4

G Wireless Standard

Introduction

The First generation wireless mobile communication systems were introduced in early eighties and second generations systems in the late 1980s were intended primarily for transmission of voice. The initial systems used analog frequency modulation where as the second as well as the subsequent mobile systems use digital communication techniques with time division multiplexing (TDM), frequency division multiplexing (FDM) or the code division multiple access (CDMA). The third generation wireless systems which are just getting introduced in the world markets offer considerably higher data rates, and allow significant improvements over the 2G systems. The 3G Wireless systems were proposed to provide voice and paging services to provide interactive multimedia including teleconferencing and internet access and variety of other services. However, these systems offer wide area network

(WAN) coverage of 384 kbps peak rate and limited coverage for 2 Mbps. Hence providing broadband services would be one of the major goals of the 4G Wireless systems.

Features of 4G Wireless Systems

The following are some possible features of the 4G systems :

1. Support interactive multimedia, voice, video, wireless internet and other broadband services.
2. High speed, high capacity and low cost per bit.
3. Global mobility, service portability, scalable mobile networks.
4. Seamless switching, variety of services based on Quality of Service (QoS) requirements
5. Better scheduling and call admission control techniques.
6. Ad hoc networks and multi-hop networks.

3G Vs 4G

The following table shows comparisons between some key parameters of 3G Vs possible 4G systems.

	3G	4G
Frequency Band	1.8 - 2.5 GHz	2 - 8 GHz
Bandwidth	5-20 MHz	5-20 MHz
Data rate	Up to 2Mbps (384 kbps WAN)	Up to 20 Mbps or more

Access	Wideband CDMA	Multi-carrier - CDMA or OFDM(TDMA)
FEC	Turbo-codes	Concatenated codes
Switching	Circuit/Packet	Packet
Mobile top speeds	200 kmph	200 kmph

Physical and MAC Layer specifications

One promising underlying technology to accomplish the divisiveness is multi-carrier modulation, a derivative of frequency division multiplexing. MCM was earlier used in DSL modems and digital audio-video broadcasts. It is a baseband process that uses parallel equal bandwidth channels to transmit information. Normally implemented with Fast Fourier transform (FFT) techniques, MCM's advantages include better performance in the inter symbol interference (ISI) environment, and avoidance of single frequency interferers. However, MCM increases the peak-to-average ratio (PAVR) of the signal, and to overcome ISI a cyclic extension or guard band must be added to the data.

Two different types of MCM are likely candidates for 4G as listed in the above table. These are the multi-carrier CDMA and orthogonal FDM using TDMA.

Similar to single carrier CDMA systems, the users are multiplexed with orthogonal codes to distinguish users in MC-CDMA. However, in MC-CDMA, each user can be allocated several codes, where the data is spread in time or frequency. Either way, multiple users access the system simultaneously. In OFDM with TDMA, the users are allocated time intervals to transmit and receive data.

Differences between OFDM with TDMA and MC-CDMA can also be seen in the types of modulation used in each subcarrier. Typically, MC-CDMA uses quadrature phase-shift keying (QPSK), while OFDM with TDMA could use more high-level modulations (HLM), such as, multilevel quadrature amplitude

modulation (M-QAM) (where M = 4 to 256). How-ever, to optimize overall system performance, adaptive modulation can be used; where the level of QAM for all subcarriers is chosen based on measured parameters.

Channel Access

The allocation of the spreading codes or the time slots can be done in such a way that the throughput is maximized. For example, all the resources can be allocated to a user whose channel is very clean and users who have very noisy channels can be allocated little amount of bandwidth till their channel becomes better. However, the allocation should maintain certain amount of fairness while distributing the resources.

Error control coding

In 4G systems rate-adaptive coding schemes can be used which can make use of the channel information from the measured parameters or feedback from the Mobile Terminal (MT). A Hybrid ARQ scheme can be used to minimize the overhead in case of retransmission. Space time codes, multiple antennas systems like the smart antennas can be used to further improve the data rates.

Higher Layer Issues in 4G

4G is going to be a packet-based network. Since it would carry voice as well as internet traffic it should be able to provide different level of QoS. Other network level issues include Mobility Management, Congestion control,and QoS Guarantees :

Mobility Management

Mobility Management includes location registration, paging and handover. The MT should be able to access the services at any place possible. The global roaming can be achieved by with the help of multi-hop networks that can include the WLANs or the satellite coverage in remote areas. A seamless service (Ex : soft handover of the MT from one network to another or from one kind of service to other) is also important. The hand-over techniques should

be designed so that they make efficient use of the network (routing) and make sure that hand offs are not done too often.

New techniques in location management might be implemented. Each MT need not do location registration everytime. They can instead do concatenated location registration, which reports to the network that they are concatenated to a common object. Ex- MTs in a train need to re-register only when they get off the train and till the network knows that they are in the train.

Congestion Control

Congestion control will be another critical issues in the high performance 4G networks. Two basic approaches can be taken towards the congestion control : 1. avoidance or prevention of the congestion and 2. detection and recovery after congestion. The avoidance scheme will require the network to suitably implement the admission control (measurement based or pre-computed model) and scheduling techniques. The detection and recovery would require flow control and feedback traffic management. A conservative approach might be proposed for the 4G systems because of the wide variety of QoS requirements.

Quality of Service (QoS)

4G systems are expected to provide real-time and internet-like services. The real-time services can be classified into two kinds:
1. Guaranteed : pre-computed delay bound is required for the service. Ex voice
2 : Better-than-best effort :
Predictive : Service needs upper bound on end-to-end delay.
Controlled delay : service might allow dynamically variable delay.
Controlled load : Service needs resources (bandwidth and packet processing).

Guaranteed and Controlled Load services are proposed to appear in 4G.

Some new challenges in 4G

1. Multi-access interface, timing and recovery.

2. Higher frequency reuse leads to smaller cells that may cause intra-cell interference or higher noise figures due to reduced power levels.
3. The Digital to analog conversions at high data rates, multiuser detection and estimation (at base stations), smart antennas and complex error control techniques as well dynamic routing will need sophisticated signal processing.
4. Issues in the interface with the ad hoc networks should be sorted out. 4G systems are expected to interact with other networks like the Bluetooth, hiperlan, IEEE802.11b, etc.
5. Voice over multi-hop networks is likely to be an interesting problem because of the strict delay requirements of voice.
6. Security will be an important issue.
7. A new IP protocol might be needed because of the variable QoS services and the network should do " better than best " effort.
8. Networking protocols that adapt dynamically to the changing channel conditions.
9. Seamless roaming and seamless transfer of services.

Conclusions

1. 4G is still in formative stages. They may become commercially available in 2010.
2. The work on 4G systems has begun in the industry as well the academia. Ex:- Wireless World Research Forum (WWRF) has Ericcson, Alcatel, Nokia and Siemens AG. The National Science Foundation (NSF) has announced a program in 1999 that calls for proposals that would look at issues involved in 4G systems. In the USA, Motorola, Lucent, AT&T, Nortel and other major companies are also working on 4G systems.
3. Multimedia traffic will be dominant in the future. It is estimated that voice would contribute to only 20-30 % of total traffic in the future.
4. A modified IP will be the universal network layer protocol in the future.
5. Diverse array of applications like virtual navigation, tele-medicine, etc.
6. The entire network would be digital and packet switched.

Links and References

1. The IEEE Personal Communications Magazine, October 2001 has a collection of articles that looks at the IP based issues in the 4G wireless networks.
2. Physical aspects of 4G

3. Mobility Management
4. Groups working on 4G : WWRF , projects funded by NSF , Lucent , AT&T, Motorola, etc.
5. Research : Ga Tech , Ofdm-forum
6. Frequently asked question on 4G
7. 4G in news
8. Slide show on evolution of TDMA to 3G and 4G