4G

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***Abstract*— 4G is the next generation of wireless networks that will replace 3G networks sometimes in future. 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 [1]. However, 4G can be defined as a conceptual framework for or a discussion point to address future needs of a universal high speed wireless network that will interface with wireline backbone network seamlessly. Here, in this paper we present the main issues of 4G: features, aims, development, challenges, network, industries and technologies.**

***Index Terms*— 4G (Fourth Generation), 3G (Third generation), WWRF (Wireless World Research Forum).**

I. Introduction

THERE has been a huge evolution in wireless communication technologies: in both of mobile technology and WLAN technology. This evolution is illustrated in Figure1 as follows [2]:

First Generation (1G): 1G wireless mobile communication systems, was introduced in the early 1980s. 1G wireless was analog and supported the first generation of analog cell phones. They include a signaling protocol known as SS7 (Signaling System 7).

Second Generation (2G): 2G systems, fielded in the late 1980s, were intended primarily for voice transmission and was all about digital PCS.

Third Generation (3G): 3G in wireless will be a deliberate migration to faster, data-centric wireless networks. The immediate goal is to raise transmission speeds from 125kbps to 2M bit/sec.

Fourth Generation (4G): 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 wireline backbone network seamlessly.

However, when considering the technology progressing there are some key lessons that should be learnt from 3G to deploy 4G [3].

From the extreme uncertain customer demand in 3G, 4G should start soon- it has started in Motorola since 2002- to get its requirement ready by 2005 and exploring and trialling 4G applications should be done upfront before the definition of the requirements for the system and the air interface. However, there were significant over-expectations in 3G; the 3G story for the financial community, the regulatory bodies, the end-users and research was centred around a new, more capable, air interface. Thus, the 4G story should be centred around the user experience and the 4G research should be centred around architecture and system aspects that would support an effective, open, flexible integration of multiple technologies. Moreover, unlike the vertical monolithic 3G standard bodies 4G requirements, global architecture and protocols should be coordinated at the highest level possible in a global 4G standard body. Specific element of the standard and or regional variations should be fully developed in multiple, ad-hoc, effective horizontal standard bodies.

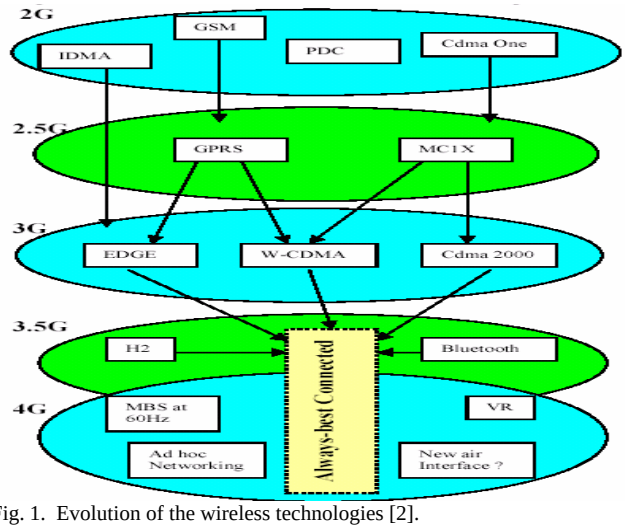

Fig. 1. Evolution of the wireless technologies [2].

II. Definition, Motivation, New and Application of 4G

A. What is 4G

4G can be defined as a conceptual framework for or a discussion point to address future needs of a universal high speed wireless network that will interface with wireline backbone network seamlessly. However, 4G can be imagined as an integrated wireless system that enables seamless

roaming between technologies. A user can be operating in cellular technology network and get handed over to a satellite-based network and back to a fixed wireless network, depending upon the network coverage and preference of charging.

B. *Motivation to have 4G*

Exceeding the 3G features, [4] 4G Support interactive multimedia services such as teleconferencing and wireless Interne over wider bandwidths and with higher bit rates. 4G also offers global mobility and service portability within a wide scalability of mobile networks, Figure2 reflects that. It is supposed that 4G will be affordable with reasonable low cost.

One of the major trends toward 4G is the great heterogeneity of the deployed networks. Given both investors' requirements for capital expenditure intensity and the technological divergence of private and public networks, the issues of service portability and interoperability have become of primary importance.

C. *What's New in 4G*

There are key new features that are available in 4G:

- Entirely packet-switched networks.
- All network elements are digital.
- Higher bandwidths to provide multimedia services at lower cost (up to 100Mbps).
- Tight network security.

TABLE I
3G VS. 4G

3G	4G
Predominantly voice driven - data was always add on	Converged data and voice over IP
Wide area cell-based	Hybrid - Integration of Wireless LAN (WiFi, Bluetooth) and wide area
Back compatible to 2G	Extend 3G capacity by one order of magnitude
1800-2400 MHz	Higher frequency bands 2-8 GHz
W-CDMA, 1xRTT, Edge Access technology	OFDM and MC-CDMA (Multi Carrier CDMA)
FEC Convolutional rate 1/2, 1/3	Concatenated coding scheme
Circuit and packet switched networks	Entirely packet switched networks
Combination of existing & evolved equipment	All network elements are digital
Data rate (up to 2Mbps)	Higher bandwidth (up to 100Mbps)
Optimized antenna design, multi-band adapters	Smarter Antennas, software multiband and wideband radios
A number of air link protocols, including IP 5.0	All IP (IP6.0)

D. *POTENTIAL APPLICATIONS OF 4G*

4G covers a wide diversity of applications [2]:

1) Virtual Presence: 4G system gives mobile users a "virtual presence" for example, always on connections to keep people on events.

2) Virtual navigation: In 4G, remote blocks of a database contain the graphical representation of streets, buildings, and physical characteristics of a large metropolis are transmitted in rapid sequence to a vehicle.

3) Tele-medicine: 4G will support remote health monitoring of patients.

4) Tele-geoprocessing: In 4G, queries dependent on location information of several users, in addition to temporal

Fig. 2. Global roaming in 4G [5].

TABLE II
4G CHALLENGES & THEIR PROPOSED SOLUTIONS [6]

	Key challenges	Proposed solutions
Mobile station		
Multimode user terminals	To design a single user terminal that can operate in different wireless networks, and overcome the design problems such as limitations in device size, cost, power consumption, and backward compatibilities to systems.	A software radio approach can be used: the user terminal adapts itself to the wireless interfaces of the networks [1].
Wireless system discovery	To discover available wireless systems by processing the signals sent from different wireless systems (with different access protocols and incompatible with each other).	User- or system-initiated discoveries, with automatic download of software modules for different wireless systems [2].
Wireless system selection	Every wireless system has its unique characteristic and role. The proliferation of wireless technologies complicates the selection of the most suitable technology for a particular service at a particular time and place.	The wireless system can be selected according to the best possible fit of user QoS requirements, available network resources, or user preferences [3, 4].
System		
Terminal mobility	To locate and update the locations of the terminals in various systems. Also, to perform horizontal and vertical handoff as required with minimum handover latency and packet loss.	Signaling schemes and fast handoff mechanisms are proposed in [5].
Network infrastructure and QoS support	To integrate the existing non-IP-based and IP-based systems, and to provide QoS guarantee for end-to-end services that involves different systems.	A clear and comprehensive QoS scheme for UMTS system has been proposed [6]. This scheme also supports interworking with other common QoS technologies.
Security	The heterogeneity of wireless networks complicates the security issue. Dynamic reconfigurable, adaptive, and lightweight security mechanisms should be developed.	Modifications in existing security schemes may be applicable to heterogeneous systems. Security handoff support for application sessions is also proposed [4].
Fault tolerance and survivability	To minimize the failures and their potential impacts in any level of tree-like topology in wireless networks.	Fault-tolerant architectures for heterogeneous networks and failure recovery protocols are proposed in [7].
Service		
Multi-operators and billing system	To collect, manage, and store the customers' accounting information from multiple service providers. Also, to bill the customers with simple but detailed information.	Various billing and accounting frameworks are proposed in [8, 9].
Personal mobility	To provide seamless personal mobility to users without modifying the existing servers in heterogeneous systems.	Personal mobility frameworks are proposed. Most of them use mobile agents, but some do not [10, 11].

aspects have many applications., it is a good idea to print the TIFF files to make sure nothing was lost in the conversion.

5) Crisis-management applications: 4G can be used effectively incase of natural disasters.

6) Education: Online education will be affordable in a reasonable cost effective manner.

Figure3 demonstrates the potential applications of 4G.

III. 3G vs. 4G

It is important to compare 4G with 3G in order to reflect the great development and achievements in 3G technology. TableI summarizes the main comparison of 3G versus 4G.

IV. Challenges & Needs

As a new technology, 4G faces a lot of challenges whom 4G is to overcome as summarized in TableII [6]. Moreover in order to build the future 4G system the following needs should be supplied:

- Lower price points only slightly higher than alternatives.
- More coordination among spectrum regulators around the world.
- More academic research.
- Standardization of wireless networks in terms of modulation techniques, switching schemes and roaming is an absolute necessity for 4G.
- Voice-independent business justification thinking.
- Integration across different network topologies.
- Non-disruptive implementation: 4G must allow us to move from 3G to 4G.

V. 4G networks (Models, features, air interface)

A. Network model

4G mobile network model is illustrated in Figure4 which includes various networks from the personal area networks up to the wider area networks [7]. The horizontal handover and the vertical handover are very important key features in 4G to provide a global seamless roaming which is depicted in the layered network structure model in Figure5 [8].

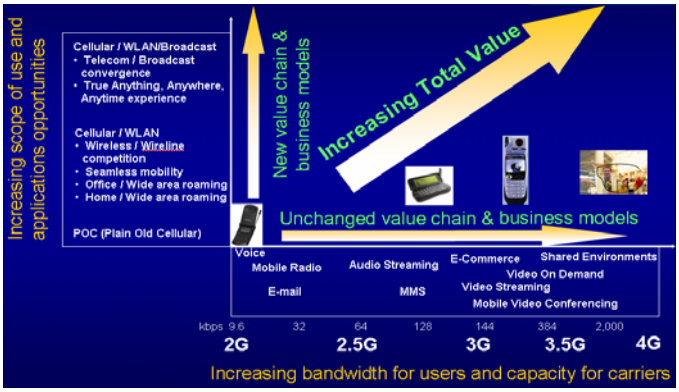

Fig. 3. Potential applications of 4G [3].

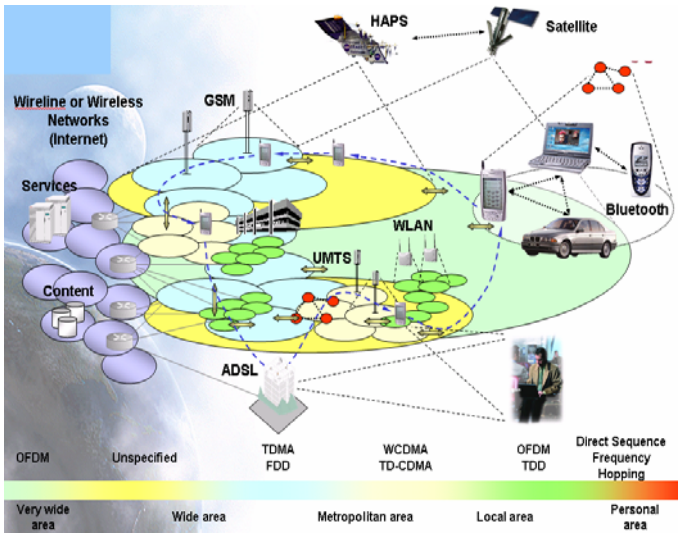

Fig. 4. 4G network model [7].

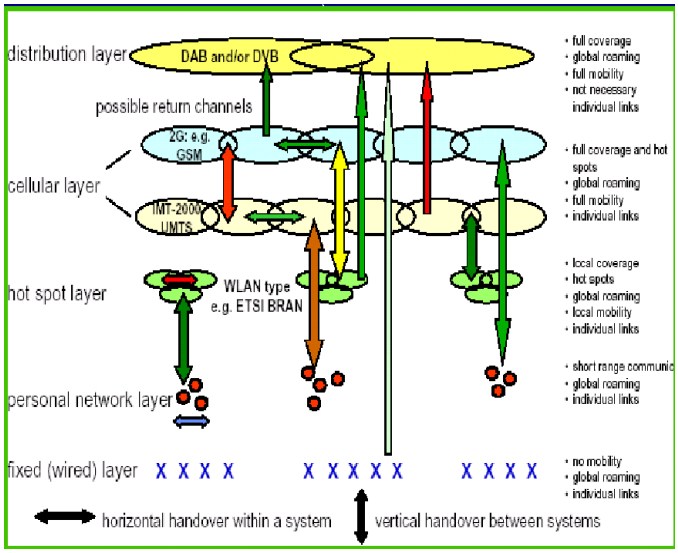

Fig. 5. Layered structure model for 4G [8].

B. Features

The 4G mobile networks could be systems:

- Horizontal communications between different access technology including cellular, cordless, WLAN, short-range connectivity, and wired technologies.
- A common platform to complement other services connection through a common, flexible, seamless, IP-based core network.
- Advanced media access technology that connects the core network to different access technologies.
- Global roaming and interworking between different access technologies; both horizontal (intrasystem) and vertical (intersystem) handover.
- Seamless service negotiation including mobility, security, and QoS.

C. Air Interface

The air interface in 4G enjoys various specifications and features which are described bellow:

- Higher bit rates than 3G (20 Mbps < peak < 200 Mbps)
- Higher spectral efficiency and lower cost per bit than 3G
- Air interface and MAC optimized for IP traffic (Adaptive modulation/coding with power control, hybrid ARQ)
- Higher frequency band than 3G (below 5 GHz preferred)
- RF channel bandwidths of 20 MHz and higher
- Frequency Domain methods: OFDM is promising for downlink
- Smaller cells, on average, than 3G
- However, cell size will be made as large as possible via:
    1) High power base station to boost downlink range
    2) Asymmetry - used to boost uplink range when necessary
    3) Adaptive antennas option

VI. Industry Initiatives

The main industrial initiative for 4G is the WWRF (Wireless World Research Forum) which consists of: Alcatel, Ericsson, Nokia and Siemens. WWRF has started a research forum for 4G. WWRF includes four working groups: User's view, Applications and services, Technologies, Spectrum. WWRF presented the multi sphere concept for 4G as shown in Figure6. For more information about WWRF you can refer to web page: http://www.ist-wsi.org. On the other hand the Japanese NTT DoCoMo has started conceptual (we mean paper) design of a 4G network.

VII. 4G Transmission Technology

Since this course is related to the physical method in wireless communications, so we present here in this part a practical physical application for 4G which is the transmission technology.

4G transmission protocols involve [2]: OFDM, W-OFDM, MC-CDMA, and LAS-CDMA.

OFDM is a digital modulation technology in which in one time symbol waveform, thousands of orthogonal waves are multiplexed. This is good for high bandwidth digital data transition. However, W-OFDM enables data to be encoded on multiple high-speed radio frequencies concurrently. This allows for greater security, increased amounts of data being sent, and the industries most efficient use of bandwidth. W-OFDM enables the implementation of low power multipoint RF networks that minimize interference with adjacent networks. This enables independent channels to operate within

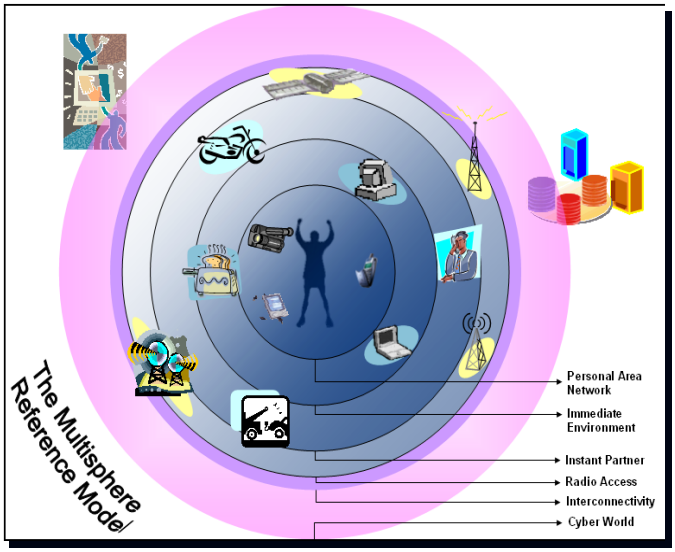

Fig. 6. The WWRF multi-sphere concept [7].

the same band allowing multipoint networks and point-to-point backbone systems to be overlaid in the same frequency band.

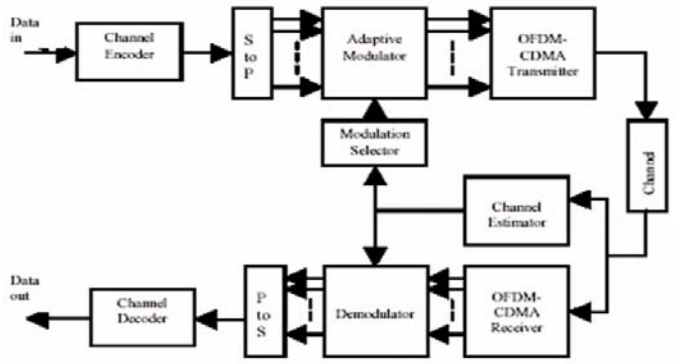

Fig. 7. Adaptive modulation based coded MC- CDMA system for 4G [12].

MC-CDMA is actually OFDM with a CDMA overlay. Similar to single-carrier CDMA systems, the users are multiplexed with orthogonal codes to distinguish users in (multi-carrier) MC-CDMA. However in MC-CDMA, each user can be allocated several codes, where the data is spread in time or frequency. However, LAS-CDMA (Large Area Synchronized Code Division Multiple Access) is a patented 4G wireless technology. LAS-CDMA enables high-speed data and increases voice capacity and latest innovative solution, CDD, merges the highly spectral efficient LAS-CDMA technology with the superior data transmission characteristics of TDD. This resulting combination makes CDD the most spectrally efficient, high-capacity duplexing system available today.

Some parameters, models, results are shown in TableIII, Figure7, Figure8 and Figure9 as examples for citation purposes. They are not discussed here.

VIII. Conclusion

4G can be imagined as an integrated wireless system that

enables seamless roaming between various telecommunications technologies. A promising 4G can support interactive multimedia services with wider bandwidths, and higher bit rates. However, 4G is still to come.

HOMEWORK

- Define the 4G, its motivation, new things, and main 4G network features and compare it to 3G.
- What is WWRF? And what are its objectives? What is the WSI (Wireless Strategic Initiative) project? And what are the WSI's project objectives?

TABLE III
OFDM PARAMETERS FOR 4G [11]

Parameter	Value 1	Value 2
Operating Frequency	2GHz	2GHz
Bandwidth (B)	4096 kHz	4096 kHz
Useful Symbol Duration (T)	62.5 μs	125 μs
Guard Interval Duration (T_g)	15.625 μs ($T/4$)	31.25μs ($T/4$)
Total Symbol Duration (T_{symbol})	78.125 μs (with GI =$T/4$)	156.25 μs (with GI =$T/4$)
Inner Channel Coding	Punctured 1/2 rate convolution code, Constraint length 7, $[133, 171]_{octal}$	Punctured 1/2 rate convolution code, Constraint length 7, $(133, 171)_{octal}$
FFT Size	256	512
Number of data sub-carriers (N_d)	216	432
Sub-carrier spacing (Δ_f)	16 kHz	8 kHz

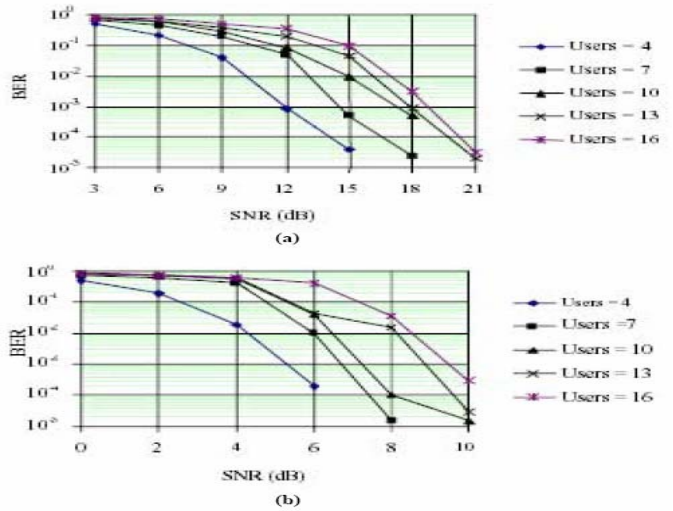

Fig. 8. BER performance of (a) 2-ary CPM and (b) 4-ary CPM based MC-CDMA system for a given number of CDMA users for 4G [12].

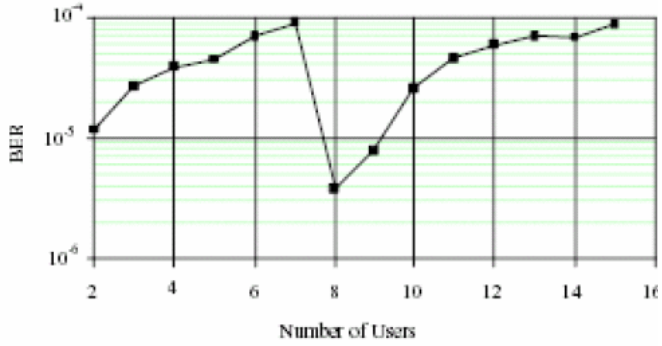

Fig. 7. BER performance of adaptive M-ary CPM (M=2, 4) MC-CDMA system with CSNR=15dB for 4G [12].

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