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Mobile Communication in 4G Technology

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ABSTRACT: Third-generation (3G) mobile networks face a new rival: so-called 4G. And, astonishingly, the new networks may even be profitable. Alvin Toffler, an eminent futurologist, once said, "THE FUTURE ALWAYS COMES TOO FAST, BUT IN THE WRONG ORDER". The state of wireless telecoms is a classic example. Even as 3G mobile networks are being switched on around the world, a couple of years later than planned, attention is shifting to what comes next: a group of newer technologies that are, inevitably, being called Fourth Generation Mobile Networks (4G). 4G is all about an integrated, global network that's based on an open systems approach. The goal of 4G is to replace the current proliferation of core cellular networks with a single worldwide cellular core network standard based on IP for control, video, packet data, and VoIP. This integrated 4Gmobile system provides wireless users an affordable broadband mobile access solutions for the applications of secured wireless mobile Internet services with value-added QoS.

KEYWORDS: Global mobility, Cellular Services, PAVR Signal, Transceiver

I .INTRODUCTION

While 3G hasn't quite arrived, designers are already thinking about 4G technology. With it comes challenging RF and baseband design headaches. Cellular service providers are slowly beginning to deploy third-generation (3G) cellular services. As access technology increases, voice, video, multimedia, and broadband data services are becoming integrated into the same network. The hope once envisioned for 3G as a true broadband service has all but dwindled away. It is apparent that 3G systems, while maintaining the possible 2-Mbps data rate in the standard, will realistically achieve 384-kbps rates. To achieve the goals of true broadband cellular service, the systems have to make the leap to a fourth-generation (4G) network.

This is not merely a numbers game. 4G is intended to provide high speed, high capacity, low cost per bit, IP based services. The goal is to have data rates up to 20 Mbps, even when used in such scenarios as a vehicle traveling 200 kilometers per hour. 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.

Motivation for 4G Research Before 3G Has Not Been Deployed?

- 3G performance may not be sufficient to meet needs of future high-performance applications like multi-media, full-motion video, wireless teleconferencing. We need a network technology that extends 3G capacity by an order of magnitude.
- There are multiple standards for 3G making it difficult to roam and interoperate across networks. we need global mobility and service portability
- 3G is based on primarily a wide-area concept. We need hybrid networks that utilize both wireless LAN (hot spot) concept and cell or base-station wide area network design.
- We need wider bandwidth
- Researchers have come up with spectrally more efficient modulation schemes that can not be retrofitted into 3G infrastructure
- We need all digital packet networks that utilize IP in its fullest form with converged voice and data capability.

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Need to Build 4G Networks for Future

To achieve a 4G standard, a new approach is needed to avoid the divisiveness we've seen in the 3G realm. One promising underlying technology to accomplish this is multicarrier modulation (MCM), a derivative of frequency-division multiplexing. Forms of multicarrier systems are currently used in digital subscriber line (DSL) modems, and digital audio/video broadcast (DAB/DVB). MCM is a baseband process that uses parallel equal bandwidth subchannels 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.

What is 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.

II .DISCUSSION

Cyclic extension works as follows: If N is the original length of a block, and the channel's response is of length M, the cyclically extended symbol has a new length of N + M - 1. The image presented by this sequence, to the convolution with the channel, looks as if it was convolved with a periodic sequence consisting of a repetition of the original block of N. Therefore, the new symbol of length N + M - 1 sampling periods has no ISI. The cost is an increase in energy and uncoded bits added to the data. At the MCM receiver, only N samples are processed, and M - 1 samples are discarded, resulting in a loss in signal-to-noise ratio (SNR) as shown in **Equation 1.**

$$SNR_{loss}=10 \log ((N+M-1)/N) \text{ db-------- (1)}$$

Comparing Key Parameters of 4G with 3G

	3G (including2.5G,sub3G)	4G
Major Requirement Driving Architecture	**Predominantly voice driven - data was always add on**	**Converged data and voice over IP**
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**

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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)**

Table 1

Two different types of MCM are likely candidates for 4G as listed in **Table 1**. These include multicarrier code division multiple access (MC-CDMA) and orthogonal frequency division multiplexing (OFDM) using time division multiple access (TDMA). 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 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. As with 3G systems, 4G systems have to deal with issues of multiple access interference and timing.

Why OFDM?

OFDM overcomes most of the problems with both FDMA and TDMA (ie ICI and ISI). OFDM splits the available bandwidth in to many narrow band channels. The carriers for each channel are orthogonal to one another allowing them to be spaced very close together, with no overhead as in the FDMA. Because of this there is no great need for users to be time multiplexed as in TDMA, thus there is no overhead associated with switching between the users. Each carrier in an OFDM signal has a very narrow bandwidth (ie 1 K Hz), thus the resulting symbol rate is low. This results in signal having a high tolerance to multipath delay spread, as a delay spread must be very long to cause ISI (i.e. >500 µsec).

THE 4G TRANSCEIVER:

The structure of a 4G transceiver is similar to any other wideband wireless transceiver. Variances from a typical transceiver are mainly in the baseband processing. A multicarrier modulated signal appears to the RF/IF section of the transceiver as a broadband high PAVR signal. Base stations and mobiles are distinguished in that base stations transmit and receive/ decode more than one mobile, while a mobile is for a single user. A mobile may be a cell phone, a computer, or other personal communication device.

The line between RF and baseband will be closer for a 4G system. Data will be converted from analog to digital or vice versa at high data rates to increase the flexibility of the system. Also, typical RF components such as power amplifiers and antennas will require sophisticated signal processing techniques to create the capabilities needed for broadband high data rate signals. **Figure 1** shows a typical RF/IF section for a transceiver. In the transmit path inphase and quadrature (I&Q) signals are upconverted to an IF, and then converted to RF and amplified for transmission. In the receive path the data is taken from the antenna at RF, filtered, amplified, and downconverted for baseband processing. The transceiver provides power control, timing and synchronization, and frequency information. When multicarrier modulation is used, frequency information is crucial. If the data is not synchronized properly the transceiver will not be able to decode it.

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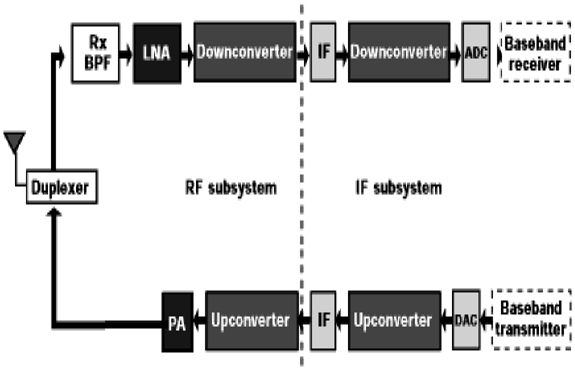

FIGURE 1: A basic RF/IF block diagram showing a typical RF/IF section for a Transceiver

III . 4G PROCESSING

Figure 2 shows a high-level block diagram of the transceiver baseband processing section. Given that 4G is based on a multicarrier technique, key baseband components for the transmitter and receiver are the FFT and its inverse (IFFT). In the transmit path the data is generated, coded, modulated, transformed, cyclically extended, and then passed to the RF/IF section. In the receive path the cyclic extension is removed, the data is transformed, detected, and decoded. If the data is voice, it goes to a vocoder. The baseband subsystem will be implemented with a number of ICs, including digital signal processors (DSPs), microcontrollers, and ASICs. Software, an important part of the transceiver, implements the different algorithms, coding, and overall state machine of the transceiver. The base station could have numerous DSPs. For example, if smart antennas are used, each user needs access to a DSP to perform the needed adjustments to the antenna beam.

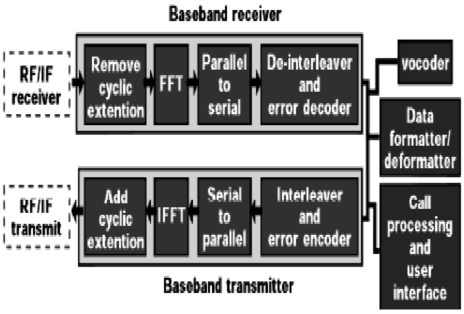

FIGURE 2: A high-level block diagram of the tranceiver baseband processing section in a 4G wireless design

IV . RECEIVER SECTION

4G will require an improved receiver section, compared to 3G, to achieve the desired performance in data rates and reliability of communication. The Shannon's Theorem specifies the minimum required SNR for reliable communication:

$$\mathbf{SNR=2^{C/BW}} \text{--------------} (2)$$

where C is the channel capacity (which is the data rate), and BW is the bandwidth For 3G, using the 2-Mbps data rate in a 5-MHz bandwidth, the SNR is only 1.2 dB. In 4G, approximately 12-dB SNR is required for a 20-Mbps data rate in a 5-MHz bandwidth. This shows that for the increased data rates of 4G, the transceiver system must perform significantly better than 3G. The receiver front end provides a signal path from the antenna to the baseband processor. It consists of a bandpass filter, a low-noise amplifier (LNA), and a downconverter. De-pending on the type of receiver

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there could be two downconversions (as in a super-heterodyne receiver), where one downconversion converts the signal to an IF. The signal is then filtered and then downconverted to or near baseband to be sampled.

The other configuration has one downconversion, as in a homodyne (zero IF or ZIF) receiver, where the data is converted directly to baseband.The challenge in the receiver design is to achieve the required sensitivity, intermodulation, and spurious rejection, while operating at low power.

V . BASEBAND PROCESSING

The error correction coding of 4G has not yet been proposed, however, it is known that 4G will provide different levels of QoS, including data rates and bit error rates. It is likely that a form of concatenated coding will also be used, and this could be a turbo code as used in 3G, or a combination of a block code and a convolutional code. This increases the complexity of the baseband processing in the receive section. 4G baseband signal-processing components will include ASICs, DSPs, microcontrollers, and FPGAs. Baseband processing techniques such as smart antennas and multi-user detection will be required to reduce interference.

MCM is a baseband process. The subcarriers are created using IFFT in the transmitter, and FFT is used in the receiver to recover the data. A fast DSP is needed for parsing and processing the data. Multi-user detection (MUD) is used to eliminate the multiple access interference (MAI) present in CDMA systems.

VI . TRANSMITTER SECTION

As the data rate for 4G increases, the need for a clean signal also increases. One way to increase capacity is to increase frequency reuse. With the wider bandwidth system and high PAVR associated with 4G, it will be difficult to achieve good performance without help of linearity techniques (for example, predistortion of the signal to the PA). To effectively accomplish this task, feedback between the RF and baseband is required. The algorithm to perform the feedback is done in the DSP, which is part of the baseband data processing.Power control will also be important in 4G to help achieve the desired performance; this helps in controlling high PAVR - different services need different levels of power due to the different rates and QoS levels required.

The digital-to-analog converter (DAC) is an important piece of the transmit chain. It requires a high slew rate to minimize distortion, especially with the high PAVR of the MCM signals. Generally, data is oversampled 2.5 to 4 times; by increasing the oversampling ratio of the DAC, the step size between samples decreases. This minimizes distortion. In the baseband processing section of the transmit chain, the signal is encoded, modulated, transformed using an IFFT, and then a cyclic extension is added. Dynamic packet assignment or dynamic frequency selection are techniques which can increase the capacity of the system. Feedback from the mobile is needed to accomplish these techniques. The baseband processing will have to be fast to support the high data rates.

VII . APPLICATIONS

1.VIRTUAL NAVIGATION AND TELEGEOPROCESSING:-

You will be able to see the internal layout of a building during an emergency rescue. This type of application is some time referred to as 'telegeoprocessing'.
A remote database will contain the graphical representation of streets, buildings and physical characteristics of a large metropolis. Blocks of this database will be transmitted in rapid sequence to a vehicle, where a rendering program will permit the occupants to visualize the environment ahead. They may also 'virtually' see the internal layout of buildings to plan an emergency rescue or engage hostile elements hidden in the building
.

2.TELEMEDICINE:-

A paramedic assisting a victim of a traffic accident in a remote location could access medical records (X-rays) and establish a video conference so that a remotely based surgeon could provide 'on-scene' assistance.

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3.CRISIS MANAGEMENT APPLICATION:-

In the event of natural disasters where the entire communications infrastructure is in disarray, restoring communications quickly is essential. With wideband wireless mobile communications, limited and even total communication capability(including Internet and video services) could be set up within hours instead of days or even weeks required at present for restoration of wire line communications.

4.TELE-GEOPROCESSING APPLICATIONS:

This is a combination of GIS (Geographical Information System) and GPS (Global Positioning System) in which a user can get the location by querying.

5. EDUCATION :

For people who are interested in lifelong education, 4G provides a good opportunity. People anywhere in the world can continue their education through online in a cost effective manner.

IX .ADVANTAGES OF 4G

1. Support for interactive multimedia services like teleconferencing and wireless Internet.
2. Wider bandwidths and higher bitrates.
3. Global mobility and service portability.
4. Scalability of mobile network.
5. Entirely Packet-Switched networks.
6. Digital network elements.
7. Higher band widths to provide multimedia services at lower cost(up to 100 Mbps).
8. Tight network security

X . LIMITATIONS

- Although the concept of 4G communications shows much promise, there are still limitations that must be addressed. A major concern is interoperability between the signaling techniques that are planned for use in 4G (3XRTT and WCDMA).
- Cost is another factor that could hamper the progress of 4G technology. The equipment required to implement the next-generation network are still very expensive.
- A Key challenge facing deployment of 4G technologies is how to make the network architectures compatible with each other. This was one of the unmet goals of 3G.
- AS regards the operating area, rural areas and many buildings in metropolitan areas are not being served well by existing wireless networks.

XII . CONCLUSION

System designers and services providers are looking forward to a true wireless broadband cellular system, or 4G. To achieve the goals of 4G, technology will need to improve significantly in order to handle the intensive algorithms in the baseband processing and the wide bandwidth of a high PAVR signal. Novel techniques will also have to be employed to help the system achieve the desired capacity and throughput. High-performance signal processing will have to be used for the antenna systems, power amplifier, and detection of the signal. A number of spectrum allocation decisions, spectrum standardization decisions, spectrum availability decisions, technology innovations, component development, signal processing and switching enhancements and inter-vendor cooperation have to take place before the vision of 4G will materialize. We think that 3G experiences - good or bad, technological or business - will be useful in guiding the industry in this effort. To sketch out a world where mobile devices and services are ubiquitous and the promise of future fourth generation (4G) mobile networks enables things only dreamed of, we believe that 4G will probably become an IP-based network today.

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