Evolution of Technologies, Standards, and Deployment of 2G–5G Networks

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INTRODUCTION

The fourth and fifth generation wireless mobile systems, commonly known as 4G and 5G, are 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 providing seamless roaming and providing connection always via the best available network [1]. The vision of 4G wireless/mobile systems is the provision of broadband access, seamless global roaming, and Internet/data/voice everywhere, utilizing for each the most "appropriate" always best connected technology [2]. These systems are about integrating terminals, networks, and applications to satisfy increasing user demands ([3], [4]). 4G systems are expected to offer a speed of over 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.

The fifth generation communication system is envisioned as the real wireless network, capable of supporting wireless world wide web (*wwww*) applications in 2010 to 2015 time frame. There are two views of 5G systems: evolutionary and revolutionary. In the evolutionary view the 5G (or beyond 4G) systems will be capable of supporting wwww allowing a highly flexible network such as a Dynamic Adhoc Wireless Network (*DAWN*). In this view advanced technologies including intelligent antenna and flexible modulation are keys to optimize the adhoc wireless networks. In revolutionary view 5G systems should be an intelligent technology capable of interconnecting the entire world without limits. An example application could be a robot with built-in wireless communication with artificial intelligence.

The 4G system is still predominantly a research and development initiative based upon 3G, which is struggling to meet its performance goals. The challenges for development of 4G systems depend upon the evolution of different underlying technologies, standards, and deployment. We present an overall vision of the 4G features, framework, and integration of mobile communication. First we explain the evolutionary process from *2G* to *5G* in light of used technologies and business demands. Next we discuss the architectural developments for 2G-5G systems, followed by the discussion on standards and services. Finally we address the market demands and discuss the development of terminals for these systems.

2G–5G NETWORKS: EVOLUTION

The first generation of *mobile phones* was analog systems that emerged in the early 1980s [5]. 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*) [5] and Code Division Multiple Access (*CDMA*) [6] in different countries. Expectations for 3G included increased bandwidth; 128 Kbps for mobile stations; and 2 Mbps for fixed applications [7]. 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 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 varies from country to country. However, as major technical advances are being standardized it becomes more complex for industry alone to choose a suitable evolutionary path. Many mobile system standards for Wide Area Networks (WANs) already exist, including the 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*). HSPDA uses shared channels that allow different users to access the channel resources in packet domain. It provides an efficient means to share 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.

Another recent development is a new framework for mobile networks that is expected to provide multimedia support ([8], [9]) for IP telecommunication services, called IP Multimedia Subsystems (IMS) [10]. 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 multiparty audio and video conference. IMS overcomes such limitations and makes these scenarios possible.

The future of mobile systems is largely dependent upon the development and evolution of 4G systems, multimedia networking, and to some extent, *photonic networks*. It is expected that initially the 4G mobile systems will be used independent from other technologies. With gradual growth of high speed data support to multimegabits per second, an integrations 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. The evolutionary view of 4G systems to 5G include a support of wireless world wide web allowing highly flexible and reconfigurable dynamic ad hoc networks.

Network Architecture

The basic architecture of wireless mobile system consists of a mobile phone connected to the wired world via a 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 as "horizontal handoff" in this article) occurs when a mobile system changes its BS. The mobile station communicates via the BS using one of the wireless frequency sharing technologies such as FDMA, TDMA, CDMA, and so forth. Each BS is connected to a mobile switching center (MSC) through fixed links, and each MSC is connected to others via Public Switched Telephone Network (*PSTN*). The MSC is a local switching exchange that handles switching of mobile user from one BS to another. It also locates the current cell location of a mobile user via a Home Location Register (HLR) that stores current location of each mobile that belongs to the MSC. In addition, the MSC contains a visitor