Emerging Wireless Technologies

A look into the future of wireless communications – beyond 3G

Forward: The Public Safety Wireless Network (PSWN) Program is conducting an ongoing assessment of advancements in the wireless communications industry. The scope of this assessment is to identify emerging wireless services and technologies for potential public safety use in the near future and beyond. This particular document is the first of a series of emerging wireless technologies studies. This study will concentrate primarily on the fourth generation of mobile telecommunications and beyond.

Although the new, third generation (3G) wireless technology has not yet been implemented, leading companies in the industry are already laying the groundwork for what some are calling fourth generation (4G) technology. For the purposes of this article, 4G will be considered those technologies that are still in the planning stages and will not be deployed within the next five years. Researchers are continuing their ideas in the development of an undefined wireless world, which could become operational by 2010.

The first generation (1G) and second generation (2G) of mobile telephony were intended primarily for voice transmission. The third generation of mobile telephony (3G) will serve both voice and data applications.

There really is no clear definition of what 4G will be. It is generally accepted that 4G will be a super-enhanced version of 3G – i.e., an entirely packet switched network with all digital network elements and extremely high available bandwidth. For the most part, it is believed that 4G will bring true multimedia capabilities such as high-speed data access and video conferencing to the handset. It is also envisioned that 4G systems will be deployed with software defined radios, allowing the equipment to be upgraded to new protocols and services via software upgrades. 4G also holds the promise of worldwide roaming using a single handheld device.

Wireless Generations At-a-Glance

As with all technology progressions, the "next" upgrades must be in planning and development phases while its predecessors are being deployed. This statement holds true with all mobile telecommunications to date. It seems that it will also hold true for the next generations of wireless networks.

The original analog cellular systems are considered the first generation of mobile telephony (1G). In the early 1980s, 1G systems were deployed. At the same time, the cellular industry began developing the second generation of mobile telephony (2G). The difference between 1G and 2G is in the signaling techniques used: 1G used analog signaling, 2G used digital signaling. As experience shows, the lead-time for mobile phone systems development is about 10 years. It was not until the early to mid 1990s that 2G was deployed.

Primary thinking and concept development on 3G generally began around 1991 as 2G systems just started to roll out. Since the general model of 10 years to develop a new mobile system is being followed, that timeline would suggest 4G should be operational some time around 2011. 4G would build on the second phase

of 3G, when all networks are expected to embrace Internet protocol (IP) technology.

During the last year, companies such as Ericsson, Motorola, Lucent, Nortel and Qualcomm came up with "3G-plus" concepts that would push performance of approved, though still emerging, standards beyond current ones.

Interoperability and the Evolution of Network Architectures

One of the most challenging issues facing deployment of 4G technologies is how to make the network architectures compatible with each other. New signaling techniques are being designed specifically to enhance today's second generation (2G) networks, deliver unprecedented functionality for 3G, and successfully drive the Fourth Generation (4G) of wireless, thus delivering immediate and long-term benefits to carriers. With the architecture of each generation of wireless devices addressed in the development of advanced technologies, carriers can easily evolve their systems without additional network modifications, significantly reducing costs and implementation time. Currently, different wireless technologies (e.g., GSM, CDMA, and TDMA[1]) are used throughout the world for the 2G, 2.5G, and eventually 3G networks.

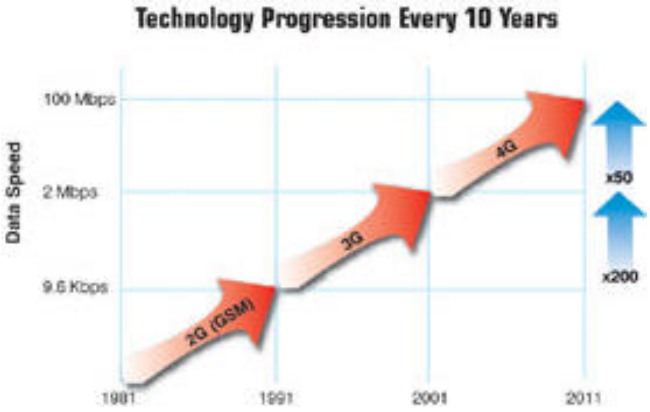
There are two approaches being used to develop 4G access techniques: 3xRTT (currently 1xRTT for 2.5 and 3G) and Wideband CDMA (W-CDMA). These disparate access techniques currently do not interoperate. This issue may be solved with software defined radios.

LinkAir Communications is developing a new access technology called large-area-synchronized code-division multiple access (LAS-CDMA). LAS-CDMA will be compatible with all current and future standards, and there is a relatively easy transition from existing systems to LAS-CDMA (using software defined radios). LinkAir emphasizes that LAS-CDMA will accommodate all the advanced technologies planned for 4G and that LAS-CDMA will further enhance either 3xRTT or W-CDMA system's performance and capacity.

Internet Speeds

2.5G is the interim solution for current 2G networks to have 3G functionality. 2.5G networks are being designed such that a smooth transition (software upgrade) to 3G can be realized. 2.5G networks currently offer true data speeds up to 28kbps. In comparison, the theoretical speed of 3G can be up to 2 Mbps, i.e., approximately 200 times faster than previous 2G networks. This added speed and throughput will make it possible to run applications such as streaming video clips.

It is anticipated that 4G speeds could be as high as 100 Mbps. Thus, 4G will represent another quantum leap in mobile Internet speeds and picture quality. Ericsson confirms that 4G could bring connection speeds of up to 50 times faster than 3G networks and could offer three-dimensional visual experiences for the first time. The following graph represents what has been the typical progression of wireless communications:



1 *GSM – Global System for Mobile Communications*
CDMA – Code Division Multiple Access
TDMA – Time Division Multiple Access

Quality of Service Challenges

In wireless networks, Quality of Service (QOS) refers to the measure of the performance for a system reflecting its transmission quality and service availability (e.g., 4G is expected to have at least a reliability of 99.99%). Supporting QOS in 4G networks will be a major challenge. When considering QOS, the major hurdles to overcome in 4G include: varying rate channel characteristics, bandwidth allocations, fault tolerance levels, and handoff support among heterogeneous wireless networks. Fortunately, QOS support can occur at the packet, transaction, circuit, and network levels. QOS will be able to be tweaked at these different operating levels, making the network more flexible and possibly more tolerant to QOS issues.

Varying rate channel characteristics refers to the fact that 4G applications will have varying bandwidth and transition rate requirements. In order to provide solid network access to support the anticipated 4G applications, the 4G networks must be designed with both flexibility and scalability. Varying rate channel characteristics must be considered to effectively meet user demand and ensure efficient network management.

Spectrum is a finite resource. In current wireless systems, frequency licensing and efficient spectrum management are key issues. In 4G systems, bandwidth allocations may still be a concern. Another concern is interoperability between the signaling techniques that are planned to be used in 4G (e.g., 3xRTT, W-CDMA).

In comparison with current 2G and 2.5G networks, 4G will have more fault tolerance capabilities built-in to avoid unnecessary network failure, poor coverage, and dropped calls. 4G technology promises to enhance QOS by the use of better diagnostic techniques and alarms tools.

4G will have better support of roaming and handoffs across heterogeneous networks. Users, even in today's wireless market, demand service transparency and roaming. 4G may support interoperability between disparate network technologies by using techniques such as LAS-CDMA signaling. Other solutions such as software defined radios could also support roaming across disparate network technologies in 4G systems.

These major challenges to QOS in 4G networks are currently being studied and solutions are being developed. Developers believe that QOS in 4G will rival that of any current 2G or 2.5G network. It is anticipated that the QOS in 4G networks will closely approximate the QOS requirements in the wireline environment (99.999% reliability).

The emergence of next generation wireless technologies is going enhance the effectiveness of the existing methods used by public safety...

4G Applications and Their Benefits to Public Safety

One of the most notable advanced applications for 4G systems is location-based services. 4G location applications would be based on visualized, virtual navigation schemes that would support a remote database containing graphical representations of streets, buildings, and other physical characteristics of a large metropolitan area. This database could be accessed by a subscriber in a moving vehicle equipped with the appropriate wireless device, which would provide the platform on which would appear a virtual representation of the environment ahead. For example, one would be able to see the

internal layout of a building during an emergency rescue. This type of application is sometimes referred to as "Telegeoprocessing", which is a combination of Geographical Information Systems (GIS) and Global Positioning Systems (GPS) working in concert over a high-capacity wireless mobile system. Telegeoprocessing over 4G networks will make it possible for the public safety community to have wireless operational functionality and specialized applications for everyday operations, as well as for crisis management.

The emergence of next generation wireless technologies will enhance the effectiveness of the existing methods used by public safety. 3G technologies and beyond could possibly bring the following new features to public safety:

Virtual navigation: As described, a remote database contains the graphical representation of streets, buildings, and physical characteristics of a large metropolis. Blocks of this database are transmitted in rapid sequence to a vehicle, where a rendering program permits the occupants to visualize the environment ahead. They may also "virtually" see the internal layout of buildings to plan an emergency rescue, or to plan to engage hostile elements hidden in the building.

Tele-medicine: A paramedic assisting a victim of a traffic accident in a remote location could access medical records (e.g., x-rays) and establish a video conference so that a remotely based surgeon could provide “on-scene” assistance. In such a circumstance, the paramedic could relay the victim's vital information (recorded locally) back to the hospital in real time, for review by the surgeon.

Crisis-management applications: These arise, for example, as a result of natural disasters where the entire communications infrastructure is in disarray. In such circumstances, restoring communications quickly is essential. With wideband wireless mobile communications, both limited and complete communications capabilities, including Internet and video services, could be set up in a matter of hours. In comparison, it may take days or even weeks to re-establish communications capabilities when a wireline network is rendered inoperable.

Limitations of 4G

Although the concept of 4G communications shows much promise, there are still limitations that must be addressed. One major limitation is operating area. Although 2G networks are becoming more ubiquitous, there are still many areas not served. Rural areas and many buildings in metropolitan areas are not being served well by existing wireless networks. This limitation of today’s networks will carry over into future generations of wireless systems.

The hype that is being created by 3G networks is giving the general public unrealistic expectations of always on, always available, anywhere, anytime communications. The public must realize that although high-speed data communications will be delivered, it will not be equivalent to the wired Internet – at least not at first. If measures are not taken now to correct perception issues, when 3G and later 4G services are deployed, there may be a great deal of disappointment associated with the deployment of the technology, and perceptions could become negative. If this were to happen, neither 3G nor 4G may realize its full potential.

Another limitation is cost. The equipment required to implement a next-generation network is still very expensive. Carriers and providers have to plan carefully to make sure that expenses are kept realistic. One technique currently being implemented in Asian networks is a Pay-Per-Use model of services. This model will be difficult to

implement in the United States, where the public is used to a service-for-free model (e.g., the Internet).

Conclusions

4G networks may eventually deliver on all the promises. At times, it seems that technological advances are being made on a daily basis. These advances will make high-speed data/voice-over-Internet-protocol (VoIP) networks a reality.

In the meantime, it is important for industry to develop a strong 3G offering that is palatable for the general public. Equally as important, industry must ensure that expectations are realistic and that services meet and exceed those expectations.

If all goes according to what the industry envisions, it may be sooner, rather than later that we will see wireless communications evolve. This evolution will give the general public as well as the public safety community amazing functionality from the convenience of a single handheld device.

Postscript: The purpose of this article is to introduce the reader to next-generation wireless communications. In coming articles, further developments in 4G (e.g., services, billing, protocols, and standards) and other emerging wireless technologies will be presented in greater depth.

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