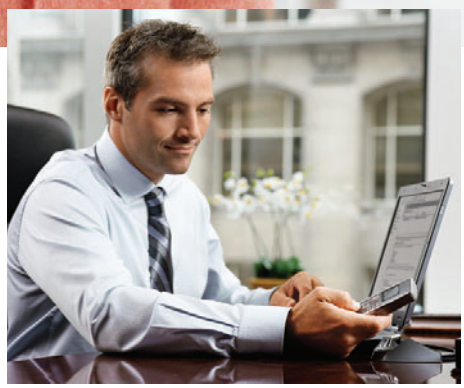
White Paper

Radio Network Evolution

The roadmap towards multi-access networks



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Contents

Abstract

Wireless is the preferred way of working and communicating, however, the performance bar set by fixed-line broadband access is not only high (and going higher), it is also determining market expectations. The industry is therefore facing a current and on-going challenge. This white paper covers the industry's response: the technologies and standards that have been developed in order to take mobile performance to the highest possible level. There are intrinsic constraints set by physical laws, and it is clear that radio performance can never match that of wireline, but it can keep pace with and even outpace the needs of end users.

There are numerous competing players in the market, which is hardly surprising given its size, and this results in a number of conflicting claims. It is therefore all too easy to be confused, which is unfortunate, since a confused market does not buy, it waits. This paper therefore aims to replace confusion with clarity.

The target audience comprises GSM/WCDMA network operators, analysts and other informed and interested parties, e.g. editors, journalists and new entrants into the world of broadband radio access.

Executive summary

Enhancing the performance of radio networks is driven by the needs of end users, particularly those that have experienced fixed-line broadband access. Radio access data rates are evolving towards those of fixed-line networks, a development that will facilitate the delivery of new services, increase their usage and create new revenue streams for operators.

GSM/EDGE/WCDMA is the optimal way to evolve and these technologies continue to provide the most efficient business solutions for operators. Nokia is driving developments that will enhance these solutions and provide performance and functionality that matches the needs of the market. This will ensure the competitive position of mobile operators and future-proof their services against new technologies.

Mobile network operators and the new wireless entrants (e.g. fixed and broadband operators) can choose from various radio technologies, both licensed and unlicensed. They can also employ cellular together with a complementary radio access technology such as Wi-Fi. Mobile device users are demanding solutions that enable wide area access combined with the best available performance. In addition they require seamless interworking of services. These requirements will be met via fixed-mobile convergence and the multi-access features of networks and terminals.

Nokia's vision is based on a single network and multi-access. Different radio technologies will complement each other and end users will be able to employ different radio access networks, i.e. the one that delivers the best available performance, e.g. Wi-Fi in fixed locations. High Speed Packet Access (HSPA) combines similar data rates with WCDMA's wide area coverage. In turn, WCDMA is complemented by GSM/EDGE and upcoming EDGE evolution. In addition, different proximity technologies such as Bluetooth and Near Field Communication (NFC) will expand the usability of end user terminals, enable additional applications and enhance the end user experience.

The end user perception of the one network vision is the ability to reach all services at any time and from any location. This is emerging as a 'must have' function so seamless interoperability between different access methods will be essential. This entails the ability to employ personal services via different access networks while retaining the same interface, i.e. the user experience does not change.

Evolution is on-going

In the last 15 years radio access networks have transitioned from analog to digital technologies and moved on from voice-only services. When GSM started in the early nineties radio services took off: literally. Today's GSM/ EDGE and WCDMA networks are pushing the performance of the wireless interface to a completely different level and we can expect this development to continue for the foreseeable future.

GSM/EDGE is evolving: the next step being discussed is EDGE future evolution. This performance enhancement to current networks will result in a significantly improved end-user experience and a longer lifetime for the network. The performance of these radio technologies will therefore continue to be competitive, thereby ensuring the continued efficiency of the mobile operator's solution. This also means that wireless becomes a viable alternative in locations where fixed line broadband access is not available or when it is not viable because of high costs.

WCDMA has evolved: HSPA (High Speed Packet Access) services are coming on stream and the long term evolution of WCDMA – (sometimes referred to as 3.9G) – is being discussed in 3GPP. This represents the most advanced wide area network solution that mobile operators can deploy in the next few years. After that we have 4G, a generic term used to refer to a new radio access network technology that has not been defined. 4G is still in the research stage but Nokia's view is that the performance target should be above 1 Gbps and that the chosen technology should be a global standard. Standards make markets, as evidenced by the global and on-going success of GSM and WCDMA.

Evolution is driving bit rates up from today's figure of 384 kbps towards 200 Mbps in 3.9G and eventually above 1 Gbps in 4G. In addition, the cost efficiency of networks will increase over time. Figure 1 indicates the key technologies that make up the future radio evolution and when they will be delivered.

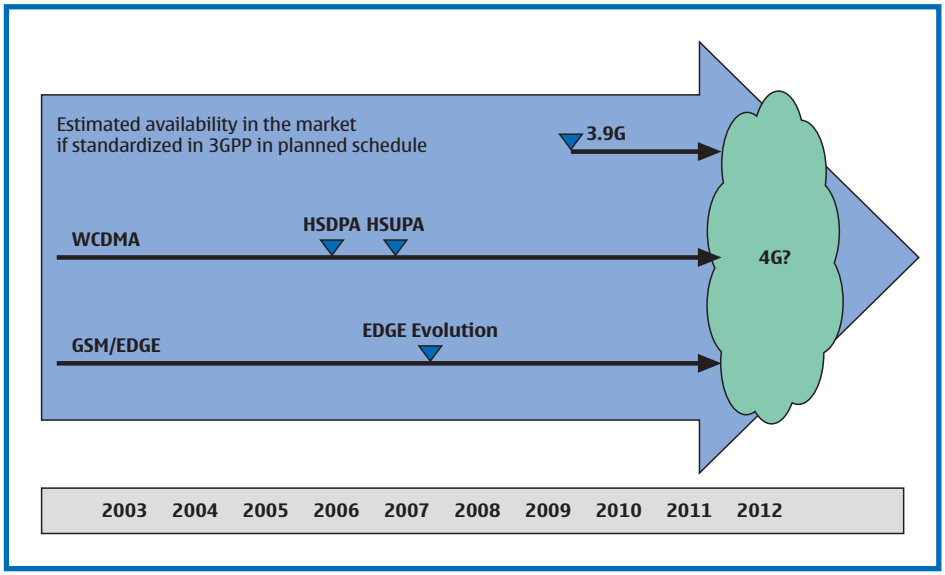

Figure 1. Radio evolution roadmap towards 3.9G and 4G.

Driven by the market

Better radio services are what the market expects our industry to deliver. Better involves performance, a consistent user experience and sophisticated applications. Users drive the market, not the technology.

This fundamental fact is the reason why Nokia continues to innovate and evolve the network. The new generation of mobile device users have accessed the Internet since their childhood and they naturally expect similar performance and capabilities from the mobile environment. The performance and functionality of their broadband Internet access in the home is the benchmark. Why settle for less? Thus, end user habits and their need to access information, anywhere and at any time, is what evolution is all about.

The benchmark is currently set by xDSL fixed broadband, however, this technology is also evolving: it is not a fixed target. Radio therefore needs to adapt and evolve. Users will not stop looking for better services and faster response times.

Radio performance requirements

Many of the services that are currently available in today's telecom and IP networks can be supported in current GSM/EDGE/WCDMA networks and they provide similar user experiences. There are, however, other services that will require more advanced radio and network performance in order to be competitive. This means that we shall witness significant advances in the next one to two years.

It starts with HSPA, which is taking WCDMA to a performance level that is superior to any other comparable radio technology. The Nokia HSPA Solution comprises two key steps: High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA).

Figure 2 summarizes the two key network performance parameters – bit rate and latency – that define the end-user experience for the different applications that radio network evolution will enable.

In order to provide cost-effective delivery of these services over a wide area comprising indoor and street environments, moving cars, etc., the most cost-efficient technologies must be deployed. HSPA and EDGE Evolution, for example, combine full mobility with very-high bit rates and low latency. However there are other complementary technologies that can add value to the end user experience.

These technologies (some of which are still in development) include: WiFi, WiMAX (802.16), MBWA (802.20), RFID, Bluetooth and DVB-H. Each one has a role to play in multi-access networks and they are able to support specific applications in a cost-optimized way. Figure 3 shows how different radio technologies meet different end user requirements.

Better technologies are also needed in order to remain competitive in the market. Bandwidth is a limited resource, so the ability to use it in the most cost-effective way is extremely important for network operators. Cost per bit has been declining, but operators must continue the delivery of Mega bytes at even lower cost per bit.

From a spectrum efficiency point of view, radio technologies are already getting close to the theoretical maximum. Shannon's law determines how much information can be transmitted over the radio channel having a certain bandwidth and HSPA performance is very close to that limit. Within a 5 MHz carrier bandwidth, performance cannot be significantly improved. Further improvements in efficiency are achieved only by introducing wider carrier bandwidths or more advanced antenna systems.

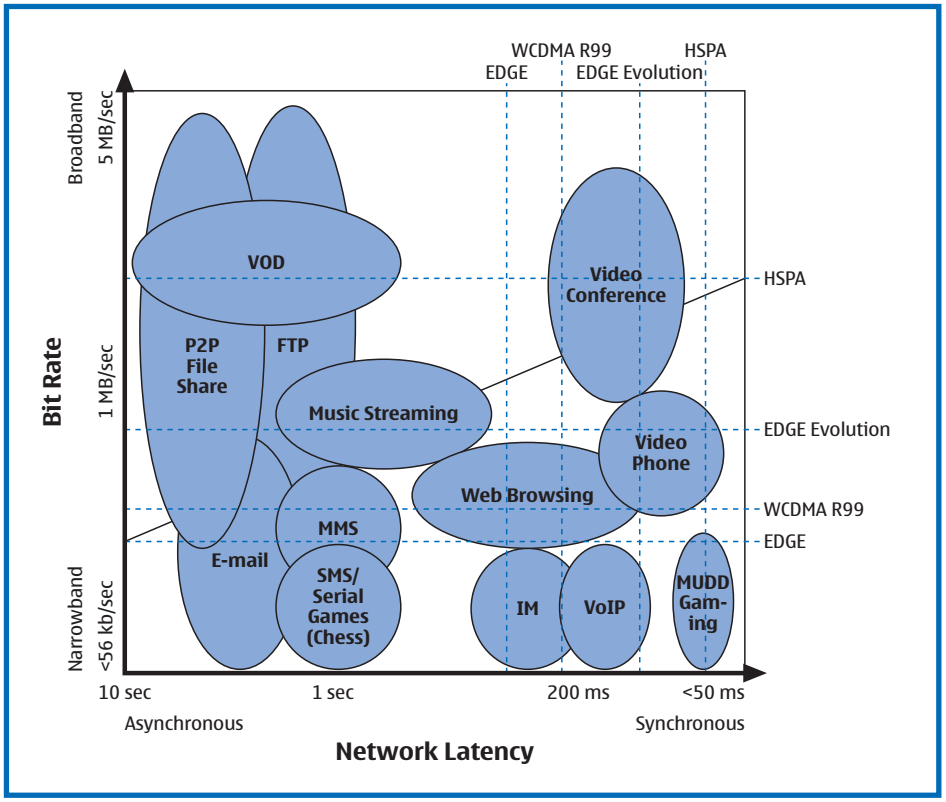

Figure 2. The bit rate and latency requirements of different packet data applications.

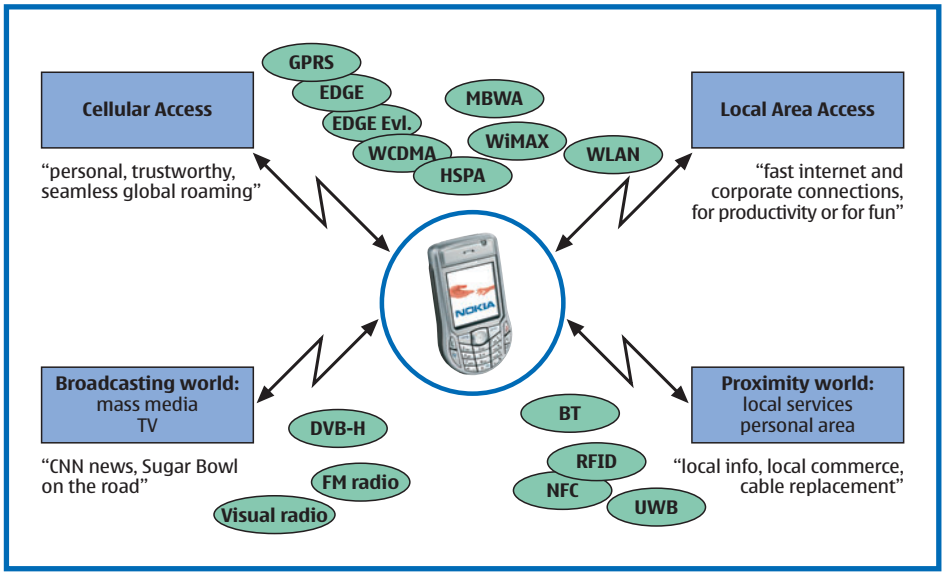

Figure 3. Multi-access radio networks will support growing service portfolio cost efficiently.

Discussions about UMTS RAN's (Radio Access Network) long-term evolution have started in 3GPP and this technology is targeted to go above current capabilities in WCDMA and HSPA. Higher performance can be realized, for example, by introducing wider bandwidth per carrier (i.e. 20 MHz). These evolution steps will reduce cost/bit down to a level that will allow operators to be very competitive. Figure 4 illustrates cost per progress in radio networks.

The ability to make continuous and significant reductions in this area is required in order to maintain margins in a market that is highly competitive. The tariffs of current broadband access networks are normally based on flat fees and some of the first wireless networks are using this model. Voice over IP (VoIP) is also competing with traditional voice services, i.e. those based on circuit-switched technology. Operators are therefore facing a tough set of challenges in the constant battle to stay ahead of competition.

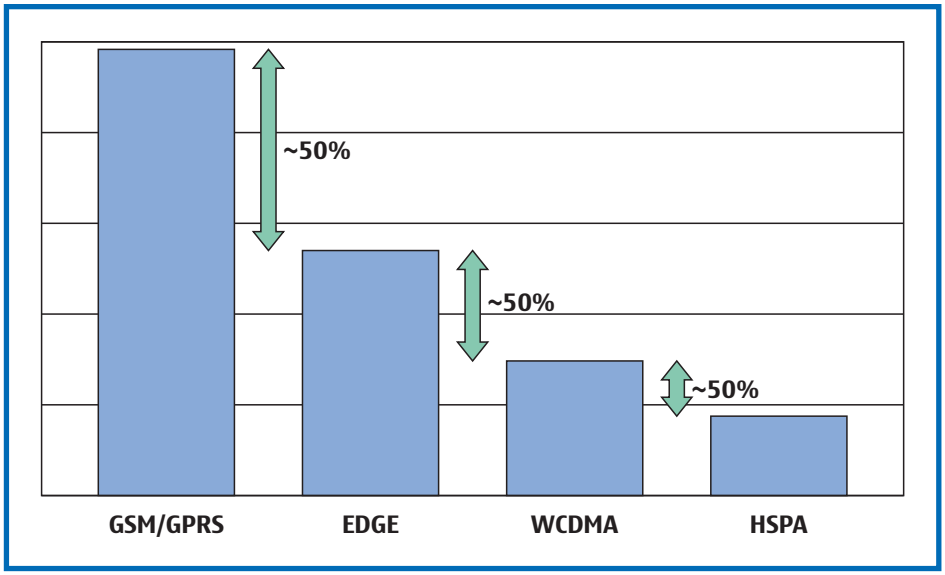

Figure 4. Cost per delivered Mega Byte development in mobile networks.

Network developments

GSM/EDGE: A seamless evolution

Most GPRS operators have upgraded their networks to EDGE. This technology has the proven ability to enhance the bit rates three-fold and higher rates have accelerated mobile multimedia usage. Usage by EDGE customers is typically two to three times higher than that of GPRS users. EDGE is a seamless service; it is used in the same way as GPRS and the same terminals are used.

A simple network upgrade

EDGE was originally defined in 3GPP standard release 99, but it has evolved and today's bit rates are enhanced by network features based on 3GPP standard releases 4 and 5. These include NACC/NCCR (Network Assisted Cell Change and Network Controlled Cell Re-selection) and E-AMR (8-PSK modulated, narrow band, half rate AMR codecs). Release 6 will bring additional enhancements to GSM/EDGE networks.

EDGE creates more capacity with fewer transceiver units in the BSS (Base Station Subsystem), thereby allowing operators to grow with fewer BTS sites. EDGE improves cost effectiveness and enables the delivery of new 3G services over GSM bands. It also provides a first-class experience to customers and better performance, particularly when bandwidth-hungry services are used. EDGE is therefore an ideal way to prepare customers for the advanced services. Additionally EDGE enhances the WCDMA service continuity improving also the operator WCDMA business.

EDGE Evolution

EDGE Evolution discussions are ongoing and it is likely that some evolutionary steps will be included in 3GPP standardization. The target is a further two- to four-fold increase in both bit rates and voice/data spectral efficiency, and at least half the latency. These increases in performance are required for the new real time multimedia services.

There are several potential technology candidates that would enable gains of this magnitude, e.g. antenna diversity and dual carrier. The dual symbol rate and possibly latency can be reduced by moving some of the PCU (Packet Control Unit) functionality to the BTS. These improvements could be included in 3GPP Releases 7, 8 and 9. This means that some of these advances could be available for mass markets around 2007–2008.
EDGE Evolution can therefore provide another significant boost to an operator's GSM/EDGE business and expand the lifetime of the legacy EDGE capable GSM/GPRS network infrastructure.

WCDMA Evolving to HSPA

From a performance perspective, WCDMA is currently the most advanced, global radio technology in commercial use. The current service is based on 3GPP Release 99 and it can transport IP traffic. Data rates reach 384 kbps and the service supports delay sensitive applications such as VoIP.

The next evolution step, HSPA, is defined in 3GPP Releases 5 and 6. As mentioned earlier, Nokia's solution comprises HSDPA and HSUPA. With these technologies users will experience better Internet and intranet access, faster downloads of large files, and be able to employ high-quality streaming applications on their notebooks and smart phones.

HSDPA and HSUPA boost system capacity and increase user data rates. HSDPA improves the downlink direction from the radio access network to the mobile terminal. HSUPA improves the uplink for transmitting data from mobile terminals to the access network. HSDPA provides cell throughput gains two to three times higher than those of Release 99 and deliver much higher data rates: up to 14.4 Mbps per user. With HSUPA, the cell throughput is expected to be 20–50% greater than in Release 99 and user data rates will reach 5.76 Mbps.

The improved performance of HSDPA is based on:

1) Adaptive modulation and coding
2) A fast scheduling function, which is controlled in the BTS, rather than by the RNC (Radio Network Controller)
3) Fast retransmissions with soft combining and incremental redundancy.

HSDPA data rates are dynamically adjusted during the call according to radio link quality. This ensures the highest possible data rate for the user.

The main technological improvements with HSUPA are:

- Fast uplink scheduling function based in the BTS
- Fast retransmission with control in the BTS

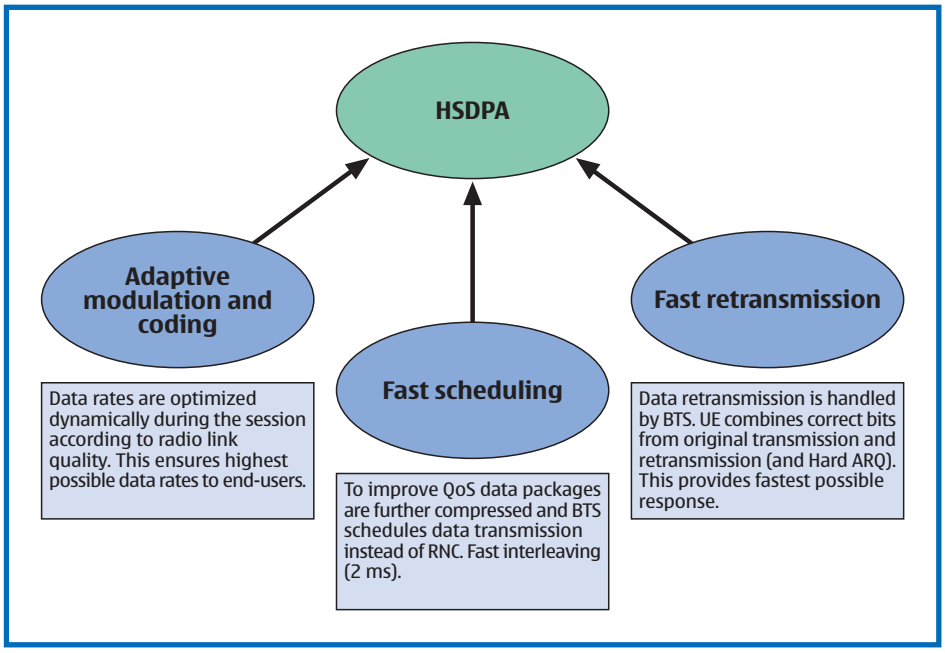

Figure 5. HSDPA performance improvement is coming from three different areas.

Modulation	Category	Inter-TTI	5 Codes	10 Codes	15 Codes
QPSK only	11	2	0.9 Mbps	–	–
QPSK only	12	1	1.8 Mbps	–	–
QPSK/16QAM	1	3	1.2 Mbps	–	–
QPSK/16QAM	2	3	1.2 Mbps	–	–
QPSK/16QAM	3	2	1.8 Mbps	–	–
QPSK/16QAM	4	2	1.8 Mbps	–	–
QPSK/16QAM	5	1	3.6 Mbps	–	–
QPSK/16QAM	6	1	3.6 Mbps	–	–
QPSK/16QAM	7	1	–	7.2 Mbps	–
QPSK/16QAM	8	1	–	7.2 Mbps	–
QPSK/16QAM	9	1	–	–	10.8 Mbps
QPSK/16QAM	10	1	–	–	14.4 Mbps

Table 1. Peak user data rates for HSDPA terminal categories defined by 3GPP

Coding rate	1 x SF4	2 x SF4	2 x SF2	2 x SF2 + 2 x SF4
1/2	480 kbps	960 kbps	1.92 Mbps	2.88 Mbps
3/4	720 kbps	1.44 Mbps	2.88 Mbps	4.32 Mbps
4/4	950 kbps	1.92 Mbps	3.84 Mbps	5.76 Mbps

Table 2. Theoretical HSUPA peak user data rates with spreading factor 4. HSUPA terminal categories are not yet standardized by 3GPP.

The combination of HSDPA and HSUPA enhances overall performance, as evidenced by the end user data rates. Latency is another important parameter in packet data based networks (see Figure 2). In order for users to have a good service experience with various different applications, minimal network latency is required. With WCDMA and HSPA, the latency can be as low as 50 ms. Thus, users benefit from faster response times for data services and near zero delay for voice and video over IP applications.

Evolution to 3.9G and 4G

Radio evolution is an on-going discussion in 3GPP. The first discussions about the UTRAN (UMTS Radio Access Network) long term evolution took place in the 3GPP workshop in Toronto in November 2004. The next step has no official name as yet, but it is generally referred to as 3.9G and it could be standardized in 3GPP Release 8.

The main 3.9G targets include peak data rates of 200 Mbps downlink and 100 Mbps uplink. The basic aim is to raise the performance of WCDMA to a completely different level by employing a radio access network that has been optimized for packetized traffic. The technology is at an early stage and discussions have just started in 3GPP and there are a number of open implementation issues. Nokia is actively involved and sees the need to ensure that the evolution to 3.9G will accommodate the anticipated growth in data traffic and at the same time provide even better performance. Figure 6 gives an estimate of 3.9G market availability.

The next step after 3.9G is 4G. This technology is at the research stage and has not, as yet, been discussed in any standardization body. This indicates that 4G is on the horizon but not yet on the radar screen. Moreover, there are different assumptions about the composition of 4G.

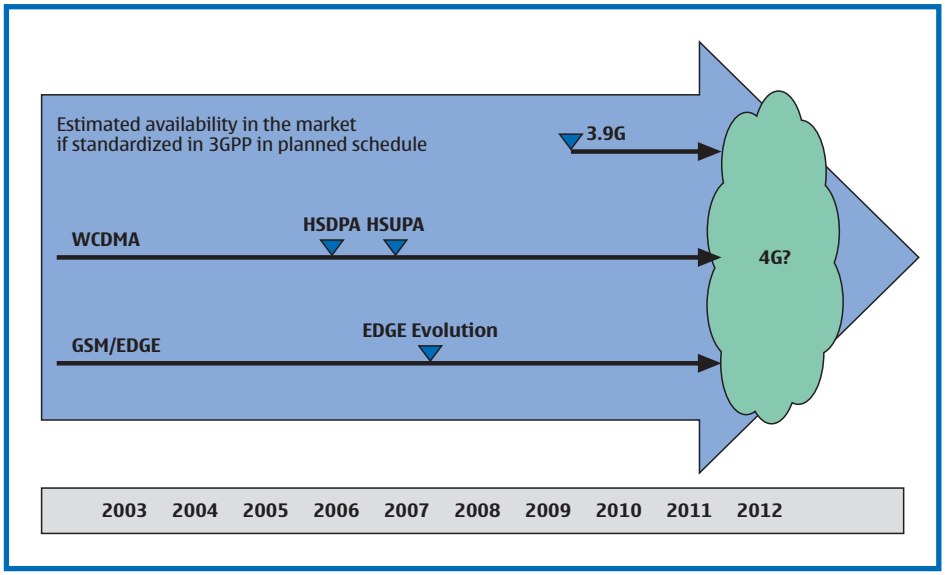

Figure 6. (A repeat of figure 1) Radio evolution roadmap towards 3.9G and 4G

The Nokia view of 4G is very basic: it should be an evolution from existing cellular networks and it must provide a significantly better radio interface. Ideally it would be a brand-new radio interface that would interoperate with existing core networks. New 4G-compliant terminals would be able to use the new interface as one of several multi-access alternatives, i.e. it would work in parallel with existing technologies.

The required performance figures of the new radio interface are a local area data rate of 1 Gbps and a wide area rate of 100 Mbps. In addition, the difference between local and wide area performance should not impact the need for a ubiquitous, high-quality seamless service. Thus, 4G would raise the radio performance bar and also ensure that the end user experience was also raised to the highest possible level.

Complementary radio technologies

The previous sections covered radio evolution from a cellular GSM/EDGE/WCDMA point of view. However, there are a number of other access technologies, e.g. W-LAN, WiMAX, Mobile Broadband Wireless, and Bluetooth. For historic reasons all of these technologies serve different market segments, but network boundaries are dissolving so they no longer compete, instead they are complementary. Moreover they are an integral part of the need to enable ubiquitous, seamless access.

Today's mobile networks provide efficient business solutions and the evolution path described in this paper indicates that they will continue to be the preferred wide area option. Mobile cellular operators are therefore in pole position in the value-added services race. They can leverage the existing infrastructure: make it more efficient; enhance network performance; take it to a level that makes it competitive against any wireless technology; optimize the end user experience via ease-of-use, convenience, performance and cost. But, as indicated earlier, complementary radio technologies will play an important role in the multi-access network.

Figure 7 illustrates the roles played by today's radio access technologies. The X-axis shows the technology from a performance perspective i.e. the high data rates. The Y-axis considers the mobility perspective i.e. how well each technology supports wide area mobility.

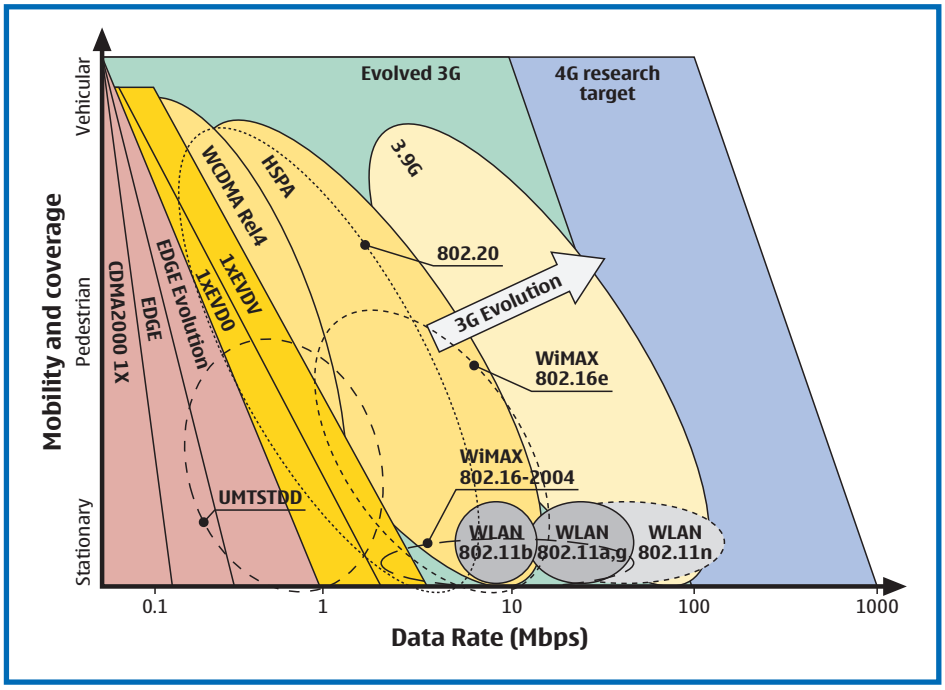

Figure 7. Mobility and coverage vs. the data rates of different radio technologies

WLAN

Wireless LAN is a data-centric technology that features high data rates and low latency connections. It works well for VoIP telephony when the user stays in the vicinity of the access point. Coverage is therefore limited. Multiple access points (APs) have been deployed in office environments but mobile telephony, moving from one small cell area to the next, introduces a number of significant issues. Limited coverage and mobility are hindering usage of WLAN as a wide area coverage solution. It can complement cellular networks and therefore add user value in some environments.

WiMAX

WiMAX is a forum that promotes IEEE 802.16 technologies. The 802.16 set of standards supports two different types of usage: one for cellular backhaul and the other for mobile broadband access in a MAN (Metropolitan Area Network). The mobile version of WiMAX is known as 802.16e and combines high bit rates with low latency. Here too we have a technology that complements existing cellular standards and it creates opportunities for operators that do not have WCDMA licenses. WiMAX will employ higher frequencies than existing cellular technologies and could be used, for example, in the 3.5GHz band in Europe.

MBWA

The IEEE working group for 802.20 standard was established to develop an MBWA (Mobile Broadband Wireless Access) standard that would support full mobility with high data rates. Standardization has started but it will be a few years before commercial products are available. In future, 802.20-compliant networks could be an alternative to fixed or broadband operators who are looking for MBWA business opportunities.

UMTS-TDD

UMTS TDD (Time Division Duplexing) technology is part of the 3G standard in 3GPP. Although many 3G operators have a license for TDD, wider scale implementation has not really started in 3G networks. The need to deploy UMTS-TDD networks comes after operators who have a license for both Frequency Division Duplexing (FDD) and TDD bands have built their WCDMA networks and then need additional capacity. This could take some time and operators should have enough capacity from the FDD band.

Fixed and broadband operators who are looking at business opportunities in the broadband wireless access market could also employ TDD radio networks. TDD is a viable way of providing additional wireless broadband capacity as and when it is needed.

Fixed-Mobile Convergence and Multi-Access Radio Evolution

FMC (Fixed-Mobile Convergence) is a hot topic that is widely debated. FMC is being trialed by leading operators and when commercial services start the impact will be significant. FMC will unify existing broadband access networks and mobile networks. This development enables those operators who have both access types to offer new and better services to their customers.

End users want to be able to employ seamless interworking of personalized services and applications, i.e. they should not be concerned about the access network they are using or need to know anything about the location of the services/applications. That is part of the FMC vision. It also allows operators to employ the most cost efficient access method and deliver the best service experience to their customers. This experience should be technology agnostic: same services and profiles at home using Wi-Fi access via an AP in so-called hot spots, or in the wider world of EDGE/WCDMA networks. Figure 8 visualizes this concept.

The new access options such as UMA (Unlicensed Mobile Access), which is delivered over Wi-Fi and Bluetooth interfaces, can provide additional capacity to service providers or be used to improve their service offer. Both fixed and broadband operators can enable wireless services using UMA. Mobile operators benefit from the cost-efficient broadband wireless alternative they can offer in the home and small office environments.

This development (fixed-mobile convergence) allows subscribers to continue employing their personalized services at home. Convergence therefore enables the optimum combination of cellular or fixed broadband access. The user experience doesn't change: the same voice and multimedia services are used in the same way.

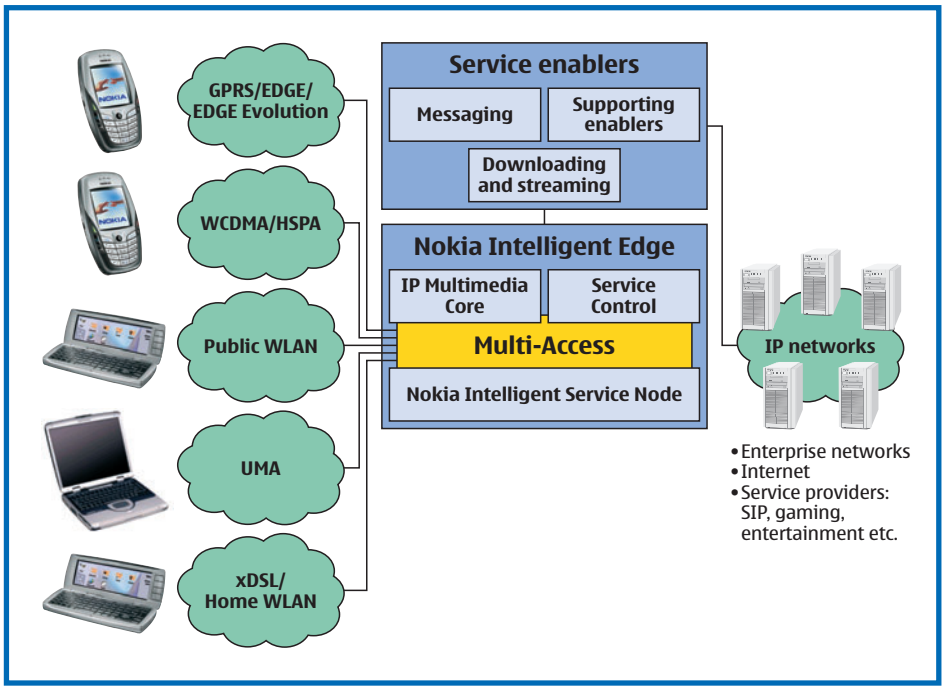

Figure 8. Nokia Multi-Access network architecture

Note that in some countries indoor cellular coverage is poor or even nonexistent, so enabling access over Wi-Fi is an important, complementary benefit. In addition, the same personalized services can be employed in offices that have WLANs and in public hot spots.

In short, multi-access networks will be an essential part of radio evolution. The goal is to deliver very high performance, deploy multiple access technologies, and enable seamless interoperability. This will allow services to be delivered over radio interfaces in the most cost-efficient way and give end users the best possible experience, anywhere and at any time.

Conclusions

This paper covered a lot of ground. It outlined the GSM/EDGE/WCDMA roadmap and gave the timelines for the various milestones along the way to 3.9G and 4G. The key message was very simple: radio access is an evolutionary process. However, the performance of the newer technologies does represent a revolution. Wireless is the preferred way of communicating and these evolutionary developments will ensure that WCDMA and various complementary technologies carry that concept further by enabling high-speed, seamless access and unified end user experiences.

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