military authorities' attitude toward and interest in the data collected by the sensors has emerged. However, perhaps the biggest unresolved challenge is to ensure that the sensors have a minimal, and preferably zero, impact on the functioning of the submarine fiber-optic cable that is hosting them. One solution to this problem was introduced in an article published in *Science* in 2018, proposing that the fiber itself is used as the sensing element detecting, for example, earthquakes even without adding any sensors in the submarine part of the cable (Marra and others 2018).

## Case Study: The Arctic Ocean as a Potential Game Changer in the Global Submarine Communications Cable Network

The need for faster connections and alternative cable routes has intensified international interest in the Arctic submarine fiber-optic cables. The history of projects attempting to connect Europe and East Asia through the Northeast Passage goes back to early 2000s, when the Russian Optical Trans-Arctic Submarine Cable System (ROTACS) project was launched. Despite having received the necessary approvals from the Russian authorities and financial support, for example, from the Ministry of Telecommunications in January 2013, the project never materialized. One reason behind the lack of progress may be the sanctions that Western countries imposed on Russia after the annexation of Crimea in the spring of 2014. Prior to that event, the US-based TE Subcom—which used to be known as Tyco Telecommunications and was also involved in the early plans of the project—had already been awarded a contract in 2012 to implement the fiber-optic cable system (TeleGeography 2016; United Nations, Economic and Social Commission for Asia and Pacific 2014, 96).

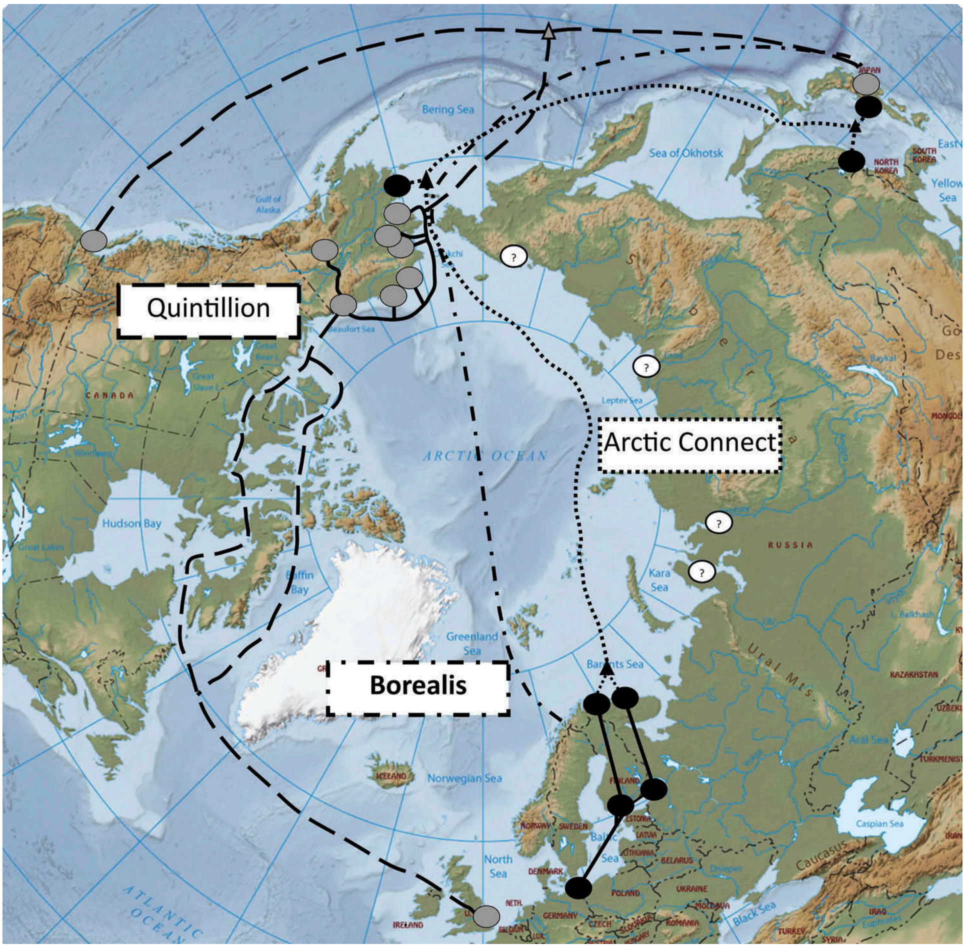


FIG. 3—The planned submarine fiber-optic cable projects through the Arctic Ocean.

The more recent interest in the Arctic Ocean as a potential locus for submarine communications cables has taken shape in various new projects illustrated in Figure 3. In North America, Quintillion's project to install a submarine communications cable between Japan and Great Britain via Alaska and the Northwest Passage has advanced to a point where the Phase 1 —a regional system, including both submarine and terrestrial cables—has been completed and is in use. While Quintillion has recently announced their partnership with APTelecom and moved on to planning phases 2 (a submarine cable connecting Japan to Washington State), 3 (connecting Alaska to Canada), 4 (connecting Canada to London), and 5 (connecting the Phase 1 to the transoceanic submarine cable installed in Phase 2), other regional projects are also advancing, for example, in the Kativik region of Canada (WFN Strategies 2018; Hernandez 2019; Quintillion 2020).

In Eurasia, the Arctic Connect project, originating from Finland but international in nature, claims to bring 25–40 percent decrease in latency (roundtrip delay between East Asia and Europe from 250 milliseconds to as low as 150 milliseconds) compared to the traditional southern route (Bannerman 2018) and has advanced under the leadership of Cinia Ltd. (a private data communication and information technology conglomerate that is mainly owned by the Finnish state). This project took a major step forward in June 2019, when a memorandum of understanding between Cinia and its Russian partner MegaFon was announced. Although these two companies have already created a joint venture called Arctic Link Development OY, the names of their international partners, expected to include companies at least from Japan and the Nordic countries, have not yet been announced. The submarine fiber-optic cable system, which would connect East Asia, North America, and Europe through the Northeast Passage, ought to be completed in 2023. This planned cable system is designed to comprise both fiber pairs landing in the Russian Far North—in undisclosed areas with significant industrial activity—and direct connections between Europe and East Asia. In addition, after landing in Kirkenes, Norway, the new cable will be connected to the existing submarine cable between southern Finland and Germany, either with a terrestrial connection through Finland or with another new submarine cable installed at the bottom of the Bothnian Bay (Saunavaara 2017; Saunavaara 2018; Cinia 2019; Magdirila 2020).

Meanwhile, in April 2018 the Russian Ministry of Defense announced its plan to connect the Arctic and the Far East, through the installation of a 12.7 thousand kilometers long fiber-optic cable between Severomorsk and Vladivostok. This cable would serve the navy and also coastal troops. Besides recognizing the conventional benefits related to the rapid transmission of high volumes of information, the military authorities also pointed out the possibility to utilize this kind of infrastructure—if hydro-acoustic sensors are plugged into it—to gain immediate information about objects spotted in the Arctic Ocean (Nilsen 2018; Navy Recognition 2018). While not much was heard from this project during the months that followed, new information was revealed in March 2019. This time the trans-Arctic cable was linked to Russia's plan to build a new closed internet fully isolated from the World Wide Web. According to information provided by the military officials, the armed forces had already begun preparing for the laying of the cable, and the project was said to be based on resources and communications systems developed within Russia (Staalesen 2019).

The submarine cable route proposed in the Borealis initiative by Digital Footprint AS, which envisions a new submarine cable connection between Norway and Asia, differs drastically from the aforementioned initiatives. The

Borealis project envisions a submarine fiber-optic cable that would cross the North Pole rather than to follow either the Northeast or the Northwest Passage. While proposing a route that in itself would bring forth great technical challenges for the installation process, the Borealis project also includes a strong scientific element, as it would be utilized in ocean and climate monitoring and disaster warning (Fouch 2018; The Joint Task Force for Smart Cables 2018).

Despite the differences between these proposed Arctic routes, and with the exception of the Russian military initiative, the basic idea of each of them is the same: the Arctic is a shortcut that enables shorter cable connections among continents and hence less network latency. While a similar logic can be found as background to the plans to utilize the Arctic as a new shipping route between East Asia and Europe, there is one basic factor that makes the telecommunications initiatives more tempting. Namely, while the Arctic conditions have significant effects on the speed of the ships, thus reducing the total time saved by the shorter route, they do not have similar effects on the transmission speed within a submarine fiber-optic cable. The relatively low temperatures at the bottom of the Arctic Ocean should not affect the operation of properly conditioned fiber-optic cables (see, for example, Thomes and others 2008). In addition, the sea ice, which can be troublesome when installing and repairing the cable (Figure 4), can in fact protect it from human activities (such as fishing and anchor dragging) that form the greatest threat to the functioning of these cables (Wargo and Davenport 2014). Another asset shared by all proposed international and commercial projects is their capability to increase the diversity of the existing global network through new routes and new landings. The thawing (subsea) permafrost is also an Arctic-specific factor that can impact offshore infrastructure. Although the installation of terrestrial fiber-optic cables has already accelerated the melting process through the removal of the insulting topsoil and vegetation (Grove 2018; Angelopoulos and others 2019), available knowledge concerning the relationship between subsea permafrost and fiber-optic cable burial (that takes place only in relatively shallow waters and clearly differs from oil and gas pipeline construction) remains limited.

With the exception of Quintillion Phase 1, which was still a national project, the Arctic submarine fiber-optic cable projects have not yet reached a stage where license and permission application processes discussed earlier would have been launched. Yet, security-related concerns have already been identified and analyzed. The Team Telecom has designated the Quintillion network a critical infrastructure for the U.S. national security (Woolston 2018) and University of Jyväskylä led an international research group, in cooperation with the Arctic Connect project stakeholders and Finnish decision makers, which has published a report analyzing the Arctic Connect project from geopolitical, strategic intelligence, and cybersecurity perspectives (Lehto and others 2019). Therefore, there seems to be hardly any reason to expect that the international Arctic cable projects, of which regulatory framework does not differ from the projects taking place in the southern latitudes, would escape the delays typical to the cable industry elsewhere.


FIG. 4—The cable-laying ship Ile de Batz that installed the Quintillion cable system in Alaska. Photograph taken in Brest, 2007. (Wikimedia commons, File: Ile de Batz cable-laying ship.jpg. This file is licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license.)

Although, based on the information currently available, the Arctic submarine fiber-optic cable projects are not connected with the trend towards single ownership but follow the traditional consortium model, they would utilize the technological innovations that have generated significant increases in the carrying capacity. Furthermore, the idea of dual-purpose undersea cables is especially tempting in the context of the Arctic Sea, because the Arctic Ocean is sparsely researched in comparison to other marine areas around the world. The desire of academics to cooperate with commercial actors has most likely been strengthened by the fact that the installation of research infrastructure is more troublesome and expensive in the Arctic than in other regions. Against this background, it is unsurprising that the Borealis project has placed cooperation with academia at its core. The representatives of Cinia have also mentioned the possibility of this kind of cooperation when describing the possibilities bound to the Arctic Connect Project (Joensuu 2018).

However, all of the reasons that have prevented the introduction of new routes, greater diversity, and the large-scale utilization of SMART cables in other parts of the world are also very much present in the Arctic. The unusually great distance between the newly proposed and existing cable systems increases the uncertainties typical to all new cable routes. Moreover, the characteristics of the

Arctic region—that is, its remoteness, vast size, and low population density—are far from ideal for a point-to-point technology like fiber-optic cables. It is also worth remembering that some of the companies that may appear as strong candidates to participate in the Arctic fiber-optic cable initiatives have, in fact, already invested in communications infrastructure that competes with the proposed projects. Against this background, resistance to the Arctic Connect project that has reportedly come from, for example, Rostelecom (Rytkönen 2019a) is unsurprising.

The completion of the Arctic cable projects would not change the fact that the submarine fiber-optic cable network carrying information mirrors the global flows of capital and trade. The Arctic would simply offer a new route and the cable at the bottom of the Arctic Ocean would enable, for example, the shaving of milliseconds off financial transactions between London, Frankfurt, Tokyo, and other global financial centers. The fact that the local inhabitants (the number most often given to describe the total population of the Arctic is four million) can hardly bear a major part in the total investment may not be a major hindrance to the success of these developments. The proposed projects are first and foremost industry-driven initiatives aiming to connect European, East Asian, and North American centers through the Arctic. Therefore, both the funding of the projects and the data traffic they carry are expected to originate outside the Arctic region (for details of a failed attempt to collect significant investment from local actors, see Starosielski 2015, 18).

Nevertheless, the idea of growth through improved international connectivity is incorporated into various regional development strategies in different parts of the circumpolar north. Many Arctic and northern communities are expecting that the proposed submarine fiber-optic cable projects will bring in material benefits, for example, in the form of data-center investments. Some of them have invested in the planning of these projects. Besides the economic benefits, the possibility to improve social services such as e-healthcare or e-learning are often mentioned when these projects are promoted (Saunavaara 2018; Rytkönen 2019b). However, the meaning and value of the projects to the people and communities located in the Arctic, assuming that the projects are implemented, depend for example on the local telecommunications companies' readiness to improve local terrestrial networks, cooperation between different types of connectivity providers, and the national governments' willingness to subsidize such activities.

## Conclusion

Although pressures arising from economic protectionism and national security concerns make the regulatory framework challenging, the submarine fiber-optic cable industry is currently booming. At the same time, the sector is going through a major transformation due to the changes in the structure of cable ownership. However, it seems that neither technological development nor the laying of tens or even hundreds of thousands of kilometers of new submarine cables will necessarily resolve the fundamental problems of the global cable network. New technology allows significant increases in carrying capacity, but it does not change the fact that the speed of transmission depends on the physical length of the cable. Similarly, the improvements in the diversity and robustness of the overall network achieved through the new cable systems remain minor, if they simply follow the same routes utilized by other cables in the past.

The Arctic fiber-optic cable projects seem to offer solutions for faster connections and greater diversity. However, they have not, at least so far, been able to solve the general problems related to the establishment of new cable routes. The coming years—perhaps even the coming months—will show whether the actors behind the Arctic submarine fiber-optic cable initiatives manage to find partners from each country involved and convince investors of the technological and economic feasibility of their projects. Only after solving the fundamental questions concerning project partners and funding will we learn more about the flexibility and decision-making ability of the Arctic countries and regions in such practical issues as permits and zoning.

The Arctic submarine cable projects' primary value is in their promise to speed up connections by generating new links between nodes in the network(s) (that is, the value arises from the links' relation to the overall global network of interactions). They may generate new nodes as well, depending on for instance the selection of landing sites. Moreover, they may generate additional links when cables following the Arctic routes are connected to new nodes along the shoreline. This, again, will extend the technical, but also metaphorical, extent of the global network. Increased pace of transmission, and the movement it enables, will further thicken global, overlapping networks of political, economic, religious, judicial, and cultural interaction. Simultaneously, improved communication coverage will connect the Arctic firmer to the global network of exchanges, which may or may not serve the interests of local communities as well. For certain, it will disseminate and integrate network thinking in to the minds of people.

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