EMERGING SUBSEA NETWORKS: NEW MARKET OPPORTUNITIES FOR, AND SOCIETAL CONTRIBUTIONS FROM, SMART CABLE SYSTEMS

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Abstract: The subsea telecommunications cable industry has the opportunity to enter a new era with the emergence of game-changing dual-purpose cable systems. These SMART cables will incorporate small external sensor packages to transmit real-time environmental data without any impact on commercial traffic. The sensors will precisely measure temperature, pressure and three-axis acceleration across the world's ocean floor on a sustained basis in response to an increasing international need to monitor and mitigate climate and sea-level change and radically improve tsunami hazard warnings. SMART cable systems will provide new market opportunities, engage non-traditional users, and make profound societal contributions.

1. INTRODUCTION

The telecommunications industry has been successful for over a century in establishing a network of subsea telecommunication cables for global and regional exchange of all forms of information between communities. More recently, cables have become the communications backbone of international financial trading. Strangely, despite this long history, significant legal issues remain unresolved [1]. Much research and development has been invested in improving cable reliability and transmission speed. Fiber optics have replaced copper; optical technology and multiplexing of wavelengths have increased the volume and speed of data through cables; repeaters have become more advanced and now spaced apart at greater distances; improved seabed mapping and efficient cable deployment techniques have reducing installation costs; globally-distributed cable maintenance vessels ensure rapid repairs; system costs for installation, maintenance and operations have been reduced but with consequentially lowered profit margins for vendors.

The last two decades have seen the emergence, evolution, and dominance of hardware, software and communication companies driven by rapid evolution in Internet-enabled commerce. Traditional stock market leaders such as Exxon-Mobil, Shell, Chevron and BP have now been displaced by Apple, Google, Microsoft, Oracle, Amazon, Netflix, and Facebook.

This Internet-induced revolution has affected many aspects of the economy, society, and personal lives. Examples include: high frequency stock market trading; remarkable increase in communication demands from smart phones, cloud computing, cable television; rise of readership using tablets and smart phones at the expense of print media; dramatic influence of social media such as Facebook, Twitter, Instagram, YouTube, and LinkedIn; increased role of digital information, reporting, and learning within educational systems; near-instant news reporting and worldwide communication affecting political, government and social decision-making; and real-time and near real-time reporting of critical environmental data in response to current concerns for climate change and hazard mitigation.

How does this revolution affect the subsea telecommunications industry? Obvious demand has been for additional cables, improved multiplexing within cables, and faster communication. There are over operating 200 fiber optic cables in the undersea network, carrying more than 95% of the transoceanic voice and data traffic [2] [3] [4]. Underwater cables carried 51 billion gigabytes per month in 2013 – a rate expected to increase to 132 billion gigabytes by 2017. An example of a new system is the consortium of China Mobile International, China Telecom Global, Global Transit, Google, KDDI and SingTel with NEC as the system supplier deploying the FASTER cable between Japan and USA with an initial design capacity of 60Tb/s (100Gb/s x 100 wavelengths x 6 fiber-pairs).

These changes represent rapid incremental developments of the long-standing industry's technology and network. However, the network has an unexploited capacity to provide an additional flow of environmental data to meet urgent societal demands by developing and marketing "green", "dual-purpose", or using the more preferred term of SMART cables (with SMART = Science Monitoring And Resilient Telecommunications). This concept was advanced in 2010 [5] and then formally expanded through reports, workshops, and conference presentations by the Joint Task Force (JTF) [6] established in 2012 by three United Nations agencies, namely the International Telecommunication Union (ITU), the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC-UNESCO), and the World Meteorological Organization (WMO).

Hence, this paper argues that the subsea telecommunications industry is poised to exploit a new era of opportunity and commercialization to gradually build an enhanced subsea cable network, equipped with sensors that will deliver key real-time environmental data on climate and sea level change and revolutionize warnings for major disasters such as tsunamis and submarine slope failures.

2. SMART SUBSEA CABLE SYSTEMS

Given space limitations, this paper will just address SMART subsea cable systems advocated by the JTF while acknowledging that alternative options may exist for adding sensors to cables, for deploying different sensors, and responding to specific environmental data required or procured by sponsoring agencies.

The concept is to add three of the most useful environmental sensors at numerous locations along new or refurbished trans-ocean or regional/coastal cable systems. These are temperature, pressure and three-axis acceleration sensors, which are already marketed, proven and deployed on scientific cabled ocean observatories such as: NEPTUNE (Ocean Networks Canada), off British Columbia to 2700m [7] [8] [9]); DONET, off eastern Honshu, Japan to 4000m [10] [11]; Ocean Observatories Initiative's Cabled Array, off Washington and Oregon to 2900m [12] [13]; and Aloha Observatory, Hawaii, to 4800m [14] [15]. Such sensors are small, reliable, operate down to water depths of 7000m and can operate fault-free for more than a decade. Established manufacturers include Paroscientific Inc., Seattle, USA and RBR Ltd., Ottawa, Canada.

SMART subsea systems would package the three sensors and integrate them within, or close to, conventional repeaters. No maintenance would occur once deployed; should one or more sensors fail they would not be replaced, but others working would suffice for a regional picture of environmental changes.

Recently, ITU solicited selected subsea telecommunication companies for financial support for studies on the technical requirements of such sensor systems. Three companies (Fujitsu, Huawei Marine Networks and Nexans) and IOC-UNESCO contributed. These studies, after a six-month embargo, are now posted on the JTF website [6]: Functional Requirements [16], Wet Demonstrator [17] (both 2015), and Green Cables Funding Study (2016) [17]. The specific sensor performance parameters advocated by the first two studies (Mallin Consultants) are shown in Tables 1-3.

Temperature sensors shall have the following performance parameters:

Range	-5.0 to +35ºC
Initial accuracy	±0.001ºC
Stability	0.002ºC / year
Sampling rate	0.1 Hz
Sample resolution	24 bits

Table 1: Temperature Sensor Parameters

Absolute pressure sensors shall have the following performance parameters:

Range	0 to 73MPa (0 to 7,000m)
Overpressure tolerance	84MPa (8,000m)
Accuracy	±1mm relative to recent measurements 0.01% of full range absolute
Maximum allowable drift after a settling-in period	2kPa/year
Accuracy after drift correction	For further study
Hysteresis	≤ ±0.005% of full scale
Repeatability	≤ ±0.005% of full scale
Sampling rate	20 Hz
Noise floor	0.14 Pa^2/Hz
Sample resolution	32 bits
Compensating sensor sampling rate	20 Hz
Compensating sensor resolution	24 bits

Table 2: Pressure Sensor Parameters

Accelerometer sensors shall have the following performance parameters:

Configuration	3-Axis
Response	0.1 to 200Hz

Resonant frequency	>2,000Hz
Full scale range	±1.5g where g is 9.8 m/s^2
Noise	≤ 2ng / √Hz
Amplitude response	±1% across frequency range
Linearity	±1% of full scale
Cross-axis sensitivity	<1%
Sampling rate	400Hz
Sample resolution	24 bit

Table 3: Acceleration Sensor Parameters

3. SENSORS AND DATA MANAGEMENT

Real-time data return is key in using the pressure sensor data for tsunami hazard warnings. Data return can be via the supervisory channel or by a dedicated wavelength or fiber to avoid interference with primary data transmission. The three sensor types do not generate much data: approximately 30kb/s per sensor location.

Data management for such modest amounts, even from multiple SMART cable systems, is of minimal concern and readily accommodated by existing organizations such as NOAA (US) or cabled ocean observatories (e.g., Ocean Networks Canada, Ocean Observatories Initiative, or EMSO) [19] [20]. These have both a commitment to long-term data storage and sophisticated data management systems for reporting and visualization.

4. NEW ENVIRONMENTAL AND SOCIETAL IMPERATIVES

Ocean climate change, sea level rise, and tsunami and slope failure hazards represent major factors in environmental change and threats, with profound global and regional socio-economic impacts. Advances in sensor technologies, cabled ocean observatories, and partnerships with the subsea telecommunications industry, all combine to advocate for new SMART Cable Systems in providing critical environmental data on regional and global scales. These advances address global issues affecting societies and future generations, and can save vast resources from destruction because of imprecise and incomplete tsunami hazard warning systems and sea-level change quantification. Failure to mitigate and adapt to climate change is the greatest threat facing the world's economy in 2016, according to annual survey results of the World Economic Forum (WEF January 2016).

A. CLIMATE CHANGE

Climate change is the most serious issue facing humankind during this century. The Industrial Revolution and later developments have led to progressive increase in atmospheric CO_2, now exceeding 400ppm. A parallel increase in mean global temperatures [21] [22] has prompted serious warnings of natural and societal consequences [23] [24] [25] [26]. In December 2015, 195 countries participating in the UNFCCC COP21 climate summit reached, by consensus, the Paris Agreement. Members agreed to reduce their carbon output as soon as possible and to do their best to keep global warming to well below 2 °C above pre-industrial levels.

The oceans are the main controlling factor in climate change, holding much of the heat and greenhouse gases, with a complex circulation system. Despite analysis in the

5th IPCC Assessment Report [21], key data are unavailable or sparse for the deeper parts of the oceans [27]. The complex conveyer belt systems operating through all oceans [28] reveal the urgent need for real-time bottom temperatures via SMART cable sensors.

B. SEA LEVEL RISE

A consequence of warming oceans is global sea level rise, although varying regionally. This rise is generated by progressive melting of polar ice-caps [29] and glaciers, and by thermal expansion of the water column. IPCC [21] estimated a rise of about 90cm by 2100, but ice cap melting is progressing faster than assumed by many climate models and this estimate may be conservative.

Such sea level rise may seem modest, but is critically significant to many low-lying countries (e.g. Maldives, Bangladesh, Netherlands), coastal regions (e.g. Florida), many coastal cities worldwide, and will produce large population migrations and massive costs to urban infrastructure. Monitoring sea level changes is partly achieved through coastal tide gauges, but SMART cable sensors could capture real-time changes throughout ocean basins over decades for long-term monitoring and help calibrate satellite gravity data [30]. Short-term oceanic events such as cascades of dense water from shelves into deep ocean basins [31] or climate tipping points could likewise be detected.

C. HAZARD MITIGATION (TSUNAMIS AND SLOPE FAILURES)

Over a dozen major tsunamis in the last decade (notably from large earthquakes in Indonesia (2004), American Samoa (2009), Chile (2010, 2015), Haiti (2010), and Japan (2011)) have caused hundreds of thousands of deaths and destroyed infrastructure in the billions of dollars. SMART cable systems would generate real-time data over wide ocean basins and coastal areas and dramatically improve early warning systems, mitigating loss of life, damage, and costs. Proven examples of observatory arrays of SMART sensor networks are established in tsunami and slope failure hazard areas off British Columbia [32], in European and Mediterranean seas [33], and off Japan [34]. While being regional facilities, they can also monitor distant hazards [35].

5. SMART INTERNATIONAL LEADERSHIP BY THE SUBSEA TELECOMMUNICATIONS INDUSTRY

Over the past century, the many advances in the subsea telecommunications industry include improved cable transmission rates, copper to fiber optics, lower costs, increased routes, etc. With burgeoning data volumes, devices, and connectivity, how can the industry diversify beyond traditional technology/commercial areas? All successful industries respond to changing societal needs and commercial opportunities, with smart companies investing ahead of the curve. Given the profound societal and economic implications of future climate and sea level change and the scale and cost of tsunami and slope failure hazards, there can be no doubt of the urgent need to understand and quantify these threats. For the industry this means adoption and rapid implementation of SMART cable systems.

A. NEW MARKET OPPORTUNITIES

Existing cable systems will continue to evolve. The SMART cable proposal advocates marketing "dual-purpose cable" systems whereby an additional value-added component produces real-time, critically needed, environmental data from three sensors (T, P, Accel.) integrated with repeaters (or some equivalent technology). The cost has been estimated at 5-8% of a typical trans-ocean cable system, with no change in deployment methods, and no ongoing maintenance. There may be some NRE expenses depending on current R&D work for any particular company: the proposed JTF Wet Demonstrator project [17] would develop a generic system, deliver proof-of-concept, and reduce or eliminate such expenses.

B. ENGAGING NON-TRADITIONAL USERS

A key part of marketing SMART cable systems is to recognize the range of potential new non-traditional users. Clearly the scale of the environmental and economic threats facing the planet now and through this century are requiring government agencies, insurance and re-insurance companies, port authorities, cruise ship companies, coastal city planners, emergency/disaster organizations, ENGOs, etc., to seek more precise, real-time, ocean environmental and hazard data for evidence-based decisions, advice and policies.

As one example, government agencies such as US NOAA are responsible for generating, analyzing, interpreting, and globally distributing climate and tsunami data. Likewise, the US Geological Survey reports on earthquakes nationally and worldwide. Their options and obligations have been given wider approval recently by unanimous support by both US House and Senate for passage of the Tsunami Warning, and Education, and Research Act of 2015 (awaiting further reconciliation approval later in 2016). This Act encourages the use of sensors on marine cable systems: "Development of practical applications for existing or emerging technologies, such as modeling, remote sensing, geospatial technology, engineering, and observing systems, including the integration of tsunami sensors into Federal and commercial submarine telecommunication cables if practicable". Two NASA workshops [30] likewise presented strong support for SMART sensor networks. These three large US agencies are well-positioned to engage with and support telecommunication companies in the development and deployment of SMART cable systems.

6. SUMMARY

Climate change (with associated sea level change) is now recognized as the most serious issue for the economy and society's well-being in the 21st century (World Economic Forum; IPCC; President Obama). The cost and loss of life and infrastructure from major earthquakes, tsunamis, and submarine slope failures have devastated many regions. Many sectors (government and UN agencies, insurance industry, coastal and port authorities, etc.) are desperate for improved scientific data for their decision and policy making. What role can the subsea telecommunications industry play?

This industry is mainly concerned with providing systems for high-speed data transmission and worldwide communications. With rapid transition into the Digital Age and a host of new digital devices, the industry is playing a vital role in installing and maintaining subsea cable networks.

Yet, the industry can forge a new era by promoting and installing SMART (Science Monitoring And Resilient Telecommunication) cable systems with repeaters that host small sensors (temperature, pressure, three-axis acceleration). These can transmit real-time data over decades via the supervisory or equivalent channels, with no special deployment methods or maintenance. These data can address key issues of deep ocean circulation (patterns of conveyer belt circulation, ocean cascades, tipping points, progressive warming, impact of polar ice-cap melting, etc.). The progressive installation of SMART ("dual purpose") cables would dramatically enhance the current tsunami warning capability, augmenting the present vandal-prone system of DART buoys and coastal tide gauges with a reliable, global, high-precision real-time network.

Marketing of the new SMART cable systems is essential by industry and the ICPC, with continued advocacy by the ITU, WMO, IOC-UNESCO, and their Joint Task Force (JTF). This industry must increase its reach to non-traditional users, in particular to those agencies and industries that desperately need these key environmental data for decision and policy making to address the environmental threats facing the society and the planet in the 21st century.

How and when will the subsea telecommunications industry fully recognize, reinvent, and respond to this challenge?

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