4G MOBILE COMMUNICATION SYSTEMS – A STUDY

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Received: May 05, 2018 Accepted: June 30, 2018

ABSTRACT *Recent activity in 4G (fourth generation) mobile communication systems has steeped the race in its implementation at the earliest. 4G wireless being an upcoming standard witnesses burgeoning interest amongst researchers and vendor. It is being designed to allow seamless integration and communication between wireless devices across diverse wireless standards as well as broadband networks wirelessly. Access to different radio technologies is facilitated due to IP –based – 4G mobile communication system connecting the user. This paper attempts to make an assessment in development, transition, and roadmap for fourth generation mobile communication system with a perspective of wireless convergence domain and future research issues.*

Keywords:

1. Introduction

The approaching 4G mobile communication systems are projected to solve –remaining problems of 3 G (third generation) systems and to provide a wide variety of new services, from high – quality voice to high-definition video to high-data –rate wireless channels. The term 4G is used broadly to include several types of broadband wireless access communication systems, not only cellular telephone systems. One of the terms used to describe 4G is MAGIC –Mobile multimedia, anytime anywhere, Global mobility support, integrated wireless solution, and customized personal service [1]. As a promise for the future, 4G systems, that is, cellular broadband wireless access systems have been attracting much interest in the mobile communication arena. The 4G systems not only will support the next generation of mobile service, but also will support the fixed wireless networks. This paper presents an overall vision of the 4G features, framework, and integration of mobile communication. The features of 4G systems might be summarized with one word – integration.

2. 4G Mobile Communication Systems

Technically, 4G stands for one integrated, IP –based environment for all telecommunications requirements including voice, video, broadcasting media and Internet that utilizes both fixed and wireless networks. In 4G, the user is the central focus point. By means of intelligent terminals, the user can get simple broadband access to a range of services that take into account his personal preferences and context. Even without interrupting ongoing conversation, work or video viewing, the user can change terminals or switch unnoticeably between the underlying fixed and mobile networks (UMTS, WLAN, etc.). And by means of ad-hoc networking, his mobile terminals can form networks among themselves or with the terminals of third parties. Throughout all this complex procedures, the user always maintains full control over privacy, security risks and costs. This extraordinary vision regarding 4G networks and services is a natural extension of the current development of broadband Internet and 3G mobile networks like UMTS.

2.1. The Goal of 4G

4G must be clearly more than 3G in terms of services, applications, and technology. As a comparison, 4G is not a combination of High Speed Uplink/Downlink Packet Access (HSUPA/HSDPA) or Wireless LAN (WLAN).

3G + HSDPA + HSUPA (= 3.5G?)<4G
3G +WLAN < 4G
3G+ HSDPA + WLAN < 4G

3G networks are inadequate to accommodate WLANs as access networks, which offer data rates of 11 Mbps. The goal of 4G will be to replace the entire core of cellular networks with a single worldwide cellular network completely standardized based on the IP for video, Voice over IP (VoIP) and multimedia services. Table – I compares the different wireless communication technologies.

Table 1: Comparison of Wireless Communication Technologies

	1G	2G	2.5G	3G	4G
Transmission	Ana-log	Digital	Digital	Digital	Digital

Architecture		Circuit Switch	Packed Switch	Circuit And Packet Switch	Packet Switch
Speeds		9.6 to 14.4 Kbits/s	64 to 144 Kbits/s	384 Kbits/s to 2 Mbits/s	100 Mbits/to 1000 Mbits/s

2.2. Desirable Characteristics of 4G

The move to 4G is complicated by attempts to standardize on a single 3G protocol. Without a single standard on which to build, designers face significant additional challenges. 4G does not have any solid specification as of yet, so the key design parameters rely on general proposals.

In short the desirable characteristics of 4G are – (1) Carrier frequency: 5GHz. (2) Channel band width /operators: 50MHz (3) Target data rate: 100 to 1000 Mbits/s. (4) High bandwidth efficiency: 2 to 20bitsHz (5) Channel is assumed to be extremely frequency – selective. (6) Ubiquity: Seamless Communication Next –generation internet supporting IPv6, Mobile over IP. (7) Lower system cost: 1/10-1/100 lower than that of 3G Infrastructure cost: 1/10 lower than that of 3G. (8) Multiplexing options: single – carrier (SC), multi carrier (MC) (including orthogonal frequency- division multiplexing (OFDM). (9) Multi-access options: TDMA, CDMA.

2.3. Current Merits of 4G

4G is esteemed to possess benefits such as High usability providing accessibility anytime and anywhere through a range of technologies, increased data transfer speed, improved quality of service, and wide variety of interactive services. Following are some current technical merits (from 2007 perspective), in brief are – (1) Presently, 4G is unregulated, it requires no license. Hence, an ease of experimentation. (2) 4G will be completely wireless thereby requiring no ditch digging. It will completely by pass any low capacity wired connection. (3) Accessibility of multimedia services to users at any place, and at any time. (4) 4G will be cheap, thereby, allowing carriers to upgrade inexpensively. (5) Evolution of new type input/output devices for fast data exchange (glasses, displaying 3D virtual world, collapsible screens, e-paper, and voice and handwriting recognition). Hence there will be growth in markets of PCs, consumer electronics, microprocessors and software. (6) Increased competition amongst application and service providers for users. (7) Quality of Internet wireless access will not lack any in any way in comparison to wired access. (8) It follows that the mobile networks should be stable and dependable, should be available for 24 hour per day. (9) Conception of a global telecommunication system, for example, a telephone or data call from a isolated place such as desert to an advance mega-city will be trouble free (satellite-based backbone telecommunication systems). (10 Easy interconnection amongst different systems (e.g. GPS, Internet, other communication networks)

2.4. Key Challenges for 4G

4G must be dynamic and adaptable with built-in intelligence. Key challenges will be personalization, seamless access, and quality of service, intelligent billing [2]. Table II summarizes the major key challenges in migration to 4G.

Table II: Key Challenges for 4G

4G Definition	Consensus on the 4G definition is needed for the purpose of the standardization.
Seamless Connectivity	Inter-network and intra-network connectivity is fundamental to the provision of temporally and spatially seamless services. Vertical and horizontal handovers are critical for 4G. In the former case the heterogeneity and variety of networks exacerbate the problem.
Latency	Many 4G services are delay sensitive. Guaranteeing short delays in networks with different access architecture and coverage is far from straight forward.

New Access	More study is required to replace the non
Architectures	Conventional access architectures to conventional ones.
Concealing Complexity	The complexity of 4G network needs to be hidden from the user.
Spectrum Issues	As the spectrum for 4G has not yet been allotted hence it is difficult to design a wireless system without knowing the channel.
Complex Resource Allocation	Management of time, frequency and spatial resources in a multi –network, multi user environment is far from trivial.
Interference	Multiple access interference control and mitigation in heterogeneous environments (coexisting air interfaces, varied terminals and
Power Consumption	Power consumption in future multi-function multi-standard 4G terminals will sharply increase. Usability is seriously compromised; hence heat management becomes an issue [3].
Personalization	In short required provisioning for advanced signaling & session control, AAA (authentication, authorization, accounting); open third party access (e.g. web services); communication (protocols); reconfigurable terminals; new strategies for pervasive/ ubiquitous computing; programmable open platforms.
Seamless Access	In short, requirements are seamless network integration based on IP, terminal mobility, personal mobility, service mobility, session mobility, dynamic resource allocation at all network /system levels, high adaptability /programmability of network components good security but simple
Quality of Service	This encompasses the customer perception of Qos, the offered Qos and the Qos actually delivered. Qos modeling and signaling would be crucial factors for a system that integrates
Intelligent Billing	(i) User requirement – QoS dependent charging, billing support to diverse access; support to real time billing information; support to interworking of prepaid systems; support to "per-call" services situations. (ii) Operator requirement –billing support to IP traffic; flexibility; of costs calculations (time, volume, QoS dependent, access dependent); distribution of revenue by value chain operators; customer relationship management; reliability of billing operations; instant fraud detection and cut-off.
Security	A good security system needs to be designed, which needs co-operation amongst; Government regulator, Network infrastructure provider, Wireless service provider, Wireless equipment provider, Wireless user.
Cost	Cost of terminal and service are required to be kept low for practical mass implementation.

2.5. Dangers Associated with 4G

Following enumerates the dangers associated with 4G.

1) *Tracking:* GPS devices and mobile navigation systems determine our location quite precisely and allow others to easily track us down.
2) *Mobile devices will be complex,* new layers of technological abstraction will be added, lower layers may be fairly secure, and software at higher layer may introduce vulnerabilities or vice-versa.
3) *Attacks on application level:* 4G cellular wireless devices will be known for software application which will provide innovative feature to the user but will introduce new holes, leading to more attacks at the application level.
4) *Jamming and spoofing:* Jamming happens when a transmitter sending out signals at the same frequency displace a GPS signals. Spoofing refers to fake GPS signals being sent out, in which case the GPS receiver thinks that the signals comes from a satellite and calculate the wrong co- ordinates. Criminals can use such techniques to interfere with law enforcement agency work.
5) *Location Based Services (LBS):* Law Enforcement Agencies with the help GPS receiver can quickly determined which units is closest to the location of a reported incident and can get there fast. Alternatively criminals can deceive the Law Enforcement Agencies by using such smart methods.
6) *Encryption:* If a GPS receiver has to communicate with the central transmitter then the communication link between these two components is not hard to break and there is a need of using encrypted data.
7) *WiFi, Hotspots and WLANs:* 4G technology will lead to the development of mobile devices with multiple application and the misuse will increase, particularly when devices those communicate with Wifi, Hotspots and WLANs. Data transmitted over such networks can often be intercepted quite easily, resulting in real security risk.

2.6. Driving and Impeding Forces for Adopting

4G Figure 2 summarizes and illustrates the key major forces in adoption of 4G wireless network.

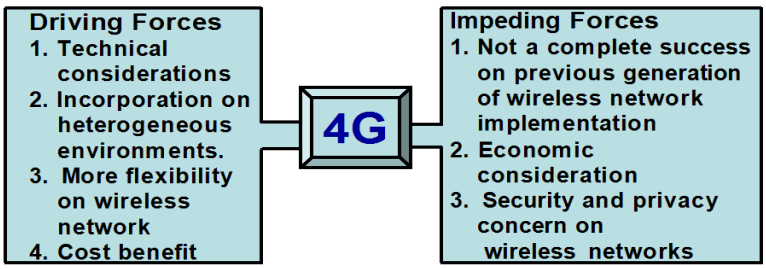

Fig. 2 Driving and impeding forces for adoption of 4G wireless network

2.7. Standardization Move

The two groups within the International Telecommunication Union (ITU) are specifically engaged to define the next generation of mobile wireless. These two groups are: -

- Working Party 8F (WP8F) in section ITU-R.
- Special Study Group (SSG) "IMT 2000 and Beyond" in section ITU-T.

WP8F is focused on the overall radio-system aspects of 4G, such as radio interfaces, radio-access networks. In April, 2007, the ITU convened a global congress to set a course for the 4G standards development process. China expressed the desire to submit the standard in 2008. Presently it is doubtful that we will see an ITU standard before 2012. Nor are standards necessarily the final word on the subject. In the meantime, there is nothing to stop the various SDOs and wireless operators from deploying so-called 4G systems without waiting for the completion of the formal standards process. The World Radio-communication Conference (WRC) in October/ November 2007 at Switzerland will decide on the spectrum assignment for 4G. This will clear the way forward for defining technologies and standards. The road map of the ITU-R (International Telecommunication Union Radio-communication Sector) targets the availability of 4G standard proposals for the year 2012. As soon as frequency bands for 4G are defined, 4G standardization activities are expected to start.

3. Transition to 4G

The success of Second-generation (2G) mobile systems in the previous decade prompted the development of third-generation (3G) mobile systems. While 2G systems such as GSM, IS-95, and cdmaOne

were designed to carry speech and low-bit-rate data, 3G systems were designed to provide higher data-rate services [5]. A range of wireless systems including GPRS, IMT-2000, Bluetooth, WLAN and HiperLAN have been developed with their own merits and demerits targeting different service types, data rates, and users. However, no single efficient system exists for integration of all these technologies. 4G system that integrates existing and newly developed wireless systems is currently in incipient stage and international standards do not exist [6]

Figure 3 illustrates the emergence of 4G technology from 3G networks. 3G technology has proper standards and many big companies have invested huge sums to acquire the needed spectrum space. The dilemma is there that, should companies by-pass 3G, and straightaway adopt 4G. It is being argued that 3G and 4G technologies are not mutually exclusive but are complementary to each other. Those countries that have made huge investments in 3G require an evolutionary path for migration to 4G. But the countries which have not made investments for 3G need not follow the 3G migration route as they can easily by-pass 3G technology and adopt directly 4G networks. In an effort to bypass expensive and ineffective 3G wireless strategies, many wireless operators already envisage rolling out 4G systems and compete directly with 3G systems as soon as possible. Worldwide many mobile operators, industry experts, and researchers have diverse visions of potential 4G features and its implementations.

In general, as discussed earlier in this paper that 4G systems are expected to provide, high usability and global coverage, broadband connectivity and high QoS, high network capacity, service personalization, user oriented services and low cost. 3G still possesses bandwidth limitations; 4G core networks are all IP networks.

Table III: Major Aspects in Migration to 4G

Adaptable Capability – Aware Service Provision	Different wireless access networks differ significantly in terms of coverage area and supported bandwidth, mobile network; their capabilities should be considered so as to refine the list of applicable services [7].
Transparent Mobility and Universal Roaming Capability	Seamless user mobility across different wireless access technologies (e.g. WLAN, UMTS etc.) with minimal or zero user intervention must be supported by efficient inter-system mobility management and hand over procedures. Roaming should build on cross industries standard protocols and architecture, such as hierarchical Mobile IPv6. As different systems may entail different charges, it should include QoS and pricing information as part of mobility management signaling.
Automated Protocol Configuration Mechanisms	The multiple options capable of accommodating the same set of services will result in accruing different charges in 4G mobile environments, thus users to be informed regarding the pricing preferences [8]
Policy Based Management and Information Models	Policy based management demarcates between enforcer entities and decision entities in the infrastructure which results in realization of flexible management architecture that spans across multiple administrative domains. Policy protocols also support both outsourcing and provisioning modes of operation, making policy based management an ideal approach for 4G mobile environments.

Pricing Billing	Network related pricing models must be completely independent from service related ones, with regarding to formulation as well as application matters.
Application and Mobile Execution Environment Aspects	As million mobile terminals and different manufacturers with different characteristics and applications will use 4G environment so there is a need to develop universal hardware platform with hassle free application with interpreted languages. The independent service provider will be relieved from the burden of developing, supporting and maintaining multiple versions of their applications for

4. Potential Applications of 4G

Some key potential applications of 4G are:

1) *Virtual Presence:* 4G system gives mobile users "virtual presence" -- for example, always-on connections that keep people involved in business activities regardless of whether they are on-site or off.
2) *Virtual Navigation:* A remote database contains the graphical representation of streets, buildings, and physical characteristics of a large metropolis. Blocks of this database are transmitted in rapid sequence to a vehicle, where a rendering program permits the occupants to visualize the environment ahead.
3) *Tele-medicine:* 4G will support remote health monitoring of patients. For e.g. the paramedic assisting the victim of traffic accident in a remote location must access medical records and may need videoconference assistance from a surgeon for an emergency intervention. The paramedic may need to relay back to the hospital the victim's x-rays taken locally.
4) *Tele-Geoprocessing Applications:* The combination of geographical information systems (GIS), global positioning systems (GPS), and high- capacity wireless mobile systems will enable a new type of application referred to as tele-geoprocessing. Queries dependent on location information of several users, in addition to temporal aspects have many applications.
5) *Crisis-Management Applications:* Natural disasters can affect the entire communications infrastructure is in disarray. Restoring communications quickly is essential. With wideband wireless mobile communications Internet and video services, could be set up in hours instead of days or even weeks required for restoration of wireline communications.
6) *Education:* Educational opportunities available on the internet, for individuals interested in life-long education, will be unavailable to client in remote areas because of the economic unfeasibility of providing wideband wireline internet access. 4G wireless

5. Research Areas for Future Wireless Systems

The research areas which are either emerging or evolving and are considered important for future health of 4G wireless communication systems are – (1) Newdecoding algorithms for turbo codes for wireless channels. (2) New coding/modulation techniques for reducing the peak-to-mean envelope ratio, maximizing the data rate and providing large coding gain. (3) New approaches to jointly designing modulation techniques, and power amplifiers to simultaneously obtain high power added efficiency along with bandwidth efficiency [9].

(4) New demodulation/decoding techniques to simultaneously combat the near far problem and do channel decoding in multi-rate DS- CDMA systems.
(5) Communication problems unique to high frequency systems (e.g., channel estimation).
(6) Joint channel estimation and decoding/ demodulation algorithms.
(7) Multiple-access techniques for multi-rate systems with variable quality of service requirements.
(8) Space-time coding for systems with multiple antennas.
(9) Analog decoding techniques for high speed, low power systems.
(10) Ultra wideband systems and hardware design.
(11) Research in methodologies for an integrated approach to wireless communications (device layer: e.g., power and low noise amplifiers, mixers, filters; physical layer: coding, modulation; medium access layer: CDMA/ FDMA/TDMA; data link layer: hybrid ARQ; network layer: routing protocols) [9].

6. Conclusion

As the history of mobile communications shows, attempts have been made to reduce a number of technologies to a single global standard. Projected 4G systems offer this promise of a standard that can be embraced worldwide through its key concept of integration. 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 fourth generation promises to fulfill the goal of PCC (personal computing and communication)—a vision that affordably provides high data rates everywhere over a wireless network.

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