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Nippon Telegraph and Telephone Corporation
NTT Communications Corporation

Successful field experiments on a sensor-data-gathering system based on satellite communications

-Progress towards deployment of a sensor network that covers even mountains and oceans-

Since 2006 Nippon Telegraph and Telephone Corporation (NTT) and NTT Communications Corporation (NTT Com) have been studying the core technologies needed to implement sensor networks that utilize satellite communications through the project "Research and Development of a Highly Efficient Frequency Utilization Technique for Communication Satellite Transponders" [*1] funded by the Ministry of Internal Affairs and Communications (MIC).
Through this research, NTT and NTT Com have developed the "Hyper-Multipoint Data Gathering Satellite Communication System"; it aggregates various observation data streams output by large numbers of sensors spread over nation-wide areas. The system reduces communication costs by more effectively utilizing the limited bandwidths of existing satellite transponders.
Using the Engineering Test Satellite VIII "KIKU No. 8," [*2] NTT and NTT Com have successfully concluded field experiments that saw the collection of sensor data from a vessel sailing on the ocean.
This achievement advances the realization of the sensor network based on satellite communications that supports the "Safe and Secure" and "Disaster-Resistant" society.

1. Background

A "sensor network" permits various sensors to be connected to the network and the extraction of profitable information by combining these sensor data. The sensor network that aggregates meteorological, hydrographic, earthquake information, etc. from wide areas including mountains and oceans, is expected to be a key infrastructure in achieving the "Safe and Secure Society."
Since satellite communications offer extremely wide coverage, they better suit the establishment such a nation-wide sensor network than terrestrial wireless communications. Meanwhile, given the sheer number and variety of sensors, which have various characteristics, the amount of bandwidth needed would excessive if an exclusive channel was assigned to each sensor. It is clear that the bandwidth of a satellite transponder is limited and its cost increases with the bandwidth consumed. Information extraction is only really effective if data from the widest variety of sensors is collected and processed simultaneously.
To address these issues, a low cost and useful sensor network based on satellite communications is required that can use a narrow bandwidth to aggregate a large number of sensor data streams. It also should be able to combine these data effectively and to deliver the results to users via the existing public networks.

2. Features of developed system

NTT and NTT Com have developed a new system that can decrease the transponder cost. It gathers a large number of various data streams from sensors through a narrow

bandwidth by employing "(1) High efficiency channel assignment technique," "(2) High precision frequency synchronization technique," and "(3) Dynamic block demodulation technique." Moreover, the developed system can offer useful services through the Internet by adopting "(4) Environmental information leveraging technique."

(1) High efficiency channel assignment technique
The newly developed system carefully apportions the large number of data streams to channels and then efficiently schedules the channels by referring to the characteristics (data size, period, etc.) of each sensor data stream. This technique minimizes time / frequency gaps between channels and maximizes frequency utilization efficiency by changing the bandwidth of each channel dynamically.

(2) High precision frequency synchronization technique
This technique improves the frequency precision of sensor stations and compresses frequency spacing between channels to increase the number of channels supported with no increase in the bandwidth. By compensating the frequency error caused by the sensor stations and the satellite transponder, frequency error is held to less than 2% of that achieved by the conventional techniques.

(3) Dynamic block demodulation technique
A large number (more than 100) of densely and dynamically assigned channels are simultaneously demodulated by one "block demodulator" in the developed system. Frequency domain signal processing[*3] circuits with bandwidth-oriented processing power allocation achieve this functionality.

(4) Environmental information leveraging technique
Environmental information extracted from various combinations of sensor data is easily fed to WEB applications and well leveraged by using this technique. The technique comprises context extraction[*4] techniques that process / abstract the environmental information gathered via the satellite link and context storing techniques that employ a unified semantic description.

3. Roles of NTT and NTT Com
NTT (Access Service Network Systems Laboratories) has developed the lower layer of the system, i.e., satellite channel management and physical layer transmission schemes.
NTT Com has mainly developed the higher layer of the system, i.e., sensor network management and applications.

4. Outline of field experiments and results
We installed two sensor stations at Tateyama city, Chiba (Tateyama station of Tokyo University of Marine Science and Technology) and Kansai science city, Kyoto (NTT Keihanna building). A gathering station was set up at Yokosuka city, Kanagawa (NTT Yokosuka R&D center). Sensor data from the sensor stations were transmitted to the gathering station via Engineering Test Satellite VIII "KIKU No. 8." Experimental results confirmed that densely and dynamically assigned sensor data were successfully gathered with excellent performance.
We also carried out an application test, i.e., visualization of navigation information by exploiting the sensor data gathered from an experimental vessel sailing on the ocean. In this experiment, we gathered meteorological, GPS positioning, and WEB camera data, etc., from on-board sensors. The developed application successfully drew the

real-time ship track on electronic navigation charts and also demonstrated context extraction functions such as sensor-data-aided ship track prediction.

5. Future plans
To cultivate new markets for the satellite sensor network and to develop new businesses, we are carrying on further studies toward practical applications.

<This work is related to research sponsored by the Ministry of Internal Affairs and Communications through contract research "Research and Development of the Highly Efficient Frequency Use Technique for the Communication Satellite Transponder.">

Footnotes
*1 Research and Development of the Highly Efficient Frequency Use Technique for the Communication Satellite Transponder
This contract research addresses various needs for satellite communications such as satellite support of sensor networks. It also is intended to develop access control techniques and channel spacing reduction techniques for enhanced frequency utilization.

*2 Engineering Test Satellite VIII "KIKU No. 8"
The 8th Engineering Test Satellite that was launched on 2006. KIKU No. 8 was developed by JAXA (Japan Aerospace Exploration Agency), NICT (National Institute of Information and Communications Technology), and NTT to verify fundamental technologies that support future mobile satellite communication and positioning services.

*3 Frequency domain signal processing
This technique converts time-domain-oriented signal transfer to the frequency domain by utilizing Fourier transformation. Advanced signal processes such as filtering and equalization are carried out in the frequency domain.

*4 Context extraction
This technique extracts situations and/or meanings by combining multiple pieces of diverse information.

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