3G/4G Network Evolution

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Abstract— **Wireless data services are expected to see the explosive growth in demand that Internet services and wireless voice services have seen in recent years. Mobile phones are rapidly becoming the preferred means of personal communication, creating the world's largest consumer electronics industry.**
The first generation of wireless mobile communications was based on analog signaling. The second generation (2G) of the wireless mobile network was based on low-band digital data signaling. Global Systems for Mobile Communications (GSM) is the most popular 2G wireless technology which is being used in India. GSM technology is a combination of Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA). General Packet Radio Service (GPRS) and Enhanced Data Rates for Global Evolution (EDGE) etc. come under 2G.
There is some restriction in 1G & 2G technologies for speed & security so to improve the speed & security there is need of new technology & therefore the 3G comes in picture. 3G wireless technology represents the convergence of various 2G wireless telecommunications systems into a single global system that includes both terrestrial and satellite components. CDMA (Code Division Multiple Access) which comes under 3G technology uses spread spectrum technology to break up speech into small, digitized segments and encodes them to identify each call. Third Generation (3G) mobile devices and services will transform wireless communications into on-line, real-time connectivity. 3G wireless technology will allow an individual to have immediate access to location-specific services that offer information on demand.
This white paper presents an overview of current technology trends in the wireless technology market, a historical overview of the evolving wireless technologies and an examination of how the communications industry plans to implement 3G wireless technology standards to address the growing demand for wireless multimedia services. Finally, this paper presents Trillium's solutions, which enable wireless communications and Internet infrastructure equipment manufacturers to develop 3G network elements for quick and efficient deployment.
Keywords— **CDMA, FDMA, GPRS, GSM, TDMA, Trillium Solution**

I. INTRODUCTION

Third Generation (3G) mobile devices and services will transform wireless communications into on-line, real-time connectivity. 3G wireless technology will allow an individual to have immediate access to location-specific services that offer information on demand. The first generation of mobile phones consisted of the analog models that emerged in the early 1980s. The second generation of digital mobile phones appeared about ten years later along with the first digital mobile networks. During the second generation, the mobile telecommunications industry experienced exponential growth both in terms of subscribers as well as new types of value-added services.

Mobile phones are rapidly becoming the preferred means of personal communication, creating the world's largest consumer electronics industry. The rapid and efficient deployment of new wireless data and Internet services has emerged as a critical priority for communications equipment manufacturers. Network components that enable wireless data services are fundamental to the next-generation network infrastructure. Wireless data services are expected to see the same explosive growth in demand that Internet services and wireless voice services have seen in recent years. This white paper presents an overview of current technology trends in the wireless technology market, a historical overview of the evolving wireless technologies and an examination of how the communications industry plans to implement 3G wireless technology standards to address the growing demand for wireless multimedia services. Finally, this paper presents Trillium's solutions, which enable wireless communications and Internet infrastructure equipment manufacturers to develop 3G network elements for quick and efficient deployment.

EVOLUTION OF THE MOBILE TECHNOLOGY

The first radio telephone service was introduced in the US at the end of the 1940s, and was meant to connect mobile users in cars to the public fixed network. In the 1960s,a new system launched by Bell Systems called "Improved Mobile Telephone Service"(IMTS) brought many improvements like direct dialling and higher bandwidth. The first analogy cellular systems were based on IMTS and developed in the late 1960s and early 1970s.The systems were "cellular" because coverage areas were split into smaller areas or "cells", each of which is served by a low power transmitter and receiver.

ACCESS TECHNOLOGIES:

FDMA:

Frequency Division Multiple Access (FDMA) is the most common analogy system. It is a technique whereby spectrum is divided up into frequencies and then assigned to users. With FDMA only one subscriber at any given time is assigned to a channel. The channel therefore is closed to other conversations until the initial call is finished, or until it is handoff to a different channel. A "full-duplex" FDMA transmission requires two channels, one for transmitting and the other for receiving. FDMA has been used for first generation analogy systems.

TDMA:

Time Division Multiple Access (TDMA) improves spectrum capacity by splitting each frequency into time slots. TDMA allows each user to access the entire radio frequency channel for the short period of a call. Other users share this same frequency channel at different time slots. The base stations continually switch from user to user on

the channel. TDMA is the dominant technology for the second-generation mobile cellular networks.

CDMA:

Code Division Multiple Access is based on "spread spectrum" technology. Since it is suitable for encrypted transmissions, it has long been used for military _occupy all channels at the same time. Transmissions are spread over the whole radio band, and each voice or data call are assigned a unique code. To differentiate from the other calls carried over the same spectrum.CDMA allows for a "soft hand-off ",which means that terminals can communicate several base stations at the same times.

EVOLUTION TO 3G WIRELESS TECHNOLOGIES

Initial coverage:-

Initially, 3G wireless technology will be deployed as "islands" in business areas where more capacity and advanced services are demanded. A complete evolution to 3G wireless technology is mandated by the end of 2000 in Japan (mostly due to capacity requirements) and by the end of 2001 in Europe. NTT Decoma is deploying 3G wireless services in Japan in the third quarter of 2000. In contrast, there is no similar mandate in North America and it is more likely that competition will drive the deployment of 3G wireless technology in that region. For example, Nextel Communications has announced that it will be deploying 3G wireless services in North America during the fourth quarter of 2000. The implementation of 3G wireless systems raises several critical issues, such as the successful backward compatibility to air interfaces as well as to deployed infrastructure

Third Generation (3G) Wireless Networks

3G wireless technology represents the convergence of various 2G wireless telecommunications systems into a single global system that includes both terrestrial and satellite components. One of the most important aspects of 3G wireless technologies is its ability to unify existing cellular standards, such as CDMA, GSM, and TDMA, less than one umbrella. The following three air interface modes accomplish this result: wideband CDMA, CDMA2000 and the Universal Wireless Communication (UWC-136) interfaces. Wide band CDMA (W-CDMA) is compatible with the current 2G GSM networks prevalent in Europe and parts of Asia. W-CDMA will require bandwidth of between 5Mhz and 10 MHz, making it a suitable platform for higher capacity applications. It can be overlaid onto existing GSM, TDMA (IS-36) and IS95 networks. Subscribers are likely to access 3G wireless services initially via dual band terminal devices. W-CDMA networks will be used for high-capacity applications and 2G digital wireless systems will be used for voice calls. The second radio interface is CDMA2000, which is backward compatible with the second generation CDMA IS-95 standard predominantly used in US. The third radio interface, Universal Wireless Communications – UWC-136, also called IS-136HS, was proposed by the TIA and designed to comply with ANSI-136, the North American TDMA standard. 3G wireless networks consist of a Radio Access Network (RAN) and a core network. The core network consists of a packet-switched domain, which includes 3G SGSNs and GGSNs, which provide the same functionality that they provide in a GPRS system, and a

circuit-switched domain, which includes 3G MSC for switching of voice calls. Charging for services and access is done through the Charging Gateway Function (CGF), which is also part of the core network. RAN functionality is independent from the core network functionality. The access network provides a core network technology independent access for mobile terminals to different types of core networks and network services. Either core network domain can access any appropriate RAN service; e.g. it should be possible to access a "speech" radio access bearer from the packet switched domain. The Radio Access Network consists of new network elements, known as Node B and Radio Network Controllers (RNCs). Node B is comparable to the Base Transceiver Station in 2G wireless networks. RNC replaces the Base Station Controller. It provides the radio resource management, handover control and support for the connections to circuit-switched and packet-switched domains. The interconnection of the network elements in RAN and between RAN and core network is over Iub, Iur and Iu interfaces based on ATM as a layer 2 switching technology. Data services run from the terminal device over IP, which in turn uses ATM as a reliable transport with QoS. Voice is embedded into ATM from the edge of the network (Node B) and is transported over ATM out of the RNC. The Iu interface is split into 2 parts: circuit switched and packet-switched. The Iu interface is based on ATM with voice traffic embedded on virtual circuits using AAL2 technology and IP-over-ATM for data traffic using AAL5 technology. These traffic types are switched independently to either 3G SGSN for data or 3G MSC for voice.
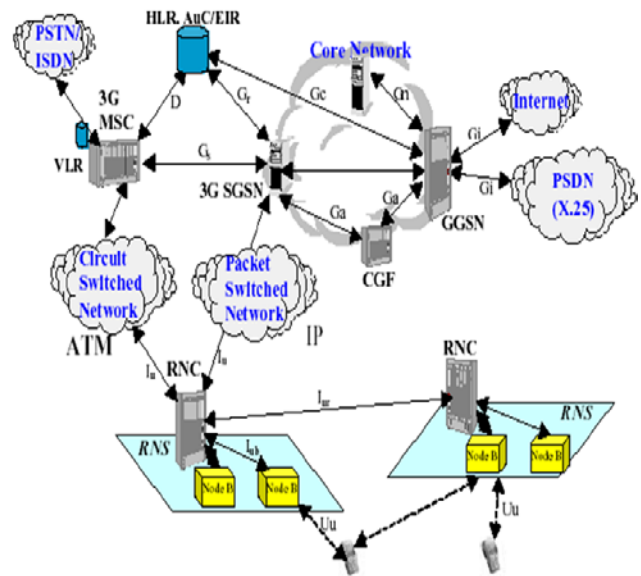

Fig. 1 3G Wireless Network Architecture

Beyond 3G:

In the field of mobile communication services, the 4G mobile services are the advanced version of the 3G mobile communication services. The 4G mobile communication services are expected to provide broadband, large capacity, high speed data transmission, providing users with high quality colour video images,3D graphic animation games,

and audio services in 5.1 channels. We have been searching the vision of 4G mobile communication systems, services and architectures. We also have been developing the terminal protocol technology for high capacity, high speed packet services, public software platform technology that enables downloading application programs, multimode radio access platform technology and high quality media coding technology over mobile networks.

Reasons to have 4G:

1. Support interactive multimedia services: Teleconferencing, wireless internet etc.
2. Wider bandwidths, higher bit rates.
3. Global mobility and service portability.
4. Low cost.
5. Scalability of mobile networks.

New in 4G:

1. Entirely packet-switched networks.
2. All network elements are digital.
3. Higher bandwidths to provide multimedia services at lower cost (up to 100Mbps).
4. Tight network security.
5. Adaptive array technology.
6. Ultra wide band technology.
7. Simulation and analysis of advanced adaptive modulations/coding schemes.
8. Reconfigurable radio systems.
9. Self-organizing networks end-to-end mobile IP and adaptive QoS (Quality of Service)
10. Simulation and analysis of MIMO techniques with multi-element array antennas at both ends of the link.

Fourth generation:

The approaching 4G (fourth generation) mobile communication systems are projected to solve still-remaining problems of 3G (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.

As a promise for the future, 4G systems, that is, cellular broadband wireless access systems have been attracting much interest in the mobile communication area.

The 4G systems not only will support the next generation of mobile service, but also will support the fixed wireless networks

The fourth generation will encompass all systems from various networks, public to private; operator-driven broadband networks to personal areas; and ad hoc networks. The 4G systems will interoperate with 2G and 3G systems, as well as with digital (broadband) broadcasting systems. In addition, 4G systems will be fully IP-based wireless Internet. This all-encompassing integrated perspective shows the broad range of systems that the fourth generation intends to integrate, from satellite broadband to high altitude platform to cellular 3G and 3G systems to WLL (wireless local loop) and FWA (fixed wireless access) to

WLAN (wireless local area network) and PAN (personal area network), all with IP as the integrating mechanism. With 4G, a range of new services and models will be available.

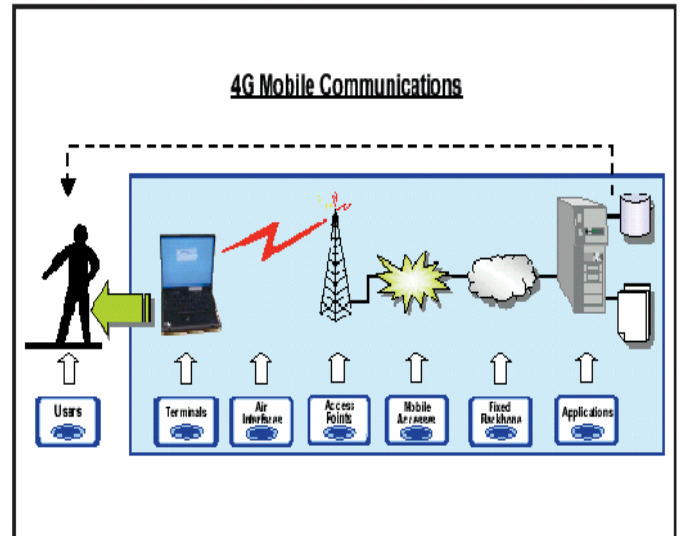These services and models need to be further examined for their interface with the design of 4G systems.

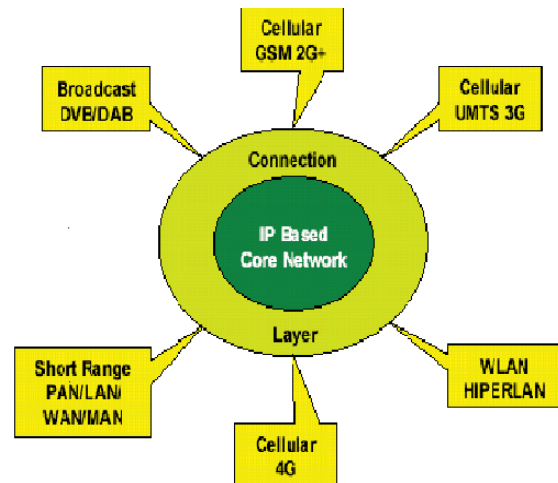

Fig.2 4G Mobile Communication Vision

Fig. 3 Demonstrate seamless connectivity of the networks.

4G WIRELESS TECHNOLOGIES:

As radio spectrum is the primary resource for wireless technologies, the main thrust of 4G research worldwide is directed towards spectrally efficient systems. New powerful technology that emerged recently promises a tenfold improvement in spectral efficiency over existing solutions. These potential 4G tools and techniques include:

Wireless access technologies-

OFDMA (Orthogonal Frequency Division Multiple Access) and MC-CDMA (Multiple Carrier Code Division Multiple Access) are the main contenders for future systems. Another more radical access scheme for the downlink is a single queue packet-based system.

One of 4G's technology drivers is orthogonal frequency division multiplexing (OFDM). Patented over thirty years ago, only recently has OFDM gained widespread use. OFDM, a form of multi-carrier modulation works by dividing the data stream for transmission at a bandwidth B into N multiple and parallel bit streams, spaced B/N apart. Each of the parallel bit streams has a much lower bit rate than the original bit stream but their summation can provide very high data rates. Orthogonal sub-carriers modulate the parallel bit streams, which are then summed prior to transmission.

An OFDM transmitter accepts data from an IP network converting and encoding the data prior to modulation. An IFFT (Inverse Fast Fourier Transform) transforms the OFDM signal into an IF analogy signal which is sent to RF transreceiver. The receiver circuit reconstructs the data by reversing this process. With orthogonal sub-carriers the receiver can separate and process each sub-carrier without interference from other sub-carriers. More impervious to fading and multipath delays than other wireless transmission techniques. OFDM provides better link and communication quality.

Using OFDM, it is possible to exploit the time domain, the space domain, the frequency domain and even the code domain to optimize radio channel usage. It ensures very robust transmission in multi-path environments with reduced receiver complexity. As shown in *Figure,* the signal is split into orthogonal subcarriers, on each of which the signal is "narrowband" (a few kHz) and therefore immune to multi-path Effects,

provided a guard interval is inserted between each OFDM symbol. OFDM also provides a frequency diversity gain, improving the physical layer performance. It is also compatible with other enhancement technologies,

such as smart antennas and MIMO.OFDM modulation can also be employed as a multiple access technology (Orthogonal Frequency Division Multiple Access; OFDMA). In this case, each OFDM symbol can transmit information to/from several users using a different set of subcarriers (sub channels). This not only provides additional flexibility for resource allocation (increasing the capacity), but also enables cross-layer optimization of radio link usage.
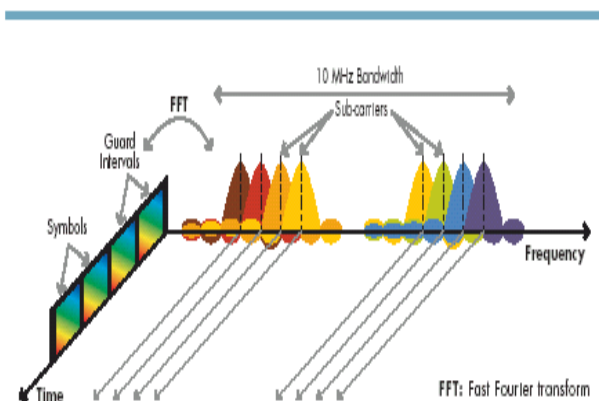

Fig.4 OFDM Principal of FFT

Opportunities in 4G:
1. It is expected and predicted that consumers will continue to replace handsets with newer technology at a fast rate.
2. Desirable higher data capacity rates, the growth opportunity for 4G is very bright and hopeful.
Applications:
1. Location application 4G location application will be based on visualized, virtual navigation scheme that will support a remote database containing graphical representation of streets, buildings and other physical characteristics of a large metropolitan area.
2. Virtual navigation and telegeoprocessing.
You will be able to see internal layout of a building during an emergency rescue. This type of application is referred to as 'telegeoprocessing'.
3. 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.
Limitations
Although the concept of 4G mobile communications shows much promise, there are some limitations. One major limitation is operating area. The 4G systems are going to inherit the drawbacks of existing networks. Although 2G (GSM) networks are covering a long area, there are many areas that are not served. Still many rural areas are not being served by existing mobile networks. This is a big obstacle in achieving the basic aim of 4G i.e. Global Roaming. Also, the hype that is being created by 3G networks is giving the general public unrealistic expectations of always on, always available, anytime communication. People should realize that although there is high-speed data communication allowed, it will not be equivalent to wired Internet.

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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