2G–4G Networks

Shakil Akhtar
United Arab Emirates University, UAE

INTRODUCTION

The fourth-generation wireless mobile systems, commonly known as 4G, is expected to provide global roaming across different types of wireless and mobile networks; for instance, from satellite to mobile networks and to Wireless Local Area Networks (WLANs). 4G is an all IP-based mobile network using different radio access technologies and providing seamless roaming and connection via always the best available network (Zahariadis & Kazakos, 2003). The vision of 4G wireless/mobile systems will be the provision of broadband access, seamless global roaming and Internet/data/voice everywhere, utilizing for each the most "appropriate" always-best connected technology (Gustafsson & Jonsson, 2003). These systems are about integrating terminals, networks and applications to satisfy increasing user demands (Ibrahim, 2002; Lu & Berezdivin, 2002). 4G systems are expected to offer a speed of more than 100 Mbps in stationary mode and an average of 20 Mbps for mobile stations, reducing the download time of graphics and multimedia components by more than 10 times compared to currently available 2 Mbps on *3G* systems.

Currently, the 4G system is a research-and-development initiative based upon 3G, which is having trouble meeting its performance goals. The challenges for development of 4G systems depend upon the evolution of different underlying technologies, standards and deployment. This article presents an overall vision of the 4G features, framework and integration of mobile communication. First we explain the evolutionary process from *2G* to *4G* in light of used technologies and business demands. Next, we discuss the architectural developments for 2G-4G systems, followed by a discussion on standards and services. Finally, we address the market demands and discuss the development of terminals for these systems.

2G-4G NETWORKS: EVOLUTION

The first generation of *mobile phones* was analog systems that emerged in the early 1980s (Falconer, Adachi & Gudmundson, 1995). The second generation of digital mobile phones appeared in the 1990s, along with the first digital mobile networks. During the second generation, the mobile telecommunications industry experienced exponential growth in terms of both subscribers and value-added services. Second-generation networks allow limited data support in the range of 9.6 kbps to 19.2 kbps. Traditional phone networks are used mainly for voice transmission, and are essentially circuit-switched networks.

2.5G networks, such as General Packet Radio Service (*GPRS*), are an extension of 2G networks in that they use circuit switching for voice and packet switching for data transmission, resulting in its popularity, since packet switching utilizes bandwidth much more efficiently. In this system, each user's packets compete for available bandwidth, and users are billed only for the amount of data transmitted.

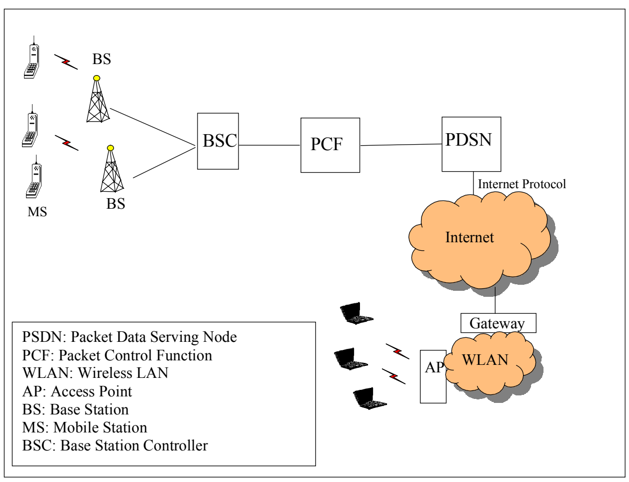
3G networks were proposed to eliminate many problems faced by 2G and 2.5G networks, especially the low speeds and incompatible technologies, such as Time Division Multiple Access (*TDMA*) (Falconer, Adachi & Gudmundson, 1995) and Code Division Multiple Access (*CDMA*) (Kohno, Meidan & Milstein, 1995) in different countries. Expectations for 3G included increased bandwidth, 128 Kbps for mobile stations and 2 Mbps for fixed applications (Lu, 2000). In theory, 3G should work over North American as well as European and Asian wireless air interfaces. In reality, the outlook for 3G is not very certain. Part of the problem is that network providers in Europe and North America currently maintain separate standards' bodies (*3GPP* for Europe and Asia; *3GPP2* for North America). The standards' bodies have not resolved the differences in air interface technologies.

There is also a concern that in many countries 3G will never be deployed due to its cost and poor performance. Although it is possible that some of the weaknesses at the physical layer will still exist in 4G systems, an integration of services at the upper layer is expected.

The evolution of mobile networks is strongly influenced by business challenges and the direction mobile system industry takes. It also relates to the radio access spectrum and the control restrictions over it that vary from country to country. However, as major technical advances are being standardized, it becomes more complex for the industry alone to choose a suitable evolutionary path. Many mobile system standards for Wide Area Networks (WANs) already exists, including popular ones such as Universal Mobile Telecommunications Systems (*UMTS*), CDMA and *CDMA-2000* (1X/3X). In addition, there are evolving standards for Personal Area Networks (PANs), such as *Bluetooth* wireless, and for WLANs, such as IEEE 802.11.

The current trend in mobile systems is to support the high bit-rate data services at the downlink via High Speed Downlink Packet Access (HSDPA). It provides a smooth evolutionary path for UMTS networks to higher data rates in the same way as Enhanced Data rates for Global Evolution (*EDGE*) do in Global Systems for Mobile communication (*GSM*). HSDPA uses shared channels that allow different users to access the channel resources in packet domain. It provides an efficient means to share a spectrum that provides support for high data-rate packet transport on the downlink, which is well adapted to urban environment and indoor applications. Initially, the peak data rates of 10 Mbps may be achieved using HSPDA. The next target is to reach 30 Mbps, with the help of antenna array processing technologies, followed by the enhancements in air interface design to allow even higher data rates.

Figure 1. Wireless mobile system network architecture



Another recent development is a new framework for mobile networks that is expected to provide multimedia support (Short & Harrison, 2002; Thom, 1996) for IP telecommunication services, called IP Multimedia Subsystems (IMS) (Faccin, Lalwaney & Patil, 2004). Real-time rich multimedia communication mixing telecommunication and data services could happen due to IMS in wireline broadband networks. However, mobile carriers cannot offer their customers the freedom to mix multimedia components (text, pictures, audio, voice, video) within one call. Today, a two-party voice call cannot be extended to a multi-party audio and video conference. IMS overcomes such limitations and makes these scenarios possible.

The future of mobile systems is largely dependent upon the development of 4G systems, multimedia networking and, to some extent, *photonic networks*. It is expected that initially the 4G mobile systems will be developed and used independent from other technologies. With gradual growth of high-speed data support to multimegabits per second, an integration of services will happen. In addition, developments in photonic switching might allow mobile communication on a completely photonic network, using Wavelength Division Multiplexing (*WDM*) on photonic switches and routers.

Network Architecture

The basic architecture of a wireless mobile system consists of a mobile phone connected to the wired world via single-hop wireless connection to a Base Station (BS), which is responsible for carrying the calls within its region called cell (Figure 1). Due to limited coverage provided by a BS, the mobile hosts change their connecting base stations as they move from one cell to another. A hand-off (later referred to