4G–Beyond 3G and Wireless Networks

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Abstract

The rapid growth in interactive multimedia applications, such as video telephonic, video games and T.V broadcasting have resulted in spectacular strides in the progress of wireless communication systems. The current third generation (3G) wireless systems and the next generation (4G) wireless systems in planning support higher bit rates. However the high error rates and stringent delay constraints in wireless systems are still significant obstacles for these applications and services. On the other hand, the development of more advanced wireless systems provides opportunities for proposing novel wireless multimedia protocols and new applications and services that can take the maximum advantage of the systems. The symposium aims at increasing the synergy between academics and industry professional working in the area.

1. Introduction
Fifteen years ago mobile telephones were an exotic extravagance. Today, as cellular phones, they are often given away as freebies in support of marketing schemes and product promotions. Having become a mainstream voice communications medium, they are poised to take on new challenges, transmitting (fairly) high-speed data, video, and multimedia traffic, as well as voice signals to users on the move. The primary need is fueled by increasingly mobile workforces in every industry. According to the Strategies Group, an average of 15% of the U.S. workforce is classified as mobile (out of the office at least 20% of the time). The technology needed to tackle the challenges is known as third-generation mobile telephony (3G). Background Access speeds in wire line and wireless environments are defined either as narrowband, (less than 64 kb/s), or broadband, (greater that 64 kb/s). The majority of mobile data offers available to date fall into the narrowband category. This enables simple data push, two-way
.messaging (SMS) and limited, Internet browsing using the wireless Internet protocol (WAP) or Internet clipping. In Europe, narrowband data access is currently provided over the global system for mobile communications (GSM) networks, using SMS. In Japan, data services operate over NTT's iMode network. In the United States, data services use network overlay architectures such as cellular digital packet data (CDPD) (with a maximum theoretical speed of 19.2 kb/s) or CDMA One (with a maximum theoretical speed of 14.4 kb/s). There are also a number of dedicated mobile data networks already in existence, namely the Advanced Radio Data Information Service (ARDIS), Mobitex (BSDW) used by Palm.net, and Bell South Mobile Data (RAM) which support paging services, and Metricom's MCDN.

2. Modern Techniques

2.1 Adaptation Technique in Wireless Multimedia Networks

Next generation wireless and mobile communication systems have two important features: heterogeneity and adaptation. Heterogeneous wireless communication platforms require inter-operability among different networks such as wireless cellular networks, wireless local area networks, wireless personal area networks, internet etc. An adaptation technique has become extremely important in such a heterogeneous environment so that quality management and provision to multimedia traffic over the unreliable wireless channels. With the development of multimedia compression and coding technologies, more and more real time applications such as video and audio can be made adaptive. Adaptation provides an alternative for resource planning, especially for bandwidth allocation/reallocation in wireless multimedia networks, where bandwidth is scarce resource. Various approaches and algorithm adopting this idea have been proposed.

2.2 Evolution from First to Third Generation Cellular

![Fig. 2: Evolution of Cellular Systems.](image)

Fig. 2 illustrates the evolution of cellular systems, including both the technology and services aspects. The first generation cellular systems, introduced some thirty years ago, were designed and optimized for analog transmission of speech signals to and from mobile subscribers. Operation in circuit switching mode these systems offered
voice band data transmission. Networks operating in the 450 and 800 MHz frequency bands used variants of frequency division multiplexing access (FDMA) schemes.

Moreover, inter working between different networks was rarely implemented. Consequently a subscriber could not use services on a network other than the one to which he or she subscribed. The advent of GSM for the second generation of cellular systems was a huge step forward. GSM was initially introduced as a pan-European system. In its original form GSM uses a Time Division Multiplexing Access (TDMA) and is available in 800, 1800, 1900 MHz frequency. The introduction of the Subscriber Identity Module (SIM) cards and the GSM Mobile Application Part (MAP) protocol enabled flawless inter working between different networks, allowing subscribers to roam worldwide. The introduction of the Third generation UMTS, based on the Wideband Code Division Multiple Access (WCDMA) technology, is a further step forward satisfying the ever increasing demand for data/Internet services. Circuit-mode speech and data as well as packet-mode data transmission is possible with UMTS. Data rates of 384 Kbit/s, with a maximum of 2 Mbit/s per user, will be made available by 3G cellular systems using WCDMA.

3. Beyond Third Generation

3.1 Technology issues related to the introduction of “Beyond 3G” Systems

The following are the technology issues related to the introduction of “Beyond 3G” systems.

1. Protocols mechanism has to be designed to allow ad hoc networking between appliances with varying capabilities.

2. The advantage of “mobility” offered by wireless is somewhat circumvented by additional security problems. Mechanisms need to be designed for user authentication, call privacy and radiation guarantees. The use of appliances with varying capabilities at different locations complicates this issue.

3. IP protocols will need to be enhanced to meet the expectations of wireless systems designers.

4. The aggregate spectrum bandwidth required by high bit rate applications in dense traffic areas could be very high. Such a spectrum bandwidth could be available in the frequency range above 60 GHz, making it necessary to develop cost effective radio technologies in these frequency bands.

5. Multi-mode appliances will have to implement software-configurable hardware architectures.

6. One of the most difficult challenges will be the need for flexible, simple to extend, multi-platform software architectures System and application related consider.

3.2 The Fourth Generation (4G)

4G takes on a number of equally true definitions, depending on who you are talking to. In simplest terms, 4G is the next generation of wireless networks that will replace 3G networks sometimes in future. In another context, 4G is simply an initiative by
academic R&D labs to move beyond the limitations and problems of 3G which is having trouble getting deployed and meeting its promised performance and throughput.

In reality, as of first half of 2002, 4G is a conceptual framework for or a discussion point to address future needs of a universal high speed wireless network that will interface with wire line backbone network seamlessly. 4G is also represents the hope and ideas of a group of researchers in Motorola, Qualcomm, Nokia, Ericsson, Sun, HP, NTT DoCoMo and other infrastructure vendors who must respond to the needs of MMS, multimedia and video applications if 3G never materializes in its full glory.

### 3.3 Comparing Key Parameters of 4G with 3G

A number of interesting observations can be made at this point. First several major technological transitions occurred between the first and third generation systems. The comparison of 3G and 4G is given in table no-1. The cellular mobile industry has gradually moved from:

1. High volume speech services to high volume/high speed data services;
2. Only circuit mode to circuit + packet mode transmission;
3. Isolated networks to inter-working between networks;
4. The introduction and evolution of GSM and UMTS have cleared shown that the development of standards for each new generation technology takes about a decade; UMTS is being introduced at the same time as GSM/EDGE are continuing to progress.

### Table 1: Comparison 4G and 3G.

<table>
<thead>
<tr>
<th>Sectors</th>
<th>3G (including 2.5G, sub3G)</th>
<th>1) 4G</th>
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<tr>
<td>Major Requirement</td>
<td>Predominantly voice driven-data was always add on</td>
<td>Converged data and voice over IP</td>
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<td>Driving Architecture</td>
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### Network Architecture
Wide area cell-based
Hybrid-Integration of Wireless LAN (WiFi, Bluetooth) and wide area

### Speeds
384 Kbps to 2 Mbps
20 to 100 Mbps in mobile mode

### Frequency Band
Dependent on country or continent (1800-2400 MHz)
Higher frequency bands (2-8 GHz)

### Bandwidth
5-20 MHz
100 MHz (or more)

### Switching Design Basis
Circuit and Packet
All digital with packetized voice

### Access Technologies
W-CDMA, 1xRTT, Edge
OFDM and MC-CDMA (Multi Carrier CDMA)

### Forward Error Correction
Convolutional rate 1/2, 1/3
Concatenated coding scheme

### Component Design
Optimized antenna design, multi-band adapters
Smarter Antennas, software multiband and wideband radios

### IP
A number of air link protocols, including IP 5.0
All IP (IP6.0)

### 3.4 The “What” of “Beyond 3G”

Subscribers on the move currently benefit from seamless “person to person” communication and access to voice, data and some multimedia services. However, future generation wireless communication systems may have to support:

- Availability of intelligent spaces, hence ability to implement Personal Area Networks (PAN).
- Ubiquitous connectivity to real time and transactional services, as well as high-speed access to multimedia services.
- Wireless access to location-based and context-related information for work and leisure.

Several technologies for the wireless transmission of information are currently available, including:

1. Direct Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB) for wide area broadcasting.
2. GSM, WCDMA, CDMA for wide area cellular networks.
3. Local Multiplication Distribution Service (LMDS) and Microwave Multipoint Distributed Systems (MMDS) for fixed wireless service.

Nearly all these technologies include arrangements for accessing Internet Services. As shown in Fig. 4, each of these technologies has been optimized for operation over a
particular range of service bit rate vs. user speed of mobility. Wide area cellular systems have reached a higher level of maturity than short-range systems.

4. Why 4G?

4.1 Lower Price Points Only Slightly Higher than Alternatives
The business visionaries should do some economic modeling before they start 4G hype on the same lines as 3G hype. They should understand that 4G data applications like streaming video must compete with very low cost wire line applications. The users would pay only a delta premium (not a multiple) for most wireless applications.

4.2 More Coordination Among Spectrum Regulators Around the World
Spectrum regulation bodies must get involved in guiding the researchers by indicating which frequency band might be used for 4G. FCC in USA must cooperate more actively with International bodies like ITU and perhaps modify its hands-off policy in guiding the industry. When public interest, national security interest and economic interest (inter-industry a la TV versus Telecommunications) are at stake, leadership must come from regulators. At appropriate time, industry builds its own self-regulation mechanisms.

4.3 More Academic Research
Universities must spend more effort in solving fundamental problems in radio communications (especially multiband and wideband radios, intelligent antennas and signal processing.

4.4 Standardization of wireless
Networks in terms of modulation techniques, switching schemes and roaming is an absolute necessity for 4G.

4.5 A Voice-independent Business Justification Thinking:
Business development and technology executives should not bias their business models by using voice channels as economic determinant for data applications. Voice has a built-in demand limit-data applications do not.

4.6 Integration Across Different Network Topologies
Network architects must base their architecture on hybrid network concepts that integrates wireless wide area networks, wireless LANS (IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, IEEE 802.15 and IEEE 802.16, Blue tooth with fiber-based Internet backbone. Broadband wireless networks must be a part of this integrated network architecture.

4.6 Non-disruptive Implementation
4G must allow us to move from 3G to 4G.
5. Regulatory Issues
   a) An open question relating to the level of standardization of solutions for ‘Beyond 3G’ is whether the new systems should be fully standardized, just able to inter-work or good enough to ensure peaceful coexistence.
   b) Although the aggregate spectrum required by many high bandwidth users might be very high, demand might only occur for short periods and could thus be met by making sufficient spectrum bandwidth available as and when necessary, rather than on a permanent basis. Mechanisms for dynamic spectrum management need to be designed to that the radio spectrum can be switched from one type to service to another, as required. Moreover, spectrum reframing between broadcast and cellular communication services must be considered.

6. Conclusion
   In view of the explosive growth of wireless communication over recent decades and the lead time required for the introduction of new technologies, the time has come to develop a clear perspective of “Beyond 3G” wireless systems and services. This “Beyond 3G” vision should exploit two complementary approaches: one based on “evolution through a network-centric view” and the other based on the recently introduced “user-centric view”. The “person to person” communication concept needs to be enhanced to include “person to machine” and “machine to machine” networking for ubiquitous connectivity to Internet services.

   Inter working between access networks implementing enhanced versions of current technologies for broadcast. Cellular and short-range communications should provide a good first solution for “Beyond 3G” services. This technology is for transmission at more than 50 Mbit/s for fast moving users as well as ultra wide band systems for wide area coverage. However, several interesting technological challenges and regulatory issues need to be addressed before the “Beyond 3G” vision becomes a reality.

References


