ISSUES AND CHALLENGES TO IMPLEMENT SEAMLESS MOBILITY IN WIRELESS NETWORKS

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ABSTRACT

The main objective of next generation wireless networks is the integration of independently developed communication networks/systems such as ISDN, Wired/Wireless internetworks and Optical Networks. Proper integration of these emerging technologies will pave a way for convergence of communication systems, information technologies and Internet world with high degree of quality of service along with the global seamless mobility. This paper describes the functional requirements and challenges of seamless mobility in wireless networks. The various issues pertaining to seamless mobility and possible tradeoffs in order to resolve these issues are discussed. To conclude, future generation wireless networks will be fully IP-based wireless Internet with global connectivity.

Keywords: Cellular Systems, Internetworking, Mobility, Seamless, Wireless Networks.

1. INTRODUCTION

The first generation analog cellular systems used large cells and omni directional antennas in the 800 MHz band. The AMPS and ETACS systems use a seven-cell reuse pattern with provisions for cell-sectoring and cell-splitting to increase capacity when needed. First-generation analog cellular systems were followed by second-generation, digital cellular systems. Digital wireless technologies support a much larger number of mobile subscribers within a given frequency allocation (i.e. higher capacity), provide superior security and voice quality, and lay the foundation for the value-added services (including data) that will continue to be developed and enhanced in future.

The wireless terminal has the potential to become a generic platform for, or gateway to, the complete range of communication services; that is, voice, data, video and multimedia. And network operators recognize that future revenue streams in competitive and mature markets will not be generated solely from providing voice connections, but also from more sophisticated services. The existing digital wireless standards continue to be developed, particularly as related to value-added services, capacity, coverage, costs and bandwidth. Three of the present cellular standards (D-AMPS/IS-136, GSM and CDMA/IS-95) are expected to provide third-generation capabilities. Therefore, one of the most important requirements of the 3G system is that it provides a seamless path of migration from present-day digital wireless networks that it be capable of inter-working.

All major providers of wireless network systems, services and terminals agree that future third-generation wireless systems should evolve from the core infrastructures contained in today's digital networks. The first enhancement for increasing data rates to reach commercial deployment will be high-speed circuit-switched data (HSCSD). Initially, this enhancement will support data rates up to 57.6 kbps using four 14.4 kbps time slots. General packet radio services (GPRS) is a packet-switched service that will allow full mobility and wide-area coverage with data transmission rates up to 115 kbps. Enhanced data rates for GSM evolution (EDGE) will use enhanced modulation and related techniques, further improving local mobility (typically in urban areas) with data rates up to 384 kbps. The existing GSM carrier bandwidth of 200 KHz will remain unchanged as will the complete TDMA frame structure, logical channel structure, frequency plans and methods. Channels with EDGE functionality will be able to operate in either GSM/GPRS or EDGE modes. Coexistence of this kind in the same network will make it possible to introduce EDGE technology incrementally. Operators will be able to offer third-generation wireless services in any of today's GSM frequency bands: 900, 1800 and 1900 MHz.

Existing standards evolving to give third-generation capability, when fully evolved, the GSM and D-AMPS air-interface standards will be IMT-2000 systems using EDGE technology. As such, they will allow—with comparatively little new hardware and software upgrades— future-generation wireless network services to be offered [1].

2. LOOKING TO THE FUTURE WIRELESS NETWORKS

Recent years have witnessed the rapid evolution of commercially available mobile computing environments. This has given rise to the presence of several viable, but non-interoperable wireless networking technologies – each targeting a mobility environment and providing a distinct quality of service. The lack of a uniform set of standards, the inconsistency in the quality of service, and the diversity in the networking approaches make it difficult for a mobile computing environment to provide seamless mobility across different wireless networks. Besides this, inter-network mobility will typically be accompanied by a change in the quality of service. The application and the environment need to collaboratively adapt their communication and data management strategies in order to gracefully react to the dynamic operating conditions.

The next significant development in wireless communication will consist of enhancements to the radio access that enable true multimedia services to be delivered at high bit rates. New third-generation wideband systems will deliver bit rates up to 384 kbps for wide-area coverage, and 2 Mbps for indoor or fixed applications, maximizing the efficiency of available radio spectrum. Today's digital wireless networks and standards will also evolve to provide similar capabilities. To realize the potential of seamless mobility and ensure continued profitability, mobile service providers have to focus as equally on WLAN implementations as they do on their cellular WWANs. Wi-Fi (Wireless Fidelity) and traditional wireless services are add-on that can exist and succeed together and provide consumers what they want, when they want it.

Customers will use these technologies for different reasons and at different times. The 2.5G and 3G technologies such as GPRS, EDGE, CDMA 1xRTT, and CDMA 1xEV-DO will be used for applications requiring instant access of bursty data like e-mail, text messaging, and multimedia message service (MMS), among others. But WLANs will be used in specific locations where users need access to their corporate files and Intranets. To provide the new WCDMA radio access, ETSI has decided to base the UMTS core network on the core switching network evolved from GSM. Furthermore, the ITU has allocated a new 2 GHz frequency band to third-generation services (IMT-2000) being used in Europe and most of Asia (including Japan). However, WCDMA can also be deployed in existing reformed frequency bands (initially, 2x5 MHz minimum). [2]. The new WCDMA access will coexist with existing and evolved GSM access and, with the help of dual-mode mobile terminals, will support full roaming and handover from one system to another. The use of dual mode terminals in the introductory phases of WCDMA ensures that subscribers can roam and interwork with the rest of the GSM community from the very outset.

3. ROLE OF NEXT GENERATION CELLULAR NETWORKS

With the advancement in mobile information technologies like ultra high-speed transmission, wireless Internet protocol (IP version 6), user-controllable software defined radios, and the potential users would be able to

- Access the Internet as they do in the office – anywhere, anytime but on the move.
- Use cell phone or laptop computer or any other PDA (Personal Digital Adaptor) as mobile communication terminal.
- Choose freely the services, applications and service providing networks.
- Achieve advanced mobile E-commerce applications with higher levels of data security and integrity during transactions.

This would also mean enhancement of present 2G/2.5G/3G Cellular systems. The usage environment would demand high-speed wireless access techniques in hot-spots i.e. inadequate signal reception areas or indoor multi-structured buildings, and would also require ultra short-range connectivity in order to access laptop or desktop terminals with a remote wireless digital device using technology such as blue-tooth or Wi-Fi.

4. FUNCTIONAL REQUIREMENTS

i) Very high-speed and high-quality transmission: Future mobile communication systems should be able to handle a large volume of multimedia information like downloading a full song or sending a complete data file or several video clips. This would be possible by various means like transmitting data at 50-100 Mbps, having asymmetric data speeds in up and down links, having continuous coverage over a large geographical area, applying quality of service (QoS) mechanism (e.g. efficient encoding, error detection and correction techniques, echo cancellers, voice equalizers, etc.) at low, affordable and reasonable operating costs, etc.

ii) Flexible and varied service functions: Future mobile communication networks should be "seamless" with regard to media that means whether it is wireless or optical fiber or satellite or wire line, with regard to corresponding hosts or service provider as well as interconnectivity with other networks like GSM or CDMA or other telecom networks.

iii) Open platform: Future mobile communication systems should be "open" regarding mobile terminal platform, service nodes, and mobile network mechanisms. That would mean that user can freely select protocols, applications and networks. Advanced service providers (ASPs) and content providers can extend their services and contents independent of operators. Location and charging information can be shared among networks and applications.

iv) Expected Characteristics of Future Systems: About the expected characteristics of future mobile communication systems. The future systems will be just like a shopping mall where we can get any item ranging from household articles to infrastructure items, raw material to finished goods, various service functions like banking or postal or insurance, etc. That means the user can flexibly select the optimum wireless service according to the usage environment. This will be achieved by very high-speed transmissions in cellular environments with high grade of mobility.

v) System Perspective: Now, let us see how the future mobile communication system can be realized. Advanced cellular systems and high-speed wireless access systems will be functionally integrated into the future mobile communication systems. That means the existing cellular systems will be upgraded to introduce new features. For example**,** the downlink transmission peak bit rate will be achieved around 30 Mbps in 3.5G cellular systems by the year 2008 and 50-100 Mbps in 4G cellular systems by the year 2010 by introducing software defined radio technologies. Data rates exceeding 100 Mbps will be achieved by introducing high speed wireless access systems in selective hot spot services required by chief executives or chairman of reputed companies. The future systems will have integrated and advanced functions like multimedia mobile communications including high resolution video transmission, selection of services and applications by customers i.e. stock news, weather forecasting, location services, and seamless connection with other transmission media as well as achieving higher levels of security and authentication.

vi) Spectrum Requirements: So far what we have discussed is that future mobile system should be able to provide enhanced data transmission capabilities. For this we have to pay the price in terms of an additional spectrum of 1.2~1.7 GHz bandwidth. This estimation of additional spectrum is based on

- Enhanced service requirements.
- Introduction of ultra high-speed multimedia i.e. downlink 100 Mbps, uplink 30 Mbps or very high-speed multimedia i.e. downlink 30 Mbps, uplink 3 Mbps services.
- Rate of increase in traffic at least to be @ 50% per year.

At present 3G mobile systems like GSM cellular are operating in the frequency band of 900 MHz or 1.8 GHz, and CDMA based cellular systems are operating at 1.9 GHz. The future 4G mobile systems shall operate in frequency band of 1.7~2.5 GHz or 2.4~4.5 GHz. Frequency band above 5~6 GHz is not suitable mainly because the signal loss caused by the shadow of a human body increases significantly. [3], [4]. So, now we can say that Future Mobile communication Systems are on the move towards enhanced transmission speeds in terms of higher and higher data rate, marching ahead to achieve several 100 Mbps. The technology is migrating fast from 3G to 3.5G to 4G and so on for cellular mobile as well as indoor or hot spots environment for usage. The interworking among various phases of technologies shall be maintained. [5].

5. SEAMLESS MOBILITY – REQUIREMENTS AND CHALLENGES

There is a powerful trend towards seamless mobility in the cellular world, where mobile professionals today and eventually all consumers in the future would like to communicate and be able to do their routine business anytime, anywhere. As a result, there is real demand for ubiquitous connectivity between a wide variety of mobile devices and access technologies, which include Wireless Wide-Area Networks (WWANs) and Wireless Local-Area Networks (WLANs). Roaming and communications among these technologies are therefore "must-haves" for seamless mobility to occur. The new generation of wireless networks is intended to provide accessing information anywhere, anytime, with a seamless connection to a wide range of information and services, and receiving a large volume of information, data, images, video, and so on. The future network infrastructures will consist of a set of various networks using IP as a common protocol so that users are in control to choose every application and environment. Figure 1 demonstrates the seamless connectivity of the future Communication Networks. [6].

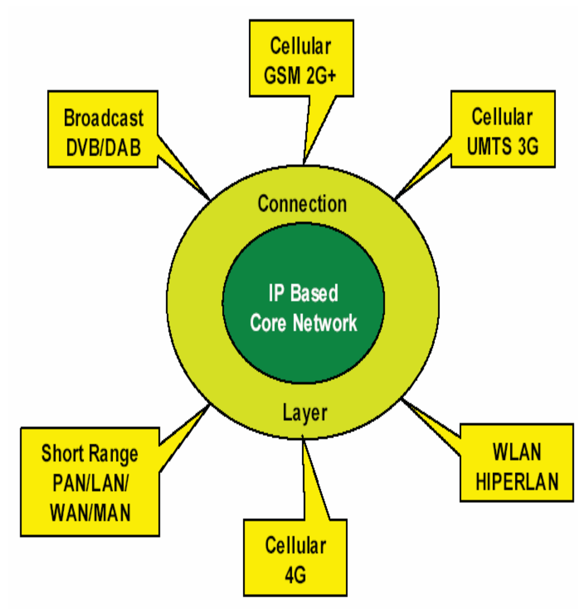

Fig. 1: Seamless Connectivity of Communication Networks

Seamless Mobility is the result of extensive primary and secondary research on a variety of industry participants including cellular service providers, equipment suppliers, Internet Service Providers (ISPs), electronic component manufacturers, and software providers, among others. Studies have been made to exploit the potential as well as to overcome the shortcomings of 3G, and demonstrate how service providers can take advantage of WLAN deployments. Technology drivers and obstacles that must be addressed to achieve growth in the WLAN market—such as roaming, security, seamless authentication, handovers, and billing, —are also important.

The handoff latency of many new access technologies such as wireless LAN devices is very large, of the order of hundreds of milliseconds. During this period mobile nodes cannot receive or transmit packets. This results in significant performance degradation during handoff operation. Furthermore, while handing off across subnets, network layer handoff can be initiated only after link layer handoff is complete. This increases the latency even further. Present cellular systems designed to handle mobility solve the latency issue by adding intelligence to the network and the interfaces. However, in the IP-based architectures the access technologies do not support the level of handoff coordination that cellular systems provide. Though packets can be buffered in a local mobility agent and then retransmitted to eliminate packet losses during handoffs, the high level of latency still exists.

Voice was the driver for second-generation mobile and has been a considerable success. Today, video and TV services are driving forward third generation (3G) deployment. And in the future, low cost, high-speed data will drive forward the fourth generation (4G) as short-range communication emerges. Service and application ubiquity, with a high degree of personalization and synchronization between various user appliances, will be another driver. At the same time, it is probable that the radio access network will evolve from a centralized architecture to a distributed one.

6. SEAMLESS CONNECTIVITY - ISSUES

Based on the developing trends of mobile communication, next generation wireless networks will have broader bandwidth, higher data rate, and smoother and quicker handoff and will focus on ensuring seamless service across a multitude of wireless systems and networks.

Present – Seamless handoffs can be designed for homogeneous networks (IEEE802.11 WLAN & cellular) – at Layer 2 and with limited participation of the mobile node (MN) in the decision.

Future – For IP to mobile node applications where there is a multiplicity of potential (wireless) access technologies, the requirement of functionality in the MN and Access Router (AR) to facilitate seamless transfer (network or MN initiated), and the need of Quality of Service (QoS), Authorization/ Authentication/Accounting (AAA), as well as the need of Security infrastructure changes are to be established.

Challenge – How do we help facilitate the future vision during transition? Assuming that IPv6 specification has fundamental mobile IP functionality and Multiplicity of (wireless) access technologies exist in a particular geography.

Figure 2 depicts the key elements of 4G Vision with seamless connectivity of the networks. [7].

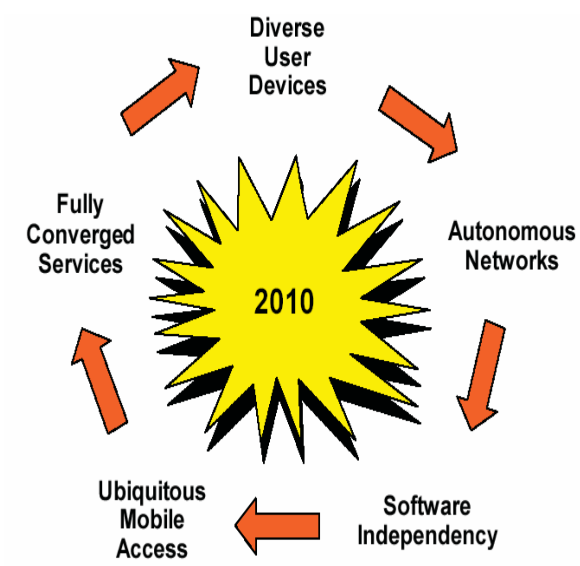

Fig. 2: Key Elements of 4G Vision

The key concept is integrating the 4G capabilities such as Application adaptability and being highly dynamic with all of the existing mobile technologies through advanced technologies. Future Mobile Communication Systems will certainly and surely achieve the concept of a “Global Village”.

7. LOCAL MOBILITY MANAGEMENT (LMM)

i) Limited scale solution - As ratio of mobile to non-mobile endpoint grows, address aggregation becomes increasingly difficult and routing table size increases. It increases seamlessness over basic mobileIP. The scale of LMM domain depends upon mix of mobile and non-mobile endpoints, frequency of re-attachment to wireless access points and in turn depends upon wireless access technology used (i.e. IEEE802.11, GPRS, Blue tooth, IR).

ii) No mobileIP delay - Only routing update delay for an interior routing protocol (usually less than inter-packet VoIP delay). It may need to support temporary bi-casting near handoff (for break before make case).

iii) MobileIP-based handoff - In order to mask delay, temporary tunnels from previous or subsequent AR need to be established. This will most likely work seamlessly within a Service Provider domain (no AAA/QoS renegotiation). Tunnels from/to different trust domains or service providers may not be established or may not have required QoS. Auditory pops/clicks may be acceptable for this case. Cross service-provider agreements may allow short-lived QoS tunnels for premium customers.

iv) LMM vs. MobileIP - Cross Trust Domain needs MobileIP (no Layer 2 solution). Within Trust Domain, how large are LMM domains (limited L2 solutions) across various wireless technologies for spectrum management, load balancing, power management, etc. The requirement is to minimize LMM routing or mobileIP flapping.

8. AAA/QoS AND MOBILE ROUTER ISSUES

i) Authentication/Authorization/Accounting (AAA) Issues - Present AAA is slow. It needs a ticket based approach. Alternatively service providers may allow “first N packets” before complete verification of a credential that appears legitimate from another trust domain (e.g., another service provider). Theft-of-service issue demands that AAA needs to be accomplished in parallel with QoS and (security of) Binding Update (for break before make case).

ii) Realizing Robust Authentication - Realizing the need for robust authentication and access control for wireless LANs, the IEEE adapted an authentication system used in wired Ethernet networks. Called 802.1x, it requires upgraded software drivers in Wi-Fi clients, firmware upgrades or replacement of access points, and the installation of a Radius (Remote Authentication Dial-In User Service) server with public key infrastructure to provide credentials for users. Radius is a draft standard for authentication and can be used with wired and wireless technologies. Microsoft offers a Radius Server add-in for Windows 2000 Server called Microsoft Internet Authentication Service, and support for 802.1x is included in Windows XP. There's even a freeware Radius server known as freeRadius.

iii) QoS Issues - Cellular voice packets are processed differently than data packets. Voice frames are optimized for minimum overhead & maximum utilization. Moreover, MAC scheduler is optimized for voice applications (e.g., about 40% voice activity factor in CDMA systems) and sent once (UDP-like) model without any use of persistence. Packets lost over wireless link are “fudged” with error concealment. However, Cellular “data (IP) packets” are limited persistence protocol on wireless link (adds delay when limited retransmission occurs). This is certainly not acceptable for VoIP (or real-time interactive application).

iv) Mobile Wireless Networks/ Routers Issues - MobileIP was not designed for high-frequency mobility or for more than one IP access link (i.e., make before break or mobile router case with multiple link characteristics). In practice, Seamless mobility across Trust Domains requires Layer 3 solutions. Limited scale of Layer 2 technology solutions can be suitable to nano-mobility applications (invisible to AR). SCTP (Single Connection Transmission Protocol) -based mobility can also be used when endpoints have SCTP capability. A combination of LMM & MobileIP L3 technologies can be used for micro/macro mobility.

9. CONCLUSION

The world of wireless communication stands on the threshold of a golden era where true wireless multimedia services can be offered seamlessly on a global scale. Future wireless networks will need to support diverse IP multimedia applications to allow sharing of resources among multiple users. There must be a low complexity of implementation and an efficient means of negotiation between the end users and the wireless infrastructure. The 4G wireless network promises to fulfill the goal of PCC (Personal Computing and Communication) — a vision that affordably provides high data rates seamlessly over a wireless network. Seamless mobility in wireless networks intends to integrate, from satellite broadband to high altitude platform to 3G cellular and 3G systems to WLL and FWA (Fixed Wireless Access) to WLAN and PAN (Personal Area Network), all with IP as the integrating mechanism. With this, a range of new services and models will be available. In addition, future generation wireless networks will be fully IP-based wireless Internet.

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