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NEXT-GENERATION BROADBAND WIRELESS NETWORKS AND NAVIGATION SERVICES

Broadband telecommunications networks provide data transmission at very high rates, and they usually use a frequency spectrum much wider than the frequency bandwidth of the transmitted signal. In practice, a wired telecommunications system might not be called a broadband network unless the data transmission is on the order of at least a few hundreds megabit per second or so. In wireless terminology, however, the practical standards deployed earlier and those soon to be implemented under the umbrella of third-generation (3G) wireless networks refer to much lower data rates. The IMT-2000 3G network, for example, which will soon be in service, can provide a maximum of only 2 Mb/s in indoor environments and to low mobility users.

The issue of quality of service is a major distinguishing factor between wired and wireless networks. Lower throughput, higher delay and delay variation, and higher bit error rate in wireless communications networks than in their wired counterparts are inevitable. For example, in a cellular network small-size user terminals, low image resolution, hidden terminal effect, and low signal-to-noise ratio in blind spots are some of the unavoidable shortcomings of the mobile environment. Currently intensive research efforts aim to provide quality of service in wired networks and especially for the Internet including differentiated services (DiffServ), integrated services (IntServ), and multiprotocol label switching (MPLS) as well as work on traffic management such as admission control and reservation protocols. These research efforts will eventually change the service quality of data transmission over the Internet from its current best effort to guaranteed services.

In a wireless environment however, because of the fundamental limiting factors mentioned above, the progress toward achievement of guaranteed services will be slower, and in some situations such services will be unattainable. Nevertheless, the efforts to enhance the wired network, which will be the backbone network of the wireless networks, can speed up the achievement of guaranteed services in wireless networks at least where such a commitment is possible. There are some wireless-specific methods that can boost progress. Those methods are a result of the mobility consideration in wireless networks and hence related to mobility management techniques.

Mobility management in a mobile network is defined as the collection of techniques that enable the network to locate and keep track of users' locations at varying degrees of granularity, depending on the task at hand. In general, mobility management can be classified into in-session and idle mobility. In-session mobility management has the urgent task of seamless handoffs for ongoing sessions to new radio resources belonging to new access points or new systems. Idle mobility management typically requires less granular location information, such as the location area, to keep track of users' whereabouts. The aim of the latter is to find the user in time in order to be able to deliver services to the user within a given delay budget and overhead signaling volume.

Recently, with wireless geolocation systems and services, determining the coordinates of mobile terminals has become a reality. Geolocation information on mobiles can not only certainly serve mobility management purposes, but also facilitate a new set of services that can be called *location-sensitive services*. The use of geolocation information for mobility management is exemplified by geolocation-aided handoff, where ping-pong handoff requests due to stationary mobiles in cellular overlap regions can be avoided; system boundary ambiguities can be resolved to alleviate unfair roaming charges; zone-based billing can be enabled with greater accuracy, radio resources can be reserved ahead of time for highly mobile users, and so on. Location-sensitive services are those that are custom tailored to the user's whereabouts, such as navigation services, mobile yellow pages, nearcasting, and geocasting. Indeed, the latter family of services gives wireless systems a competitive edge over wired systems by truly catering to the very nature of the mobile system. However, wireless geolocation in itself generates additional signaling complexity and overhead signaling volume, which need to be optimized. The sum of mobility management and location-specific service provisioning can be labeled *location management*. An optimal location management technique would aid in the provisioning of guaranteed services and improving quality of service while minimizing the cost of overhead signaling associated with geolocation and dissemination of location information.

The issue of providing quality of service in wireless networks also opens up the issue of how a particular type of service will be provided to a user when the network or a part thereof is incapable of maintaining the service at a particular time or place. This makes the internetworking of different networks an essential requirement for future networks to provide guaranteed services. Internetworking of heterogeneous networks such as cellular networks and indoor wireless LANs, analog and digital cellular networks, 2G and 3G cellular networks, terrestrial and satellite networks, and finally high-speed wired networks and wireless networks can make it possible for the service provider to switch communications session while maintaining the service at its prescribed quality level. Internetworking, however, requires the availability of seamless and transparent roaming capability among different networks. This multinetwork configuration will describe the future (4G) mobile network.

Having specified location management and internetworking techniques as the most significant parts of the future quality-guaranteed mobile networks, this feature topic issue of *IEEE Communications Magazine* tries to gather up-to-date research activities in the field of next-generation broadband mobile networks and to provide a short tutorial on related state of the art of global achievements. This feature topic can be considered

the second part of the October 2001 special issue of *IEEE Personal Communications* (now *IEEE Wireless Communications Magazine*) on 4G wireless networks and interconnecting standards, organized by the same Guest Editors, as a start to many special issues to come on 4G mobile networks.

This feature topic issue looks at different technologies and protocols that will be required in future wireless networks. Considering the limited space and number of papers allocated to this feature topic issue, it also tries to give a balanced overview of research activities toward 4G networks from academia and industry perspectives as well as in different geographical parts of the world. Three articles from academia in Europe and the United States and two articles from industry located in the United States, Japan, and Europe should be a good combination to summarize those activities. The articles are collaborative works by people from seven different countries on three continents; thus, the guest editors are proud to claim that we present a unique collection of high-quality articles within a limited space that can be used for long time as a reference edition. The guest editors had to choose from a large number of papers submitted in response to the open call for this issue. All papers were reviewed by experts in the field, and due to space limitations many good papers could not be included in this special issue.

In the first article, "Indoor Geolocation Science and Technology," K. Pahlavan, X. Li, and J.-P. Makela from Worcester Polytechnic Institute, United States, and the University of Oulu, Finland, provide a comprehensive tutorial on the existing technologies for wireless indoor location systems and introduce potential research topics related to this field. The article states that the currently available global positioning systems (GPS) and wireless enhanced 911 (E-911), though having the same goal of location finding, could not provide accurate indoor geolocation. Indoor geolocation has important applications in commercial, public safety, and military areas, and an accurate technology is accordingly required. The article gives a clear explanation of channel characteristics for indoor geolocation and illustrates several experimental results. It then summarizes several positioning algorithms. The major challenges for such accurate location finding are listed in the paper as the complexity of the radio propagation and the deployed infrastructure in these areas.

In the second article, "Wireless Networks Based on High Altitude Platforms for the Provision of Integrated Navigation/Communication Service," D. Avagnina, F. Dovis, A. Ghiglione, and P. Mulassano from Dipartimento di Elettronica-Politecnicodi Torino, Italy, describe high-altitude platforms (HAPs). HAPs have been of some peripheral interest to the wireless community for some time. These platforms are expected to provide mobility on demand, large coverage, and payload reconfigurability to personal and wireless communications systems in the future. The article provides an overview of different system concepts such as payload and segment, and discusses the feasibility of integrating HAPs with 3G and beyond wireless networks such as UMTS and navigation systems. The authors present HAPs as a promising infrastructure for future systems that will require the coexistence of navigation and communication stations for the provision of integrated services.

In the third article, "MIRAI Architecture for Heterogeneous Networks," G. Wu, P. J. M. Havinga, and M. Mizuno from Communications Research Laboratory, Japan, introduce the Multimedia Integrated Network by Radio Access Innovation project as part of the Japanese government e-Japan plan. The project is about to seamlessly integrate various wireless access systems for practical use by 2005. A common tool, a common platform, and a common access are the essential parts of the architecture proposed in this article. The common tool is a multiservice user terminal based on software-defined radio technology for access to different wireless networks. The common platform is based on a wireless version of the IPv6 network protocol. Accordingly, the article provides a nice tutorial on all those topics and lists the potential implementation milestones.

The fourth article, "Designing the Internetworking of Terrestrial and Satellite IP-Based Networks," by A. Iera and A. Molinaro from the Universities of Reggio Calabria and Messina, Italy, addresses the issue of interworking between a multimedia terrestrial backbone and a satellite access platform. The idea is to transport large-scale multimedia and IP data with guaranteed quality of service over such an integrated network. The architecture of such an integrated terrestrial-satellite platform based on IP connectivity through interworking units (IWUs) is discussed in the article. This can be considered a good tutorial on how global coverage can be realized in future wireless networks with the help of satellite networks, and at the same time quality of service can be guaranteed.

The fifth article, "Global Roaming in Next-Generation Networks," by T. B. Zahariadis, N. A. Nikolaou, K. Vaxevanakis, Ch. Tsantilas, and N. A. Zervos from Bell Laboratories, Greece, Lucent Technologies, The Netherlands, and Lucent Technologies, United States, provides a tutorial on mobility management in the existing wireless cellular networks and its requirements in future generation of wireless systems. The article discusses mobility management for indoor wireless infrastructure such as wireless LANs and also for global satellite systems.

Finally, as the guest editors of this feature topic issue, we hope the readers find it interesting and consider it a useful guide to research and development activities toward next-generation wireless networks and the new telecommunication era. We would like to thank all authors and reviewers who made this feature topic issue a unique edition of novel activities in this field.

BIOGRAPHIES

ABBAS JAMALIPOUR [S '86, M '91, SM '00] (a.jamalipour@ieee.org) has been with the School of Electrical and Information Engineering at the University of Sydney, Australia, since 1998, where he is responsible for teaching and research in data communication networks and satellite systems. He received his Ph.D. in electrical engineering from Nagoya University, Japan, in 1996. He was an assistant professor at Nagoya University before moving to Sydney. His current areas of research include wireless broadband data communication and wireless ATM networks, wireless IP networks, mobile and satellite wireless communications, traffic modeling and congestion control, switching systems, and switch design. He is the author of the first technical book on LEO satellites, entitled *Low Earth Orbital Satellites for Personal Communication Networks* (Artech House, 1998). He is an organizing committee member of the joint IEEE NSW Communications and Signal Processing chapter. He is the recipient of a number of technology and paper awards and author of many papers in IEEE and IEICE Transactions and Journals as well as in international conferences. He also serves as Secretary to the IEEE ComSoc Technical Committee on Satellite and Space Communications.

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