Guest Editorial
Recent Advances in Global Navigation and Communication Satellite Systems

THE INCREASING need of anywhere and anytime telecommunication services as well as multimedia broadcasting, navigation and positioning, remote control of instruments, electronic (e)-learning, and telemedicine, has helped the development of new communication systems that are essentially based on wireless technology. At the same time, the need to bring the previously mentioned services in geographic regions where there are very limited telecommunication infrastructures solves the problem of international digital divide.

Global Navigation Satellite Systems (GNSS) can enable us to determine exact position anywhere on or above the Earth. The first GNSS system that was developed worldwide is the U.S. Global Positioning System (GPS), which was built to meet military needs of the Department of Defense (DoD).

As of 2007, the U.S. GPS is the only fully operational GNSS. The European Union's Galileo system is considered a next generation GNSS and it is scheduled to be operational in 2010.

The Russian GLONASS is a GNSS in the process of being restored to full operation; its operation is hindered due to financial problems.

China has expressed its interest to extend its regional Beidou navigation system to become a global one. India is developing a next generation GNSS system that is expected to be working by the year 2012.

Clearly, the only operational GNSS is the GPS system of the U.S.

GPS receivers are carried by soldiers and attached to vehicles, helicopters, and aircraft instrument panels. GPS receivers are used in several aircrafts and Navy ships for minesweeping and aircraft operations. Moreover, they have become important for nearly all military operations and weapon systems. In addition, they are used on satellites to obtain highly accurate orbit data and to control spacecraft orientation.

New applications of this interesting IT technology have appeared. Vehicle tracking is one of the increasingly growing GPS applications. GPS-equipped public transportation systems, delivery trucks, and courier services use receivers to track their positions at all times. Many fire, police, and emergency medical service units are using GNSS/GPS receivers to find out the police car, fire truck, or ambulance nearest to an accident or emergency site.

Automobile makers are providing moving-map displays guided by GPS receivers as an option to newly sold automobiles. Throughout the construction of the tunnel under the English Channel, British and French crews started excavating from opposite ends: one from Dover in the United Kingdom, and the other from Calais in France. They relied on GPS receivers outside the tunnel in order to check their positions along the way and to make sure they met exactly in the middle. Otherwise, the tunnel may have been twisted.

Land and surveying departments and companies worldwide employ GPS extensively. GPS is used by surveyors, utility companies, and oil and gas surveyors for boundary finding, zoning, and precise positioning. Moreover, GPS technology is used in wireless and cellular networks in order to maintain synchronization between mobiles and base stations as well as to determine the location of mobile users.

In general, a GNSS system consists of three basic components: the space segment, user segment, and control segment.

In the GPS systems, the space segment consists of 24 satellites, each in its own orbit with 11 000 nautical miles above the Earth. They are launched so that we can receive signals from six of them nearly 100%t of the time at any point on Earth. We necessitate that many signals to get the best position information. GPS satellites are always monitored by earth stations that are installed worldwide. These satellites send signals that can be received by anyone with a GPS receiver. The user segment consists of receivers, which can be handheld or mounted in any truck or vehicle. These days, by means of the receiver, we can locate any object with a very good accuracy. The control segment is made up of ground stations (five of them, located around the world); in order to guarantee the proper operation of the satellites. Every GPS satellite requires 12 h to circumnavigate the Earth. Moreover, each satellite is equipped with a precise clock to let it transmit signals coupled with an accurate time message. The ground unit picks up the satellite signal, which travels at the speed of light. The difference between the time the signal is transmitted and the time it is received, multiplied by the speed of light, enables the receiver to calculate the distance to the satellite. In order to measure the accurate latitude, longitude, and altitude, the receiver determines the time it took for the signals from four separate satellites to arrive to the receiver. In general, GPS system can give position anywhere on or above the Earth to about 300 ft. Greater accuracy, usually within less than 3 ft, can be obtained with corrections calculated by a GPS receiver at a known fixed location.

These days, GPS receivers can be hand carried or installed on aircraft, ships, tanks, submarines, trucks, and cars. Such receivers can sense, interpret, and handle GPS satellite signals. There are over than 100 distinct receiver models are already available in the market. The size of the a typical handheld GPS receiver is about the size of a cellular telephone or even smaller for newer versions.

The main concept behind GPS is the measurement of distance (or "range") between the receiver and the satellites. The satellites also can inform us exactly about their orbits above

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the Earth. If we know our precise distance from a satellite in space, we know we are someplace on the surface of a pretended sphere with radius equivalent to the distance to the satellite radius. Now, if we know our accurate distance from two satellites, we know that we are placed somewhere on the line where the two spheres intersect. If we make a third measurement, there are only two possible points where we could be located. One of these is commonly impossible, and the GPS receivers have mathematical schemes to eliminate the impossible location.

GNSS and satellite systems, in general, can be an excellent platform to bridge the digital divide among nations and countries. These systems are strategic technology with significant economic and social impact. It is the only solution for service provision when cable technology is hardly applicable, such as in remote and low-density populated areas, aeronautical services, interplanetary communications, navigation and localization, disaster prediction and relief, safety for critical users, search and rescue, data transmission for maritime environment, aviation and trains, and crisis management. In this view, an integrated vision of navigation and communication solutions is very important. The services where the precise transmission of the position is topical are increasing their importance in strategic sectors such as wireless sensors networks, monitoring networks for the environment, and space missions. The importance of integrating systems that are traditionally dedicated to transport information with systems devoted to acquire data about the user position completed by context-aware information, if needed, is increasing. This is the case of emergency applications over isolated areas where it is important to install and configure an efficient telecommunication network as soon as possible. Designing and implementing mobile stations that can self-determine their physical location, acquire data, and transmit them over a quality-of-service (QoS)-guaranteed satellite system may be topical. On one hand, position data are often part of an overall communication network, which includes also images, videos, and voice, and have special performance requirements in terms of packet loss and delay. On the other hand, position data may also be the core of the service and they need to be supported by an efficient and secure communication system. In both cases a strict integration between navigation and telecommunication system is essential to provide a satisfying service. The success of satellite-based services, including navigation services, is strictly linked to the efficiency of the technological solutions. Among the concerns in this regard, we can mention: interference detection, power and bandwidth efficient adaptive coding schemes, improved access techniques, dynamic bandwidth allocation, high performance transport layers, low cost portable/mobile terminals, and network integration. The latter deserves particular attention as satellite networks need to be integrated with existing wireless and cable solutions and all the mentioned key points need to be seen within an integrated vision. In other words, all actions taken within a network need to be optimized together: 1) medium access algorithms cannot be defined independently of the physical layer solutions and 2) higher layer protocols such as IP, TCP, UDP, and alternatives to them cannot tune their behavior independent of what happens at medium access control (MAC) layer. Each single layer should provide a specific service to the previously discussed layers through predefined standard interfaces and all layers should be involved in the quality provision process. This integrated vision is often called cross-layer approach. In this perspective, an integrated QoS-oriented system is essential for the commercial success because the need to guarantee a wide range of services at a sustainable cost requires the convergence of different solutions and approaches.

This is the framework of this Special Issue that is devoted to global navigation and communication satellite systems that can provide the necessary QoS to the terminal users and fully use the advantages offered by navigation systems.

One of the more relevant issues is the impact that interference can have over a GNSS. Interference detection and mitigation in GNSSs is a key issue both for military and civilian applications. The presence of units, which implement solutions aimed at reducing the impact of disturbing signals, can enhance the accuracy of the transmitted position data and the quality of the overall service. The first step in this direction is the use of multiple antennas, which may be arranged in an array to be used together with array processing algorithms for improving the signal reception, e.g., for multi-path and interference mitigation. This is the topic of the first paper of this Special Issue, "Simulation of multi-element antenna systems for navigation applications," by Hornbostel *et al.* Interference migration is also the topic of the following four papers. The paper entitled, "Performance evaluation of a precorrelation interference detection algorithm for the GNSS based on nonparametrical spectral estimation" by Tani and Fantacci presents a signal processing precorrelation method to detect the presence of interference that could affect a GNSS receiver in the frequency domain. The paper entitled, "Time-frequency excision for GNSS applications," by Borio *et al.*, shows a time-frequency algorithm for interference removal by using infinite impulse-response (IIR) notch filters for cutting the interference out and analytical formulas for the disturbing signals detection. Next, the paper entitled, "Two-pole and multi-pole notch filters: A computationally effective solution for GNSS interference detection and mitigation," by D. Borio *et al.*, tackles the problem that even if in a GNSS receiver the presence of interference detection and mitigation units can be very useful, unfortunately it is usually limited to professional receivers that dispose of additional computational power. The problem can be mitigated by computationally effective solutions such as the multi-pole notch filter presented in the paper, "Integrated NAV-COM systems: Assisted code acquisition and interference mitigation" by Palestini *et al.*, which proposes an integrated navigation-communication network architecture to aid GNSS code acquisition in the presence of interference. A distributed sensor network is in charge of estimating the interference characteristics that are transmitted to a centralized assistance server, which broadcasts them to the terminals along with a rough time and frequency reference to improve code acquisition performance.

As said, the integration of navigation and communication systems should be seen within a cross-layer design as in the paper, "Cross-layer design of dynamic bandwidth allocation in DVB-RCS," by Morell *et al.*, which presents a cross-layer framework to optimize the dynamic bandwidth allocation (DBA) of a DVB-RCS satellite system by using adaptive coding. The design of the MAC methods taking into account the adaptive physical layer and the higher layers' QoS requirements is considered as an optimization problem. Nevertheless, one of the major challenges related to the design of such navigation-communication integrated networks, which often use sensor nodes and multiply different media, is to cope with energy and computational limitations. To address this problem, the paper, "Bandwidth-effective design of a satellite-based hybrid wireless sensor network for mobile target detection and tracking," by Hamdi *et al.*, proposes a hybrid architecture that integrates two sensor categories. The first one performs basic detection and tracking functions, while the second one supports complex tasks such as imaging and broadband communication via a satellite network.

The concept of cross-layer highlights the role of each single functional layer that can tune its behavior over the service received by the layer below. Functional layer optimization is not limited to lower layers but it can extend up until transport layer, as done in the paper entitled, "The TCP "adaptive-selection" concept," by Caini *et al.*, which extends the concept that underlies adaptive coding and modulation (ACM) to the transport layer and introduces a TCP adaptive-selection with the concurrent adoption of different TCP versions on the same server.

The role of navigation-communication system integration is particularly evident in space missions such as the LEO nano-satellite mission in-orbit key-test and validation of W-band (IKNOW), which will be used for a first uplink-downlink satellite channel characterization and in-orbit validation of W-band technology and space qualification processes as part of the of the W-band analysis and verification (WAVE) project. IKNOW is described in the paper, "Experimental missions in W-band: A small LEO satellite approach," by Lucente *et al.* Actually the increasingly development of technologies enabling efficient space exploration and data communications has recently fostered a number of scientific missions, aimed at supporting the research in the field of geology and astronomy. To this aim, the design of an effective telecommunication infrastructure is the challenge offered to research scientists and space engineers. In particular, the definition of a network architecture suitable to support both communication and navigation services is of paramount importance for future space missions. In this view, the paper "High performance communication and navigation systems for interplanetary networks," by de Cola and Marchese, focuses on protocols and architectures used in space missions and considers improved transmission strategies, relying upon packet-layer coding approaches, which are expected to improve the overall performance of the communication system. Working in space often involves not only the need of sending images and videos, but also critical data used to control tools. An example of it is given in the last paper of this Special Issue, "Disturbance observer-based robust control of free-floating space manipulators," by Zhongyi *et al.*, where a disturbance observer-based control scheme is presented for free-floating space manipulators with nonlinear dynamics derived using the virtual manipulator approach (VMA).

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