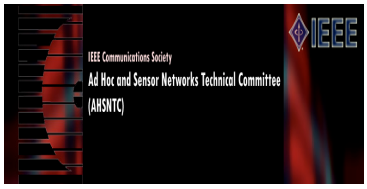
Ad Hoc and Sensor Networks Technical Committee Newsletter (AHSN TCN)



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PREFACE

The IEEE ComSoc Ad Hoc and Sensor Networks Technical Committee (AHSN TC) aims at sponsoring scientific and technical activities facilitating the dissemination of knowledge in the areas of ad hoc, sensor and mesh networks. In an attempt to make all the TC members as well as the AHSN worldwide community aware of what is going on within our main areas of concerns, this newsletter had been set up. The newsletter aims at, first, letting all the community aware of the main events that the TC technically supports; Second, publicizing these events as well as other events that would be of interest to the community; Third, reporting to you our last news and achievements;. And last but certainly not least, inviting the authors of successful research projects and experts from all around the world with large vision about an AHSN-related research activities to share their experience and knowledge by contributing short news. So, in addition to the reports and selected announcement provided by TC officers and members, the third issue of the newsletter features one high quality news item gently provided by Prof. Cheng Li and Prof. R. Venkatesan (Memorial University, Canada). We thank them as well as all the previous contributors for their effort to make this newsletter successful towards fulfilling its objectives.

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NEWS ARTICLE RELATED TO AHSN TC TOPICS

OCEAN SEAFLOOR ACOUSTIC SENSOR NETWORK

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Abstract

The Ocean Network Seafloor Instrumentation (ONSFI) Project, which commenced in 2007 at Memorial University, is a $3.2 million Canadian dollar five-year multidisciplinary research and development project to design, fabricate and validate a proof-of-concept seafloor array of wireless marine sensors for use in monitoring seabed processes, including applications such as geological imaging and earthquake detection. Individual compact, relatively low-cost sensors, called 'SEAformatics' pods, will be self-powered through ocean bottom currents and will be able to communicate with each other and to the Internet through surface master units to facilitate observation of the ocean floor from shore. Four research and development streams are included in the project: marine sensors; power generation; communication networking; and, final integration of the systems into a working prototype. This project links sensor science, wireless communications technologies, 'smart' materials, ocean current power harvesting technologies and web-based information technologies.

1. Introduction

Research and development of the Ocean Network Seafloor Instrumentation (ONSFI) is a five year project which will research, plan, develop, and test a seabed instrumentation proof-of-concept distributed system, as shown in Figure 1 for the vision diagram. The system will be designed to enable long term wide-area monitoring of seabed processes, including geological imaging and earthquake detection. The project will be built on the local expertise in sensor design, intelligent data networking and in micro-power harvesting. Innovative approaches to enable low-cost self-contained sensory nodes that can communicate among each other and to the Internet through surface master units will be developed through the project.

Rooted in the maritime tradition, the Atlantic Canada region is highly motivated to support novel ocean technologies for exploitation of natural resources, while ensuring environmental sustainability. The growing international emphasis on the management of ocean resources is giving rise to an expanding global market for novel, wide-area intelligent monitoring systems for continental shelves and oceans in general. There is a requirement for the development and use of distributed sensors and sensor systems that provide a cost-effective solution for more accurate, extensive, intelligent, interactive, real-time measurement and monitoring of events in the

marine environment, and on the seafloor in particular. Networked sensors is an area of interdisciplinary research that links sensors science, emerging low-power wireless communications technologies, 'smart' materials, micro-power harvesting technologies and web-based information access. Advances in sensor development such as the utilization of micro-electro-mechanical systems (MEMS) technology is the piece that will bring the desirable characteristic of autonomy to the networked world. The ONSFI project resulted from the recognition of the potential for the development of a seafloor sensor system technology by the researchers at Memorial University. The project entails development of a prototype of a mesh-networked distributed system, called 'Ocean Network Seafloor Instrumentation', with commercialization potential, along with partners from Dalhousie University, Rutter Technologies Inc., with project funding obtained from Atlantic Canada Opportunity Agency (ACOA), a Canadian federal initiative to promote research and development in the region.

The offshore oil and gas industry has experienced significant growth in the Canadian province of Newfoundland and Labrador over the past several years. Through this project, the immediate benefit to the offshore oil & gas industry would be the development of a type of sensor called a seismometer or accelerometer which the industry would use for marine geophysical applications such as monitoring the status of sub seafloor reservoirs. Fixed location seismometers are currently used to monitor land-based petroleum reservoirs throughout their economically-viable lives, but there is a demand from the industry for a comparable technology for use in the offshore.

This research and development project would deploy an array of MEMS-based sensors to form an acquisition network on the seafloor. A seabed-based digital seismometer sensor could allow the full seismic detail to be captured, thereby improving the quality of the final image for the geoscientist. Conventional seismometers and existing seafloor arrays are connected by cabling systems, however, a key component of this project would examine technologies that allow autonomous modules to communicate with each other over an acoustic wireless network, and then use acoustic signals to transmit the data in near real-time, to a surface buoy (master relay station) and on to a satellite link. The envisaged long term deployment necessitates the development of a stand-alone power generation system, and this is another key aspect of the project.

During the course of the five-year project, a basic prototype system is being developed to enable evaluation of a few sensor nodes in a real environment. The fifth year will involve extensive tank testing locally and field trials at Memorial University's Bonne Bay seafloor observatory. It is proposed that continued feedback from the trials will facilitate ongoing sensor enhancement, strengthen underwater acoustic networking, and lead to stable and robust sensors ready for production and commercialization following the completion of the project.

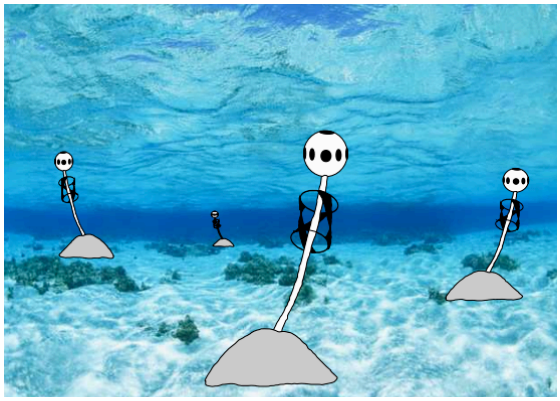

Fig. 1. Vision diagram of the ONSFI Project

2. Project Description

2.1. Objectives

The objectives of the project include:

- Develop ocean bottom sensor technologies for long-term use in harsh marine environments
- Develop a novel networking software and underlying hardware system to enable effective communication of the marine data to end users
- Develop data compression algorithms to process vast quantities of seismic and other marine data with accuracy and fidelity
- Develop a low-cost low-power energy harvesting device for marine use
- Integrate the above technologies in a unit system and test them in real situation.

The initial marine sensor to be developed will be a marine seismometer, to detect and measure seismic data on the seafloor. Existing seismometers operate in mainly terrestrial environments. This incremental research would focus on developing a low-cost low-power three-component seismometer, featuring nearly zero cross-sensitivity and the ability to operate reliable and autonomously over long periods of time in harsh marine environments. Such a seismometer sensor would allow for geological imaging of the ocean bottom for the purposes of oil & gas reservoir management or earthquake/tsunami detection. The marine seismometer would be a micro-electro-mechanical (MEMS) based system and will be the heart of an autonomous sensor device. In addition, this device will include integrated communications technology to monitor and capture/transit high volume seismic data.

The marine sensors would be distributed in a time-synchronized wireless array that can withstand seabed hydrostatic pressures and related adverse marine conditions. Each unit would be powered by a low-cost, low-power energy harvesting device that utilizes ocean bottom currents. The high volume marine data output will require data compression algorithm designs suitable for processing large volumes of seismic data, and research into non-volatile RAM memories to endure 10^{10} read/write cycles. Applied research will need to be completed on clock synchronization techniques among the units to ensure the integrity of the data. Similarly, research will be required in the area of underwater acoustic communication using marine acoustic modems. The data transfer must occur from unit to unit on the seafloor, and then merge into a data stream to a surface buoy or ship, from which it will be transmitted by telemetry to a satellite. The data will need to be available in near real-time, through remote access (on land) for processing at the desktop.

Robust operating systems and a long unit operating life will be key challenges to address in successfully designing a sensor which can withstand marine conditions over time, with built-in redundancy and wireless data transmissions. An illustration of a sensor pod is shown in Figure 2 below.

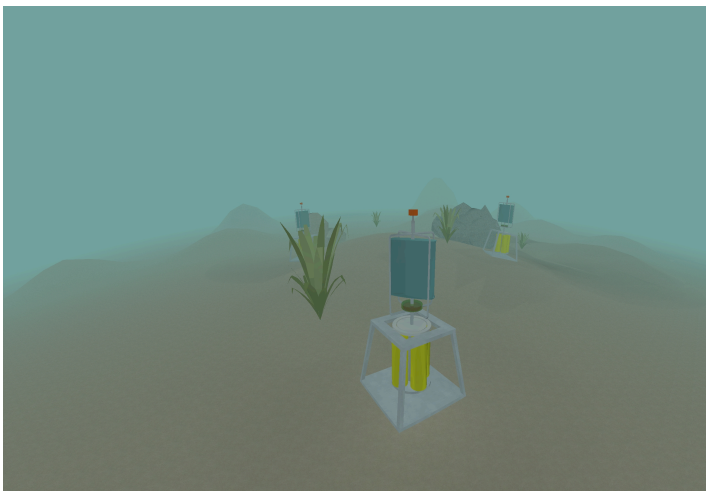

Fig. 2. An illustration of underwater sensor pod

2.2. Sensor Stream

One of the major challenges in the ocean floor seismology is a poor sensitivity of the current three-component seismometers. A high signal-to-noise ratio comparable to the best land stations can be achieved be emplacing the Ocean Bottom Seismometer (OBS) in a shallow borehole in the sea floor, however, a large cross-sensitivity is still a major limitation of the three-component accelerometers that are currently available on the market. The problem with cross-sensitivity in the current three-component seismometers is related to using a flexible link mechanism that supports the inertial mass, also called as seismic or proof mass, in the instrument. It is therefore one of our major objectives to develop a low-power, low-cost seismometer that will feature a nearly zero cross-sensitivity.

In this project, we will research and develop a small three-component seismometer with an electrostatically levitated seismic mass as well as glass fiber suspended seismic mass. The electrostatic levitation will effectively decouple the motion along different axes, resulting in virtually zero cross-sensitivity. On the other hand, a differential measurement of the seismic mass displacement in a fiber suspension can also effectively decouple the motion detection along different axes. Both techniques will be extensively researched and fusion of them in one MEMS device will be considered.

Fiber Bragg gratings have been widely used in various applications in sensors, optical communications or optical signal processing. A dual fiber Bragg grating was exploited to support two lasing modes in an external cavity laser, which were then mixed on a detector to produce a microwave signal. In this project, the dual fiber Bragg gratings will be used to design and implement a seismometer based on gratings sensitivity to physical prolongation. The goal is to design and implement a small compact low cost device that will be reliable and have a long lifetime in the marine environment.

2.3. Power Stream

Power generation in harsh seafloor environmental conditions is a challenge. Batteries cannot store power for a long time. Closed cycle engines need storage of fuel and oxygen for a long time that is not possible in seafloor conditions. Light often does not reach that area, therefore photovoltaic is not an option. Temperature differential is not high, and so, ocean thermal energy cannot be exploited. The only remaining options are a wire linked floating wave energy converter and an ocean current converter. A floating wave energy converter is not feasible since the long wire would pose an obstruction to marine transportation and pose environmental issues; this leaves us with the ocean current energy converter. Nevertheless, there is a limited

ocean current on the seafloor; studies indicate that it may be as high as 0.5*m/s* on the Grand Banks. Therefore, ocean current will be used for energy production.

In the power stream, a seafloor power generating station, such as the one shown in the Figure 3 will be researched and developed. The proposed power generating system will be designed, developed and tested at Memorial University with objective to deliver about 100W of peak electric power to the seafloor observatories (SFOs). The power system will consist of a spiral shape drag type turbine rotor, a multi-pole permanent magnet generator, energy storage, a controlled DC-DC converter, instrumentation and a microcontroller based control system. System will produce the power required for the data processing electronics and signal conditioning circuits.

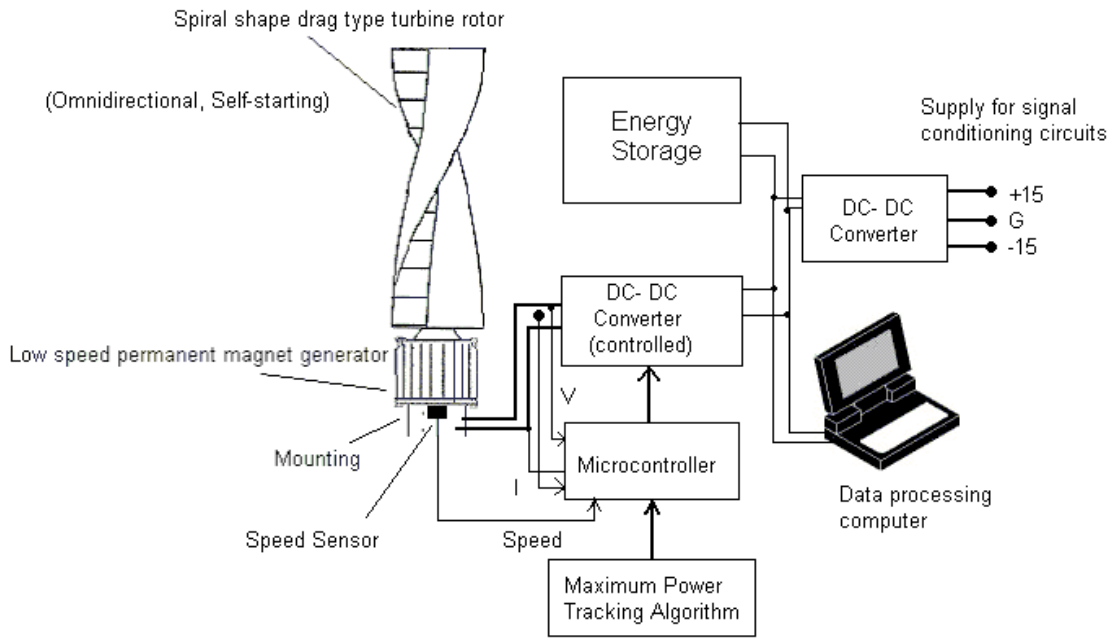

Fig. 3. An example of the power generation function module

2.4. Networking Stream

The harsh environmental conditions posed by the deep sea application, combined with the long-term (>10 years) autonomous functioning requirement of the seafloor observatories (SFOs), necessitate research in a number of areas as well as development of new technologies and diligent adaptation of certain unique:

Tetherless deployment of observatories: Over time, hundreds of SFOs will be dropped to lie on the seabed over an area of several hundred square kilometers. There will be no cabling between these units, nor will there be any cabling between any of these platforms and the Master Relay Station (MRS) that will be housed on a surface buoy. Acoustic communication is envisaged to link the various SFOs and the MRS. Therefore, each SFO would be autonomous not only in terms of generating its own power requirement, but also for taking several vital communication decisions. The communication network architecture and the associated protocols will have to be carefully designed to fit this environment.

Non-functioning units: It is conceivable that, from time to time, certain SFOs would become non-functional, or at least non-communicating. It could take months before this problem is

diagnosed and rectified by dropping another SFO in the vicinity of the failed unit. Thus, it would be required for the entire system to function in the presence of a few failed SFOs; gradual degradation of performance might be acceptable in such a situation. The communication network has to be designed to be fault-tolerant and rugged in the presence of multiple failures. In addition, the design of hardware and software should also incorporate all possible fault tolerance features.

Limited power availability: Each SFO will have to budget the available power for the acoustic communication requirements, as well as for running all the electronic devices in the data processing, data storage and data communication modules. The communication bandwidth should not be high and the communication network should be designed to avoid large power requirement in the SFOs. Efficient data compression algorithms, proper clock speed selection, use of low power electronic components, and the appropriateness of the sophistication level for the network protocols and data processing algorithms are important factors to be considered.

Clock synchronization: The long operating life of the instrumentation network brings about a unique challenge to maintain the clock drift to within acceptable limits so that the accumulated seismic data can be precisely interpreted. For example, clock drift of less than 1 millisecond over one year would be required to guarantee the integrity of the seismic data. However, most of the traditional clock technologies do not provide this precision. Furthermore, each SFO, as well as the MRS, is going to operate on its own independent clock, and so continual synchronization of the clock edges would be in order.

Endurance requirement: The long operating life requirement leads to the need for all the components to provide fault-free function for ten years or longer. One particular area of concern is the storage module that has to endure about 10^{10} read/write cycles. Most of the low power memory technologies available today, for example the flash RAM devices, are rated only for 10^{6} read/write cycles. Therefore, research is in order to identify the appropriate memory technology to suit this requirement.

High pressure environment: In general, the seabed environment is quite friendly for the electronic devices as very little noise or interference exists. However, at sea depths of several kilometers, the pressure would be 200-600 atm. It will be necessary to design and test the instrumentation, data processing and communication components for proper operation at such high pressures.

The tasks for the networking stream include: sensor interface and data processing, data storage and communication networks. An ad-hoc wireless communication network is proposed in this project. Instead of a star configuration where each SFO would be directly connected to the MRS, only a few SFOs that are located within a few kilometers of the MRS would be able to communicate directly with the MRS; these are referred to as Power SFOs, or PSFOs. A distributed ad-hoc communication network will link the various SFOs, and each SFO will have the power required to transmit over 10 kilometers. Thus, each SFO will be able to communicate with several other SFOs. This configuration drastically cuts down the power required in each SFO for communication purposes, but this necessitates multiple hops for the SFOs to be able to communicate with the MRS; thus increasing the traffic in SFOs that are closer to the MRS. The various SFOs will need to exchange the messages necessary to ascertain the availability of alternate routes so that they remain in contact with the MRS.

The sensor interface and data processing unit provides the computational intelligence for a seafloor observatory (SFO) and hence is essential to the SFO operation. The proposed unit is based on a System on a Chip (SoC) approach, which will integrate a microprocessor with the required sensor interface and communications circuitry in a single package. SoC has the advantage that it results in very low power devices that are much more compact and robust than a comparable multi-chip system. The data storage unit has certain specific issues related to endurance. In this project, newly announced technologies such as Ferroelectric RAM, FeRAM, that consume much less power than semiconductor memories, while withstanding up to 10^{10} read/write cycles, will be explored for use. A real-time operating system, which is failsafe and

fault-tolerant to ensure continued operation of the system, will be developed through this project.

Research in this project also aims at developing compression algorithms for seismic data and reliable communication using error control coding.

3. Economic Benefits

The global marine technology industry is estimated to be worth $600B. The fishing industry is worth an additional $80B annually and the offshore oil & gas industry produces more than $10B in annual revenues. It is clear that the marine technology sector is not only extremely lucrative, but an area where advances related to smaller products that have more features, or that are cheaper to produce or have lower energy requirements, would have great global appeal.

TC MID-TERM REPORT

AHSN TC Meeting at Globecom 2009

The next AHSN TC meeting will be held in Honolulu (HI, U.S.A.) during Globecom 2009 on Monday, November 30, 2009, 18:00-20:00, but the room has been changed to Tapa Honolulu Suite #5-6. Please check the link: http://www.ahsntc.trlab.ca/12/ for accessing the meeting minutes of all previous meetings. During Globecom 2009, the new slate of officers has to be elected.

IEEE ICC 2009

At ICC 2009, the "Ad Hoc, Sensor and Mesh Networking Symposium" promises to have a high quality and rich program. It received more than 310+ submissions. The symposium had a high quality program with 110 papers accepted (35% acceptance ratio) and presented in the symposium 18 sessions. The program is available through the link: http://www.comsoc.org/confs/icc/2009/

IEEE Globecom 2009

At Globecom 2009, the "Ad Hoc, Sensor and Mesh Networking Symposium" promises to be a big success with a very high-quality technical program. This one featured 27 sessions of 6 papers each which give 162 accepted papers from more than 470 submissions. Please visit the Globecom 2009 Technical Program for more details: http://www.ieee-globecom.org/

IEEE SECON 2010

The 6th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad hoc Communications and Networks (SECON) was held in Roma, Italy, June 22-26 2009.
SECON 2009 featured a very high-quality program containing:

- Two exciting panels dedicated to “Cognitive Radio Networks: Possible Paths from Research to Real World” and “Trends and Directions in Sensor Network Research”;
- A keynote speech on “Reliable Data Delivery on Unreliable Networks” by Amin Shokrollahi (EPFL);
- 81 papers had been presented in the 21 oral sessions and 26 poster/demos presentations;
- Three workshops: Networking Technologies for Software Defined Networks (SDR), Wireless Network Coding (WiNC) and Wireless Mesh Networks (WiMesh);

- And 15 poster/demos presentation as part of an invited session on European Projects.

For more information please visit this link: www.ieee-secon.org

IEEE ICC 2010

In line with the growing success of the Ad hoc, Sensor and Mesh Networks symposia at the last ICC and Globecom conferences, the AHSN TC co-sponsors the "Adhoc, Sensor and Mesh Networking Symposium" in ICC 2010. The symposium is ranked second in terms of submissions among all ICC 2010 symposiums. The Symposium will be co-chaired by Prof. Nirwan Ansari, Prof. Walaa Hamouda, Prof. Nei Kato, and Prof. Hongchi Shi. For more information please refer to the ICC 2010 webpage: http://www.comsoc.org/confs/icc/2010

Upcoming Events

IEEE SECON 2010

The 7th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad hoc Communications and Networks (SECON) will be held in Boston, Massachusetts, U.S.A., June 21-25 2010.

IEEE SECON provides a forum to exchange ideas, techniques, and applications, discuss best practices, raise awareness, and share experiences among researchers, practitioners, standards developers and policy makers working in sensor, ad hoc, and mesh networks and systems. IEEE SECON grew out of the IEEE INFOCOM conference in 2004, in order to create an event that focuses on the important and exciting topics of Sensor, Mesh and Ad Hoc Communications Networks.

The conference will provide collegiality and continuity in the discussions of the various topics among participants from the industrial, governmental and academic sectors.

Papers describing original, previously unpublished research work, experimental efforts, practical experiences, and industrial and commercial developments in sensor, ad hoc, and mesh communications and networks are solicited.

For more information about IEEE SECON 2010, please visit: www.ieee-secon.org/2010

IEEE Globecom 2010

Globecom 2010 the "Ad Hoc, Sensor and Mesh Networking Symposium" will continue its long tradition. The symposium will be co-chaired by Hossam Hassanein, Xiaohua Jia, Sirisha Medidi, Cheng Li. The deadline for paper submission is expected to be March 15, 2010.

Please visit the Globecom 2010 for more details about the CFP: http://www.ieee-globecom.org/2010/

ANNOUNCEMENTS

IEEE Globecom 2010 SAC Symposium

The IEEE Globecom 2010 Selected Area in Communications Symposium (SACS) will include a Feature Topic on “Vehicular Communications Networks and Systems”. Within this Feature Topic, some points of interest may correspond to the topics addressed by the Ad Hoc and

Sensor Networks community. More information are available through the Globecom 2010 link: http://www.ieee-globecom.org/2010/

IEEE IWCMC 2010 – Vehicular Technology Symposium

The International Conference on Wireless Communications and Mobile Computing (IWCMC) will include this year a symposium related to "Vehicular Technologies". The VT symposium is following the great success of the VehiCom Workshop that was held in June 2009 during IWCMC 2009. The VT Symposium is seeking papers that describe high-quality, original, and unpublished contributions in the area of vehicular communication, networks and systems (VCNS) and intelligent transportation systems (ITS).

Paper submission deadline: December 20, 2009.

For more information, please visit this link: http://www.iwcmc.com/CFP/VTSymposium.pdf