

## TOWARD SEAMLESS INTERNETWORKING OF WIRELESS LAN AND CELLULAR NETWORKS

Cellular networks have successfully been used in licensed spectrum for more than a decade. As a result of the increasing number of bandwidth demanding Internet-based applications for mobile users and the clear indication that third-generation wireless cellular systems (3G) will not be able to match those data rate requirements, a new direction of research and development for mobile data transmission has emerged. This new trend is referred to as beyond 3G (B3G) or 4G mobile wireless service. Although there is no consensus on the actual definition of B3G or 4G systems, it is evident that in the next generation of wireless technologies services should be available to users ubiquitously with no or minimal degradation when the user is mobile. Given the numerous available technologies, it is imperative to design consolidated solutions that can operate seamlessly on multiple platforms. Consequently, many think of B3G or 4G as an integration of current wireless technologies.

The proliferation of wireless local area networks (WLAN) in recent years has created a new momentum for research and development in low-range high-bandwidth wireless connections. IEEE has introduced a sequence of standards, mainly the IEEE 802.11 series. Despite a short lifetime, this standard has evolved through several phases by creating 802.11b/g, 802.11a, and recently 802.11n versions. Similarly in Europe, the European Telecommunications Standard Institute (ETSI) has developed the series of HiperLAN standards for short-range wireless communications. The success of these technologies can be associated with the use of unlicensed spectrum, which results in reduced equipment and operating costs. The time to market for such technologies has also been reduced by forming initiatives such as the WiFi Alliance.

As more places are becoming hotspots, more and more mobile service providers have started to think of consolidating WLAN and cellular networks, which could satisfy their customers' demands for high-speed Internet applications without sacrificing the huge investment made in the cellular network infrastructure. This trend has initiated a new era in mobile data communications in which the two separately developed networks of cellular communications and the Internet are working together for better overall service. The integration of WLAN and cellular systems has thus become the new focus of academic and industrial research, and standardization organizations such as the Third Generation Partnership Project (3GPP), which is mainly following the Universal Mobile Telecommunications System (UMTS) development, have started to carry out feasibility studies for this integrated network.

The integration of cellular mobile and WLAN systems should be viewed and investigated from several perspectives. The main challenge would be the architecture of the integrated network that could include both cellular system components and WLAN elements. The WLAN network standard (e.g., IEEE 802.11 and HiperLAN) that should be used in the integrated system, network management entity (IP backbone vs. cellular core network), resource management, data and signaling links from one or both systems, database management, customer billing and charging, customer services, service authorization, and user authentication, among others, are issues that require consideration. On top of all these issues, how air and network security could be ensured between



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the two completely different systems is a major challenge. Despite all challenges, the increasing acceptability and use of WLAN in recent years, and the introduction of inexpensive personal computers and handheld devices with embedded WLAN access cards have pushed the technology to work faster toward a successful integrated system. However, since an integrated solution has not yet materialized, many users currently use separate systems, which as a consequence might slow down the development activities for an integrated solution.

No matter how useful the cellular-WLAN integrated network will be, or how achievable in the near future, its respective research should be seen as an important step toward a much greater technology, that is, a heterogeneous network architecture that, with the support of several different access technologies and a common core network, would provide multiple services at high speed and with quality of service (QoS) to mobile users. In that sense, the interim technologies and their success would not be considered a main issue that affects the bigger goal of next-generation networks. Having this in mind, we have organized this special issue hoping that the articles presented here will have a greater span that indeed goes beyond 3G/WLAN integration.

This special issue of *IEEE Wireless Communications* is devoted to the research activities within industry and academia toward the integration of WLAN and cellular systems. Articles for this special issue were solicited through an open call for papers that attracted a large number of submissions. We have tried to accommodate research and tutorial papers discussing different aspects of WLAN, cellular systems for Internet connectivity, integration of the two systems, and performance analysis. The response to our open call for papers was so overwhelming that we could not include all good papers submitted. As a result, we included only the highest ranked papers after a meticulous peer review process. This shows the importance of the topic among the research community all around the world. As mentioned earlier, we believe that the topic is not only important for its current goal of integrating WLAN and cellular networks, but has a greater target in future generations of mobile networks consisting of many heterogeneous systems.

As the Guest Editors, we would like to thank all authors who responded to the call for papers, regardless of whether their paper has been included in this issue or had to be rejected due to space limitations. We would also like to express our sincere thanks to all the reviewers who did an excellent job. The result of all those efforts is the following eight articles that passed the magazine requirements. We would also like to thank Michele Zorzi, the magazine's Editor-in-Chief, who provided us this space.

The first article, "Seamless Continuity of Real-Time Video across UMTS and WLAN Networks: Challenges and Performance Evaluation" by A. K. Salkintzis, G. Dimitriadis, D. Skyrianoglou, N. Passas, and N. Pavlidou, discusses seamless interworking of WLAN and 3G cellular networks. The main application considered in this seamless interworking is real-time video. Through simulations, the authors have investigated the feasibility of session continuity when a video session needs to be handed over between WLAN and 3G UMTS systems.

The architectural requirements of the integrated network are also addressed in this article.

The second article, “Toward a Generic ‘Always Best Connected’ Capability in Integrated WLAN/UMTS Cellular Mobile Networks (and Beyond)” by V. Gazis, N. Alonistioti, and L. Merakos, looks at future 4G networks, where a mobile user is expected to be connected to the most optimum network at any time, known as “always best connected.” This concept is investigated within the internetworked WLAN and UMTS systems. Major implications and limitations of such integrated network toward the always best connected platform are also discussed in this article.

In the third article, “Issues in Integrating Cellular Networks, WLANs, and MANETs: A Futuristic Heterogeneous Wireless Network,” D. Cavalcanti, C. Cordeiro, D. Agrawal, B. Xie, and A. Kumar go beyond the boundaries of this special issue by introducing an architecture for state-of-the-art heterogeneous multihop networks. The article deals with the integration of different wireless networks — not just the WLAN and cellular systems — and identifies research issues that need to be addressed for successful integration of heterogeneous technologies for next-generation wireless mobile networks.

The fourth article, “Network Selection in an Integrated Wireless LAN and UMTS Environment Using Mathematical Modeling and Computing Techniques” by Q. Song and A. Jamalipour, investigates another important issue toward integration of WLAN and cellular networks, and ultimately multiple networks. The article proposes a selection technique between two or more available networks in a heterogeneous environment. While the article uses the example of WLAN and UMTS systems as the only available networks, the topic may be extended to multiple-network environments.

The fifth article, “A Framework for Seamless Roaming across Cellular and Wireless Local Area Networks” by N. Shenoy and P. Mishra, looks at a framework to support roaming across cellular and WLAN systems. The proposed framework includes a robust architecture for mobility management for different types of user mobility, QoS provisioning, intersystem message translation, and mechanisms to support user-subscribed services in the WLAN.

In the sixth article, “Interworking of IP Multimedia Core Networks between 3GPP and WLAN,” F. G. Márquez, T. R. Valladares, L. A. Galindo, M. G. Rodríguez, and T. de Miguel consider a technical contribution to the 3GPP IP multimedia subsystem for provisioning of multimedia services in UMTS. The article analyzes how the interconnection of 3GPP and WLAN networks may be performed in order to support different levels of service interconnection.

The seventh article, “SIP-Based Vertical Handoff Between WWAN and WLAN” by W. Wu, N. Banerjee, K. Basu, and S. K. Das, considers Session Initiation Protocol (SIP) for handling mobility management protocols in heterogeneous networks. The article highlights the excessive delay associated with the use of SIP as an application layer protocol and how this would affect the interconnected WLAN and UMTS systems.

The special issue concludes with the article “Seamless Inter-

working of WLANs and Cellular Networks: Architecture and Performance Issues in a Mobile IPv6 Scenario,” by M. Bernaschi, F. Cacace, G. Iannello, A. Pescapé, and S. Za. This article studies a new approach to the integration of WLAN and cellular networks based on loosely coupled architecture. The model and experimental results on internetworking performance at the network layer are also provided in the article, with some ideas on how this performance could be improved.

The Guest Editors hope that *IEEE Wireless Communications* readers find this special issue interesting and consider it a useful guide in research and development activities toward efficient integration of WLAN and cellular systems, and that this issue opens a broader research area toward the next-generation heterogeneous systems. This special issue is not the first on WLAN-cellular network integration and will not be the last. The topic of efficient internetworking will remain an important and strategic research challenge in the field of computer and telecommunications engineering for years to come.

## BIOGRAPHIES

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