Waste Not, Want Not

a report by
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All wireless technologies are pumping up their data rates, but only the GSM™ technology migration path offers the right mix of quantity and quality for voice and high-speed data.

There are many arguments as to which wireless technology is superior, but one fact that is indisputable is that no operator can afford to waste spectrum. Capacity-strapped operators can usually obtain spectrum from somewhere: at auction, by acquiring a rival or by buying from an operator that is not using all of its licences. Considering that an operator almost certainly will pay too much for the spectrum, this is a short-sighted, short-term fix that will have later repercussions.

A smarter strategy is to better utilise spectrum in the first place. Many Time Division Multiple Access (TDMA) operators in the Americas are switching to GSM to enjoy its global cost structure, roaming and economies of scale, but an equally compelling reason is the way in which GSM will be able to squeeze up to four times as many calls into the same spectrum.

Background

The voice capacity of all wireless technologies is usually measured in Erlangs, which is the number of simultaneous calls that a system can handle during a busy period before new calls start to be blocked. For example, a cell-site sector that has room for 100 simultaneous voice calls works out to 86 Erlangs under the industry rule that a system should never block more than 2% of all calls. In other words, that 100-call sector cannot contend with more than 86 calls at once because any more runs the risk of new calls being blocked.

In a real-world environment, a well-engineered TDMA system can handle about 37 Erlangs per sector, while a comparable GSM system handles about 67 Erlangs – or roughly 45% more than TDMA. That boost alone is enough for most TDMA operators to make a business case for switching to GSM, but a new voice-coding technology, currently available, more than doubles GSM's capacity to 142 Erlangs, which is nearly four times as much as TDMA.

GSM gains that fourfold advantage from adaptive multi-rate speech transcoding (AMR), which adjusts the voice-coding rates according to changing channel conditions, such as decreasing signal strength or rising interference. As AMR makes those adjustments continually throughout the call rather than just at the beginning, the network constantly wrings maximum use out of the available spectrum and infrastructure.

This is not to say that AMR's increased capacity comes at the expense of voice quality. In fact, AMR actually improves voice quality, especially on the fringes of a cell and inside buildings. That robustness could also reduce an operator's capital expense costs by eliminating the need for additional cell sites just to put a stronger signal in difficult-to-reach locations.

The actual capacity gain of AMR depends on how many of an operator's customers replace their phones with new, AMR-equipped phones. GSM operators should start reaping the benefits of AMR by mid 2003, as most wireless users replace their handsets every 18 to 24 months. Considering that the boom in mobile phone sales started to flatten out in early 2001, it is safe to assume that many GSM users will start replacing their phones in 2003, when handsets with AMR become widely available.

The Real Voice Capacity Leader

GSM operators are not the only ones using sophisticated voice coders to squeeze more calls into the same spectrum. Code Division Multiple Access (CDMA) operators use enhanced variable-rate coder (EVRC), which is similar to AMR in two respects: it increases voice capacity significantly compared with the technology it replaces, and the actual capacity gain depends on how many customers replace their phones with models that use the new vocoder.

Although CDMA operators and vendors always touted their 2G technology as being almost exponentially more spectrally efficient than Advanced Mobile Phone System (AMPS), GSM and TDMA, that promise did not always hold up in the real world. An example is the bold claim made by CDMA vendors in the mid 1990s that their technology has 20 to 30 times more capacity

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than AMPS. When CDMA systems started to be deployed a few years later, the gain turned out to be only five to six times better than AMPS. When EVRC was eventually added, the gain increased again – but still nowhere near the original claim of 20 to 30 times.

Many CDMA operators are currently in the midst of deploying 1XRTT, an interim step towards 3G that promises to use spectrum more efficiently. Time will tell whether that is the truth but the fact is that, based on best-case data from CDMA vendors, 1XRTT with EVRC handles up to 156 Erlangs per sector. Bearing in mind that GSM with AMR handles 142 Erlangs, it is a great stretch to argue that 1XRTT has a major advantage over GSM. GSM operators also can deploy dynamic frequency and channel allocation (DFCA), which assigns calls to channels based on conditions such as signal and interference. With AMR and DFCA, GSM can handle 170 Erlangs per sector – an improvement on 1XRTT's 156.

In the near future, 1XRTT operators will probably be able to deploy a technology called selective mode vocoder (SMV), which could provide 20% more capacity over EVRC. The catch is that SMV-like methods can be applied to GSM to produce almost identical capacity gains. Thus, while one technology may have slightly higher capacity gains at one point in time, another technology is always preparing to leap-frog over it.

UMTS's Fine Line Between Voice and Data

Any perceived CDMA advantage disappears when GSM operators evolve to UMTS™. In 2003, operators such as AT&T Wireless and Cingular Wireless will begin deploying Enhanced Data rates for Global Evolution (EDGE), a 3G technology. Nine other operators in the Americas have committed to EDGE, for an additional 80 million subscribers. Some vendors predict that 85% of the global market will use GSM/EDGE/wideband CDMA (WCDMA) terminals by the end of 2006.

EDGE uses a modulation scheme called Octagonal Phase Shift Keying (8-PSK), which squeezes three bits of data into a radio wave where GSM's modulation scheme can fit only one. With EDGE packing more data into each time slot, GSM can upgrade its AMR vocoder to a version that is expected to boost voice capacity by between 15% and 20%.

GSM also will be able to use enhanced power control (EPC), which adjusts a phone's power four times more often than the current technique. By using exactly the right amount of power to communicate with the cell site at all times, EPC should increase capacity by about 20%.

In 2004, some GSM operators in the Americas will begin deploying UMTS (WCDMA), the final evolutionary step towards 3G. UMTS is part of the 3G vision, where a GSM operator has multiple systems: GSM, GPRS, EDGE and WCDMA. Although, initially, the concept of four parallel systems seems a wasteful duplication, UMTS is actually highly efficient because the operator can put different types of traffic on the appropriate system. In the case of several users being on a UMTS network, some will be using it to send and receive e-mails and some for video calls, while others will be in voice calls and others using File Transfer Protocol (FTP). Each of these traffic types has different needs. A voice call, for example, uses a fairly constant amount of bandwidth, while many data applications are 'bursty', needing a large amount of bandwidth for a brief period.

UMTS provides the GSM operator with a refined way for these types to co-exist by using a technique called 'spreading', where the network shrinks and expands each channel's capacity based on the traffic type. For example, the network would expand a channel to make room for a video call by shifting a voice call to another channel. This approach makes more efficient use of available infrastructure and spectrum than other technologies that dedicate an entire channel only to high-speed data. As a result, UMTS does not have a data channel lying fallow while voice calls go begging for capacity. The bottom line is that UMTS handles 178 Erlangs per sector, a major improvement over TDMA's 37 and basic GSM's 67 and a moderate improvement over 1XRTT's 156.

Balancing Quantity and Quality

The ability of a wireless network to balance voice and data without short-changing either will become a key asset in the next few years. Voice is still the killer wireless application and probably will remain so for years, but it is also becoming a commodity.

Although the market for wireless data has not taken off as quickly as many had hoped, it is still the best chance that operators have for driving new revenue. Data services also will be a key market differentiator. The bottom line is that operators need a wireless technology that lets them roll out new services profitably without undercutting existing services, particularly voice.

As GSM operators start deploying EDGE and UMTS networks later in 2002, they and their customers will be the first in wireless to enjoy quality-of-service (QoS) mechanisms that ensure that each type of data service is assigned exactly the amount of spectrum and infrastructure resources it needs. UMTS's QoS mechanisms cover every step of a data application's journey, from the device, into the cell site, through the network and at the gateway to the Internet. No other wireless

Why Cingular Chose GSM

Bill Clift, Chief Technical Officer, Cingular Wireless

Cingular Wireless vigorously evaluated competing air-interface technologies and migration strategies, and several factors played into the decision to deploy GSM/GPRS/EDGE:

- Ubiquity – more than a half a billion GSM phones are in use worldwide, accounting for more than 70% of the digital wireless market. The economies of scale for this technology in terms of handsets, network infrastructure and applications for customers is beyond compelling, and 30% of Cingular's covered Points of Presence were already served by GSM.
- Speed – GPRS and EDGE data rates in a loaded network compare very well with any other 3G technology in a similar mobile environment.
- GSM's capacity and spectrum efficiency is competitive with any other technology choice that Cingular might have made.
- The opportunity to operate GSM at 850MHz – Cingular will be able to overlay in the 850MHz band in more disbursed coverage areas at a lower cost than overlaying exclusively in the 1,900MHz band. The commitment to 850MHz will also enable smaller regional carriers to commit to GSM.
- Support – Cingular has alliances with other major carriers to accelerate GSM build-out and expand coverage areas in North America. GSM is also backed by all of the major European carriers.

technology supports this level of QoS. UMTS has a separate QoS mechanism for each of four traffic types:

- conversational, which includes Voice over Internet Protocol (VoIP) and videoconferencing. This traffic needs a stable amount of bandwidth and minimal delay;
- streaming audio or video, as the name implies, there is a continuous flow of traffic, but it can tolerate some level of delay;
- interactive applications, such as Web browsing, that can tolerate a fair amount of delay and that do not need stringent bandwidth controls; and
- background applications, such as FTP, that deliver a good user experience, even when sufficient bandwidth is available only intermittently.

The benefits are not limited to data. UMTS operators can leverage these QoS mechanisms when they launch VoIP, the final stage of the UMTS vision, where voice and data travel over the same packet infrastructure. UMTS's Internet Protocol multimedia subsystem eliminates traditional mobile switching centres (MSCs) and instead sends voice via the same packet nodes as data. Through the use of Session Initiation Protocol (SIP), which governs the traffic flows, UMTS ensures that voice avoids delays and delivers a toll-quality experience.

Building a Better Bottom Line

UMTS's efficiency and flexibility strengthen the operator's bottom line by reducing capital expenditure and operating expenditure costs. All operators, regardless of technology, face the same decision: in order to remain in investor favour, operators have to grow profitably – but growth usually means spending more and more on infrastructure and spectrum to accommodate that growth.

This is not the case with the UMTS migration path, where GSM operators are free to add voice and data customers without the fear that the high cost of growth means that each new one pushes them further from profitability. Each upgrade stage – GPRS, EDGE and then UMTS – wrings more and more capacity out of their existing infrastructure and spectrum. Thanks to UMTS's QoS mechanisms, no user or application gets short-changed.

> *"A year and a half into our program, we believe the decision to migrate to GSM and GPRS/EDGE/UMTS was the best solution and decision for our company, our customers and our shareholders."*[1]

In the end, the GSM family of technologies provides a technologically advanced evolution path to 3G that offers the right mix of quantity and quality for voice and high-speed data. ■

1. *Rod Nelson, Chief Technical Officer, AT&T Wireless.*