

4G

The Game
is On

By David Crowe

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It seems only yesterday that the wireless industry was all abuzz about 3G. In fact, sometimes it seems to me that it was only yesterday that the industry was all abuzz about digital (now sometimes called 2G), but that actually started more than a decade ago. And sometimes, and now I'm really showing my age, it seems only yesterday that the first analog phones were morphing into handhelds, where a suitcase-sized transceiver was not needed in the trunk of your car.

But now the buzz is all about 4G. As you might guess, this will distinguish itself from 3G by higher data rates. Rather than the 1-10 Mbps speeds of 3G, the 4G technologies are aiming for 100 Mbps and starting to talk about a jaw-dropping 1 Gbps. More subtly, the 4G network will be a data network supporting voice as an application, whereas 3G evolved from a voice network with data as an add-on, although one that has grown significantly in prominence as more and more attractive data devices have come on the market.

It used to be that phones had one major function – talking. The second major function was data capabilities, starting with text messaging, followed by WAP, e-mail and now full-function Internet access. But this second function brought with it a third: the ability to use the data loaded onto the phone via this new interface for functions that did not involve communications at all, such as viewing photographs, listening to music, playing games or using downloaded productivity applications. As 4G systems bring more information into devices, their capabilities will dramatically increase as people rely more and more on their wireless devices for their work and leisure information requirements. We can expect to see larger screens, more sophisticated input methods and greater storage capabilities.

The major limitations of the 3G devices were the bandwidth of the devices and the cost of data. 4G is

aiming to correct both of those. The higher bandwidth will not only allow faster Internet access, but clearly it will exert major downward pressure on the cost of a megabyte of wireless data. If 4G proponents are successful, it should create new competition for high speed wireless applications that currently mainly run over telephone wires or cable television facilities. Cellular carriers are almost certain to upgrade their systems and new entrants may be tempted to enter the market.

Wireless technologies, by their nature, evolve by a unique mixture of private innovation and public negotiations, and 4G is definitely not an exception. The private innovation occurs in the laboratories of major wireless manufacturers and the converted garages of startup companies, while the public negotiations occur in a plethora of standards committee meetings in dull hotel rooms in nice parts of the world. The aim of the corporations that attend these meetings is twofold, with the two parts somewhat conflicting. They want to get their intellectual property, their patents, into the standards. But they also want to get a standard published that will be widely accepted. The conflict comes because a company that manipulates the process to get patents incorporated that are not really useful may end up with a pyrrhic victory – a standard that nobody much uses and that therefore generates little revenue. A company that gets only one major patent into a standard that is wildly popular (such as all the cellular phone radio interfaces currently in use in Canada) will make less money per device but much more money overall.

There is another level of competition as well, which introduces even more uncertainty: competition between standards organizations themselves. Companies have to throw their lot in with a standards organization they believe has the best chance of producing a standard that will be widely used.

There is no question this is a high stakes game. Start-up companies in particular have their very existence on the line, including the value of their shareholders' investments. Both a standard that does not include their inventions and a standard that languishes unused are fatal outcomes for them. Even standards organizations stand to gain or lose members as the need for maintaining 3G standards declines and their health relies increasingly on 4G developments which rely on their standards being used.

Right now the game is on, and we do not know who the winners will turn out to be. Let's have a peek at progress so far...

The Players

3G systems were mostly standardized by two international partnerships with the confusingly similar names of 3GPP and 3GPP2. 3GPP was formed by standards organizations from Japan (ARIB and TTC), Korea (TTA), China (CCSA), Europe (ETSI) and North America (ATIS). Specifications (technically they are not standards) from this partnership are based on the GSM 2G radio standard and have been extended to the fully 3G technology known as UMTS or Wideband CDMA. The major Canadian carrier using 3GPP technologies commercially is Rogers. 3GPP's hand in the 4G game is known as LTE (Long Term Evolution), E-UTRA (Evolved-Universal Terrestrial Radio Access), or simply Release 8.

3GPP2 has the same partners as 3GPP from Japan, Korea and China along with the TTA from North America. Their 2G offering was known as cdma2000, which was extended to 3G capabilities through EVDO (Evolution-Data Optimize). This technology is used mainly by carriers who received cellular licenses as phone companies, including TELUS and Bell Mobility. Their 4G offering is known as UMB and is being developed jointly with IEEE 802.20 (after a palace coup that

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saw the entire leadership of 802.20 replaced in late 2006).

Two major technologies in wireless seem to produce a relatively stable system, because in most areas there are at least two carriers competing, so both technologies have a fairly assured market. However, it appears that 4G will not enjoy that stability because a new entrant has come along to make life more exciting – the WiMAX Forum.

WiMAX was initiated as a high speed wireless data system without much concern for mobility, allowing it to compete with cable television companies and high speed Internet providers. But their plans did not stop there. They intend to extend WiMAX into the realm of full mobility, which will not only allow mobile devices to be operated while walking or in a car or train, but will also allow roaming access when a user has taken a device outside their home serving area. WiMAX Mobile gained significant credibility in North America when Sprint announced in August 2006 that its 4G plans were being changed from WiBro to WiMAX Mobile.

Another wild card is this South Korean system known as WiBro that Sprint embraced and then rejected, which is already in use or being trialed in several countries. There is some confusion because it is also a WiMAX mobile protocol (IEEE 802.16e) that even the WiMAX Forum claims for its own. While it shares many of the same technologies and capabilities of WiMAX Mobile, it is an earlier version and it incorporates only a single suite of capabilities from all that WiMAX would allow. This technology has momentum today because it is the only one with commercial implementations. At this stage of development, this is both an obvious benefit but also a drawback because its capabilities have become a known quantity that all competitors know they have to beat. Competitors are also very aware of its limitations

and any deficiencies. However, if it can continue to gain market share and prove that the newer technologies are not significantly better, it could still win. If WiBro is displaced, it is most likely that its current users would migrate to the broader WiMAX Mobile standard, especially given that the WiBro developers participate in the WiMAX Forum and IEEE 802.16.

From CDMA to OFDMA

The two major 3G technologies were based on CDMA (Code Division Multiple Access) radio technology. A similar commonality has developed with 4G, with all four systems being flavours of OFDMA (Orthogonal Frequency Division Multiple Access). Whereas CDMA is designed to have all users transmitting in the same radio frequency band, with orthogonal codes being used to separate out individual communications, OFDMA breaks a frequency band up into many narrow subchannels, separated just far enough to avoid interference. OFDMA allows the modulation, amplitude and coding to be set separately for each subchannel, allowing the system to better adapt to the needs of mobiles that are in different locations, transmitting and receiving at different speeds, and facing different noise and interference environments.

3GPP's LTE is based on OFDMA on the downlink and FDMA on the slower uplink. The downlink refers to the transmission from the base station to the mobile device, and in general is much easier to control because all transmissions come from a single point. The uplink is transmitted individually by many different devices at different locations with slightly different radio equipment dealing with different radio environments, and therefore is generally considerably slower. For most Internet communications, this is not a problem as more data goes

to the user than is generated by the user.

The OFDMA system in LTE can use the modulation schemes QPSK, 16QAM or 64QAM. The latter provides the highest throughput (four times higher than 16QAM as you might have guessed), but radio experts expect that this will be too easily distorted beyond recognition except for devices close to the base station.

3GPP has also chosen to rely on multiple antennas – something that can reduce multi-path fading problems. Their MIMO (Multiple Inputs Multiple Outputs) will have four antennas at the base station and up to four in each mobile device.

3GPP's target is to provide downlink data rates up to 100 Mbps in 20 MHz channels, and uplink rates about half that. For flexibility, channels can be as small as 1.25 MHz where maximum data rates will also drop proportionately.

3GPP2's UMB system will have some similarities to LTE. It will also be based on OFDMA, is designed for channels between 1.25 MHz and 20 MHz wide, and will include MIMO antennas. It is aiming for higher peak data rates of up to 280 Mbps downlink and up to 75 Mbps uplink, hoping that additional advanced antenna technologies such as beamforming will provide it with the speed advantage. Beamforming uses knowledge of the location of an individual mobile to modulate the signal so that more ends up at the destination mobile with less hitting others. This not only increases the strength of the signal where it is intended to go, but reduces interference with other devices.

The WiMAX Forum is developing a similar technology in conjunction with IEEE 802.16, with 802.16e ("Mobile WiMAX") being the version that incorporates mobility. The technology has much in common with UMB, including the possibility of including MIMO and beamforming, but is based on a

unique variant of OFDM known as SOFDM (Scalable OFDM). WiBro, from a technical perspective, provides a subset of the full suite of WiMAX Mobile capabilities.

Apart from raw bandwidth, another area where 4G technologies are trying hard to improve over 3G systems is in the area of latency – the amount of time it takes data to get from the mobile device to the base station and back again (ignoring all delays within the network). This is a significant factor in interactive sessions such as web browsing or instant messaging, often more significant than the amount of bandwidth available. This is because, in an interactive session, the user will generally wait for a response before proceeding with the next input. Pre-3G systems such as GPRS had a latency of more than half-a-second, which is a very noticeable delay. 3G systems reduced this to about 100 milliseconds, but 4G systems are aiming for about a 10 millisecond-delay that will be imperceptible in most applications.

For all of these players in the 4G gamble it is important to keep in mind that many of the specifications are just targets, and none of the systems have been fully proven in commercial implementations. They might not exactly be bluffing, but proponents of these systems tend to be optimists who may create targets that cannot be fully achieved outside of the laboratory. However, with so many experienced radio engineers working on the systems, even if the targets are not achieved exactly, 4G radio technology will definitely represent a great leap forward.

Don't Forget the Wires

It is often overlooked that modern wireless systems are not completely wireless, but in reality they combine a short (but critically important) distance of wireless access with wired access to any point in the world. The wired component usually covers much more ground (potentially thousands of kilometers) than the wireless component, which is limited to the radius of a cell. The 4G network will be based on technology that is variously called All-IP because of its use of the Internet Protocol (IP), IMS (IP Multimedia System)

or MMD (Multi-Media Domain) for all communications. This means that carriers only need to provide one backbone network based on massively wide pipes carrying only IP traffic. Above the IP network layer will be a variety of other protocols, ranging from the obscure to very familiar, supporting applications like e-mail, video, picture sharing, instant messaging, Web surfing and even voice, through protocols like SIP.

Seeing voice as just another form of data is truly a massive change, although one that has been underway for some time. While voice does not require a huge amount of bandwidth, it is a unique form of data that is very sensitive to even small delays in the arrival of its packets. If packets of voice are not delivered quickly and regularly, the voice quality can be distorted until the ability to converse is destroyed. Allowing voice traffic on a data network means that the network must support QoS (Quality of Service), guaranteeing that voice packets get a high enough priority that they arrive very promptly.

Voice is not the only challenge for IP-based systems. Mobility management systems arose to a high level of sophistication in cellular systems, allowing people with a compatible radio device to use their phone just about anywhere in the world. Mobility management systems validate the mobile user's right to make phone calls, authenticate the user to prevent fraudulent use, determine the vertical services that the user has subscribed to, and reroute terminating calls and text messages to their current location. This is all done without any user intervention and has been for years – even in some analog systems. As soon as a phone is turned on in a new location, the mobile automatically registers and mobility management is accomplished before the first call is made.

Internet-based systems do not have such sophisticated protocols. Mobile IP is not a full solution for mobility management, only handling the rerouting of packets. IMS systems have had to put mobility management together through a suite of independent protocols. And even then it is easy for the system to break, especially when systems like

NAT (Network Address Translation) devices are involved. These devices, which are unfortunately found in virtually every router and therefore in virtually every home and office with high speed Internet, create a different address space on one side than the other. This has saved the world from running out of IPv4 addresses, but conflicts with Mobile IP and some other protocols. Problems occur largely because many Internet protocols carry IP addresses above the IP layer, out of the reach of the NAT's translation capabilities. When the application moves this address down to the IP layer, it will then be incorrectly translated by the NAT and the packet will be lost somewhere in the Internet.

These problems have resulted in a push to have 4G systems rely on IPv6. Because of the huge address space, there is no need to rely on NATs. However, with virtually the entire Internet still based on the IPv4 protocol, this will be a huge challenge, especially in poorer countries where upgrading their Internet infrastructure is simply not economically feasible.

Until the transition to IPv6 occurs, protocol designers will have to work hard to improve IP-based mobility management systems to ensure that mobility is managed efficiently, which means that users will not even realize that it is there.

Looking Forwards, Looking Back

4G systems will inevitably come to Canada. Field trials can be expected fairly soon and commercial implementation will occur whenever the technology is mature enough to risk major investments in terminals and cell site equipment. Canadian wireless phone users, which nowadays means just about everyone, will benefit from a wide variety of new devices with more advanced data capabilities rivaling, or even exceeding, the capabilities Canadians currently experience at home with wired high speed Internet. ■

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