ENHANCED WIRELESS COMMUNICATION

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The paper summarizes in a scientific language and terminology, a summery of technological advancement in wireless communication and Internet data services from inception to the fourth generation technology.

- Prof. Shrikant Bhagali

ABSTRACT

Third generation and fourth generation technologies has paved the way for exciting and innovative techniques for various services which are described in this presentation. It makes the use of wide band code division multiple access and multiple carrier modulation for providing user with greater facilities. These are cost effective, provides higher speeds with greater efficiency. In the first generation Frequency division multiple access was used which favored analog communication. In the second generation technology developed and people started the use of Time division multiplexing techniques favoring digital communication. And now in this age which is called the Electronic age there is a fierce battle going on between various technologies in the field of communication. Now days as the user requires greater speeds with high efficiency for data transmission, internet services and various other value added services the new technology is bound to come in.. Paper describes the guidelines for the future technology coming into existence.

"3G" stands for the Third Generation of wireless communication technology. It represents a convergence of two very important technologies wireless telephony and Internet data services. This third generation is an outgrowth of two previous generations of advances in wireless communications. The first generation of wireless introduced analog cellular voice technology. This technology brought forth one of the first real mechanisms that enabled voice communications without the need to be constrained to a physical location. The second generation introduced digital wireless, which brought with it, increased ranges as well as improved clarity and security. Third-generation (3G) wireless services will now combine highspeed mobile access with Internet Protocol-based (IP) data services to create a whole new way to access and communicate information without the limitations of speed, capacity and cumbersome. equipment that still exist today. By using advanced network architecture it will deliver broadband services in a more generic configuration to wireless customers and support value-added services and emerging interactive multimedia configurations. With access to any service anywhere, anytime, from any device, the old boundaries between communications, information, media and entertainment will begin to disappear. This new technology enables two critical factors, high-speed data transfer and the ability to be online constantly. When you are in the office, home, airport or shopping center your communicator will automatically be able to connect to the broadband short-range wireless access networks (i.e. Wireless LAN) to provide highspeed wireless connections. Eliminating the need to dial-in, we will be able to receive email messages with file attachments that can be downloaded to hand-held devices instantaneously. With bandwidths of up to 2M bits/sec, (as compared to the 56K limitations of dial-up modems), wireless providers will be able to utilize a new business model where customers can be charged for the amount of data that is transmitted, not the amount of time that they are connected.

INTRODUCTION

As the name implies, there have been two previous generations of wireless technology. First-generation wireless service provided analog voice only, no data service. This was an entirely new form of communications that required a system-wide deployment of infrastructure for a market that did not yet exist. Established companies had the luxury of deploying digital service as an overlay to the analog network, while new carriers had to deploy entirely new digital networks, but they had the benefit of a market that was already aware of wireless telephony. The technology provided for digital voice service that was of higher quality, offering greater security and improved bandwidth. It is this technology that has become the migration path for the third generation technology. The key to 3G is convergence - not only a technological convergence of different kinds of communications but also, more importantly, a convergence for business reasons. We continue to see improved speeds that just a short time ago was impossible to imagine. Yet, the technology continues to advance, bringing with it new ideas and applications able to make use of these advancements. The technology underlying 3G is varied and complex. The convergence implies, in fact, a number of different technologies. Wireless communications involves networking hardware, communications standards and technologies for packaging and routing information. One of the most important concepts of wireless telephony is that of "multiple access", meaning simultaneous users can be supported. In other words, a large number of users share a common pool of radio channels and any user can gain access to any channel.

Current Cellular Standards

Different types of cellular systems employ various methods of multiple accesses. The traditional analog cellular systems used Frequency Division Multiple Access (FDMA). With FDMA, only one subscriber at a time is assigned to a channel. No other conversations can access this channel until the subscriber's call is finished, or until that original call is handed off to a different channel by the system. A common multiple access method employed in new digital cellular systems is the Time Division Multiple Access (TDMA). TDMA digital standards include North American Digital Cellular Global System for Mobile Communications (GSM), and Personal Digital Cellular (PDC). TDMA systems commonly start with a slice of spectrum referred to as one "carrier". Each carrier is then divided into time slots. Only one subscriber at a time is assigned to each time slot, or channel.

The CDMA Cellular Standard

CDMA (Code Division Multiple Access) uses unique digital codes, rather than separate RF frequencies, or channels to differentiate subscribers. The codes are shared by both the mobile station (cellular phone) and the base station, and are called "pseudo-Random Code Sequences." All users share the same range of radio spectrum. One of the unique aspects of CDMA is that while there are certainly limits to the number of phone calls that can be handled by a carrier, this is not a fixed number

THREE GENERATIONS OF WIRELESS STANDARDS

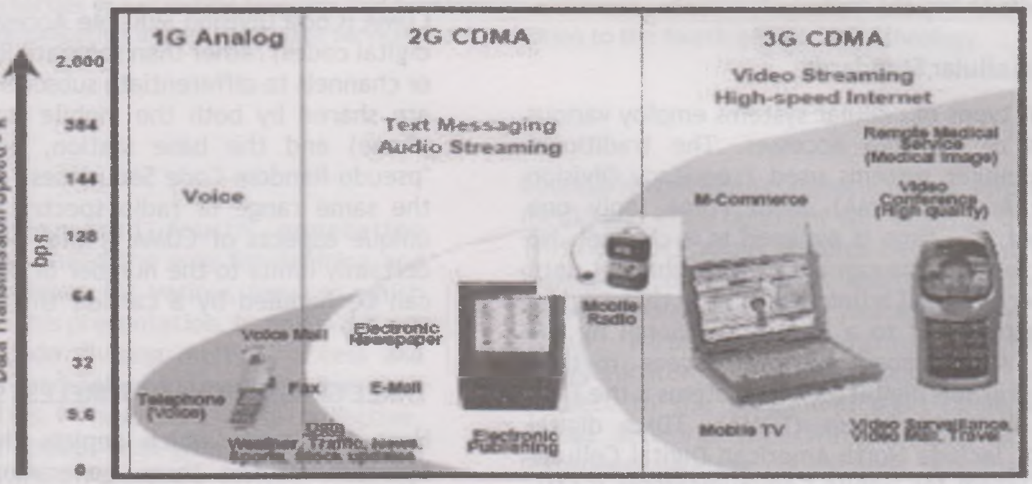
Here is a table which depicts the comparison between all the three generations which are existing:

		TECHNOLOGY	FEATURES
First-generation wireless	AMPS	Advanced Mobile Phone Service	• Analog voice service • No data service
Second-generation wireless	CDMA	Code Division Multiple Access	• Digital voice service • 9.6K to 14.4K bit/sec.
	TDMA	Time Division Multiple Access	
	GSM	Global System for Mobile Communications	
	PDC	Personal digital cellular	
Third-generation wireless	W-CDMA	Wide-band Code Division Multiple Access	• Superior voice quality • Up to 2M bit/sec. • Always-on data • Broadband data services like • video & multimedia
	CDMA-2000	Based on the Interim Standard-95 CDMA standard	

WHERE ARE WE TODAY?

Second generation wireless communication services are being implemented and continuously improved upon in preparation for the evolution to 3G. Today there are estimated 400 million mobile phone users globally and already the streams of telecommunications and data communications are converging, driven primarily by the rapid growth of the Internet. While voice remains the dominant mobile communication, other emerging technologies are changing the face of telecommunications. GPRS (General Packet Radio Service) - is currently being tested and offers users mobile Internet access at data speeds higher than those available from a fixed line. WAP (Wireless Application Protocol) - is a global, open protocol enabling users to access the Internet and utilize on-line services through their mobile phones. Bluetooth - is a new, wireless technology that was designed to replace the cables, which today link a wide range of portable and peripheral terminals and devices.

3G-High Speed Data to Mobile Phones !



FUTURE EXPECTATIONS

Already plans are in place for fourth-generation technologies such as WOFDM, which is proposed to deliver data at peak rates up to 10Mbps and allow for communications of 3-dimensional objects. Engineers involved in 4G wireless research at AT&T Labs say that this technology could be deployed in as little as f i v e y e a r s . It's not whether it's GPRS or 3G technology; the challenge is to develop a service proposition that consumers find valuable. Like CPU processors, wireless and Internet technologies will continue to evolve, delivering greater power and usability in generations to come. While 3G hasn't

quite arrived, designers are already thinking about 4G technologies. The goal is to have data rates up to 20 Mbps. Most probably the 4G network would be a network which is a combination of different technologies (current cellular networks, 3G cellular network, wireless LAN, etc.) working together using suitable interoperability protocols (for example Mobile IP). 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. MCM is not a new technology; forms of multicarrier systems are currently used in DSL modems, and digital audio/video broadcast (DAB/DVB). MCM is a base band process that uses parallel equal bandwidth sub channels to transmit information. Normally implemented with Fast Fourier transform (FFT) techniques, MCM's advantages include better performance in the intersymbol 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. **Equation 1**, describes peak to average adjustment - the difference of the PAVR between MCM and a single carrier system is a function of the number of sub carriers (N) as:

$$C(dB)=10\log N$$

(Equation 1)

Any increase in PAVR requires an increase in the linearity of the system to reduce distortion. Proposed approaches to reduce PAVR have consequences, however. One such technique is clipping the signal; this results in more nonlinearity. Linearization techniques can be used, but they increase the cost of the system, and amplifier back off may still be required. 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 sample are discarded, resulting in a loss in signal-to-noise ratio (SNR) as shown in **Equation 2.**

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$$SNB_{loss} = 10\log \frac{N+M-1}{N} (db)$$

(Equation 2)

These include multicarrier code division multiple access (MC-CDMA) and orthogonal frequency division multiplexing (OFDM) using time division multiple access (TDMA). Either way, multiple users access the system simultaneously. Differences between OFDM with TDMA and MC-CDMA can also be seen in the types of modulation used in each sub carrier. Typically, MC-CDMA uses quadrature phaseshift 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 sub carriers is chosen based on measured parameters. The line between RF and base band 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.

4G processing

Given that 4G is based on a multicarrier technique, key base band 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 base band 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. Receiver section 4G will require an improved receiver section, compared to 3G, to achieve the desired performance in data rates and reliability of communication. As shown in **Equation 3**, Shannon's Theorem specifies the minimum required SNR for reliable communication:

$$SNR = 2^{C/BW}$$

(Equation 3)

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. With any receiver, the main issues for efficiency and sensitivity are noise figure, gain, group delay, bandwidth, sensitivity, spurious rejection, and power consumption. 4G is no exception; the sensitivity can be determined as shown in **Equation 4** :

$$\text{Sensitivity } (dBm) = \text{Kto } (dBm) + 10\log (BW) + \text{NF } (dB) + SNR_{avgMCM}$$

(Equation -4)

where KTo is the thermal noise (for this equation it is -174 dBm), BW is the receiver bandwidth, NF is the receiver noise figure, and SNRavgMCM is the average SNR for a MCM system needed for an expected bit error rate. For a 4G receiver using a 5-MHz RF bandwidth, 16 QAM modulation and NF of 3 dB, the receiver sensitivity is -87 dBm. For 3G, the receiver sensitivity needs to be -122 dBm; the difference is due to the modulation and PAVR. This illustrates the need to reduce PAVR by clipping or coding. Also the gain is required to be linear, and the group delay must be flat over the bandwidth of the signal. The receiver front end provides a signal path from the antenna to the baseband processor. It consists of a band pass filter, a low-noise amplifier (LNA), and a down converter. Depending on the type of receiver there could be two down conversions (as in a super-heterodyne receiver), where one down conversion converts the signal to an IF. The signal is then filtered and then down converted to or near baseband to be sampled.

The first line of defense

The receiver band pass filter is the first line of defense to eliminate unwanted interference and noise. This filter must be able to achieve the cutoff needed for each bandwidth. In a 4G implementation, the bandwidth could be as low as 5 MHz and as high as 20 MHz. A tunable filter is needed. A measure of the linearity in the mixer section is the spurious free dynamic range (SFDR).

This is directly related to the second and third order intermodulation products also known as IP2 and IP3. The analog-to-digital converter (ADC) is the key component that can break the new system. System issues of the ADC concern whether or not to use under sampling, the PAVR of the signal, the bandwidth, and the sampling rate. For a 5-MHz bandwidth signal a typical sampling rate would be 20 MHz. If sampling is used, the aperture uncertainty or jitter must be low enough to prevent errors. The next requirement is the dynamic range. For an MCM system using the theoretical PAVR for a 512-point IFFT, the dynamic range required would be 80 dB, which is equal to 13 bits. This relationship is demonstrated in **Equation 5,** which shows quantization noise,

$$N0a = -\overline{\frac{Eb}{No}}(db) - 10\log(DB) - backoff(db) - 20(dB)$$

(Equation 5)

The desired quantization noise is determined by the average ratio of average signal power to average noise spectrum density measured in dB (Eb/No) for the subcarriers, the data rate (DR), and back off (which is generally 15 dB). The constant 20 dB is added to the end to put the quantization noise 20 dB lower than the system noise. The number of bits can be calculated as shown in **Equation 6.**

$$b = \frac{No_a + 4.77 - PAVR(dB) + 10\log(fs / 2)}{-6.02}$$

(Equation 6)

In this equation, fs is the sampling rate. If the signal has interference or blocking, the ADC requires additional bits. The required dynamic range of the ADC could increase from 15 to 17 bits.

Conclusion

Even as 3G begins to roll out, 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 base band 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. And as the improved capacities become a reality, so will the applications and services that will result.

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