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Mobility management across hybrid wireless networks: Trends and challenges

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Abstract

Future generation wireless networks are envisioned to be a combination of diverse but complementary access technologies. Internetworking these types of networks will provide mobile users with ubiquitous connectivity across a wide range of networking environments. The integration of existing and emerging heterogeneous wireless networks requires the design of intelligent handoff and location management schemes to enable mobile users to switch network access and experience uninterrupted service continuity anywhere, anytime. Real deployment of such mobility strategies remains a significant challenge. In this article, we focus on handoff management. We discuss in detail handoff decision and implementation procedures and present recent handoff techniques that aim at providing mobility over a wide range of access technologies. We also discuss some of the capabilities of mobile terminals that are necessary to implement seamless mobility over hybrid wireless networks. Furthermore, we also present and discuss limitations of recent handoff design architectures and protocols as well as outstanding challenges that still need to be addressed to achieve portable and scalable handoff solutions for continuous connectivity across wireless access networks.

Keywords: Wireless; Heterogeneous; Overlay; Mobility; Handoff; Multimode; Protocol

1. Introduction

Mobile wireless technology has gained tremendous popularity due to its ability to provide ubiquitous information access to users on the move. However, presently, there is no single wireless network technology that is capable of simultaneously providing a low latency, high bandwidth, and wide area data service to a large number of mobile users. *Wireless Overlay Networks* [1]—a hierarchical structure of room-size, building-size, and wide area data networks solve the problem of providing network connectivity to a large number of moving consumers in an efficient and scalable way. In an overlay

Abbreviations 3G, third generation; 3GPP, third generation partnership project; AAA, authentication, authorization and accounting; ACK, acknowledgement; ADSL, asymmetric digital subscriber line; AR, access router; ASCONF, address configuration; BS, base station; CA, congestion avoidance; CAR, candidate access router; CARD, candidate access router discovery; CD, communication daemon; CDMA, code division multiple access; CN, correspondent node; cSCTP, mobile stream control transmission protocol; CTAR, context transfer activation request; CTD, context transfer data; CTP, context transfer protocol; CTR, context transfer request; DAB, digital audio broadcasting; DCCP, datagram congestion control protocol; DECT, digital enhanced cordless telephone; DHCP, dynamic host configuration protocol; DMT, discrete multitone; DNS, domain name service; DSP, digital signal processors; DSSS, direct sequence spread spectrum; DVB, digital video broadcasting; EDGE, enhanced data rates for GSM evolution; FA, foreign agent; FDD, frequency division multiplexing; FHSS, frequency hopping spread spectrum; FS, fixed server; GPRS, general packet radio service; GSM, global system for mobile communication; GWFA, gateway foreign agent router; HA, home agent; HiperLAN, high performance radio local area network; HOPOVER, handoff protocol for overlay networks; HP, handoff-prepare; HSCSD, high-speed circuit-switched data; IETF, internet engineering task force; IMT, international mobile telecommunications; IP, internet protocol; L2, layer 2; LSS, location-service server; MN, mobile node; MR, multicast router; MSC, mobile switching center; mSCTP, mobile stream control transmission protocol; NACK, negative acknowledgement; NAR, next access router; OFDM, orthogonal frequency division multiplexing; PSTN, public switched telephone network; QAM, quadrature amplitude modulation; QoS, quality of service; QPSK, quadri-phase shift keying; RNC, radio network controller; RRC, radio resource control; SCTP, stream control transmission protocol; SDR, software-defined radios; SIP, session initiation protocol; SS, slow start; TCP, transmission control protocol; TDD, time division multiplexing; TDMA, time division multiple access; UMTS, universal mobile telecommunications system; VDC, virtual domain controller; VoIP, voice over internet protocol; WG, working group; WLAN, wireless local area network.

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network, lower levels are comprised of high bandwidth wireless cells that provide a small coverage area. Higher levels in the hierarchy provide a lower bandwidth but a much wider access network. A mobile device with multiple wireless network interfaces can access these networks as it moves between different network environments. Next generation wireless systems typically constitute different types of access technologies [15]. The heterogeneity that will characterize future wireless systems instigates the development of intelligent and efficient handoff management mechanisms that can provide seamless roaming capability to end-users moving between several different access networks.

2. Wireless overlay networks

Fig. 1 shows a typical structure [2] of wireless overlay networks. First, the networks' service areas are overlapped. For example, the General Packet Radio Service (GPRS) network acts as an umbrella network to the Wireless Local Area Network (WLAN) network. Even the different cells of the same network overlap. This overlapping can be utilized to reduce service disruption, by simultaneously connecting to different subnets of the same access technology during transition from one network to another. Second, the networks support different data rates and cell sizes. For instance, IEEE 802.11b WLAN supports a data rate of 11 Mbps and GPRS a much lower data rate of about 9.6 Kbps. Third, because of the different characteristics of the networks involved, it is not possible to compare the signal powers received from the base stations of different networks to decide which network to connect to. Fourth, each network may offer a different level of reliability, security, quality of service etc. As mobile hosts move across different networks, a mechanism for conveying the new IP address to the correspondent nodes is required. Also, the power consumed by the network interfaces is different for each network technology and is directly proportional to the transmitted power. For example, the Code Division Multiple Access (CDMA) transmitted power is much higher as compared to WLANs.

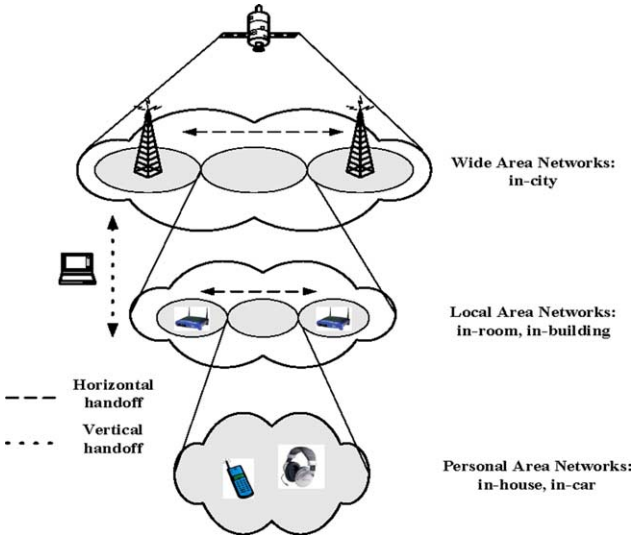

Fig. 1. Wireless Overlay Networks.

Currently, several wireless technologies and networks exist that capture different needs and requirements of mobile users. For high-data-rate local-area access, WLANs are satisfactory solutions [8]. For wide-area communications, traditional cellular networks may provide voice and data services. For worldwide coverage, satellite networks have been used extensively in military and commercial applications. Since, different wireless networks are complementary to each other, their integration will empower mobile users to be connected to the system using the 'best available' access network that suits their needs. Next generation wireless systems are envisaged to be a combination of a plethora of networking technologies. Fig. 2 illustrates a typical network architecture for next generation heterogeneous systems.

Some key features [3] of next generation heterogeneous access networks include:

- High usability with anytime, anywhere connectivity.
- Support for multimedia services with low transmission cost.
- Integrated access networks with a common IP-based core.
- Use of multimodal devices (capable of supporting various types of network access technologies).
- Support for telecommunication, data and multimedia services.
- Support for personalized services.
- Support for integrated service access from various service providers.

Table 1 shows some of the technologies, which will be part of future heterogeneous systems along with their characteristics.

3. Handoffs in wireless overlay networks

Handoff is the process by which a mobile terminal keeps its connection active when it migrates from the coverage of one network access point to another. Different types of handoffs can occur in wireless overlay networks.

3.1. Horizontal vs. vertical handoff

Handoffs that occur between the access-points of the same network technology and are termed *horizontal handoffs* or *intra-system handoffs* [4]. In other words, horizontal handoffs occur between homogeneous cells of a wireless access system, example between two cells of a cellular system, etc. Handoffs that occur between different access-points belonging to different networks (example WLAN to GPRS) are referred to as *vertical handoffs* or *inter-system handoffs*. Thus, vertical handoffs are implemented across heterogeneous cells of access systems, which differ in several aspects such as bandwidth, data rate, frequency of operation, etc. The different characteristics of the networks involved make the implementation of vertical handoffs more challenging as compared to horizontal handoffs. The terms horizontal and vertical follow from the overlay network structure that has networks with increasing cell sizes at higher levels in the hierarchy. Vertical handoffs are