Northstream™

Operator Options for 3G Evolution

A Northstream analysis of the 3G evolution paths facing GSM, TDMA and CDMA operators

Executive Summary

This Northstream report meets the current need for independent analysis of the global 3G network evolution situation. In 2000, evolution paths to 3G appeared clear for GSM, CDMA and TDMA operators, with WCDMA as an unrivalled future global radio interface, with evolved CDMA2000 variants deployed in specific markets. Some analysts and other industry players now suggest that the playing field has fundamentally changed due to the economic downturn and recent market successes, failures and delays. This report outlines Northstream's independent view on the matter. We do it by systematically analysing the factors involved in technology evolution decisions, and by putting the public media flow in its correct perspective. In doing so, we make use of a Northstream framework specifically developed to help operators who are evaluating technology evolution options.

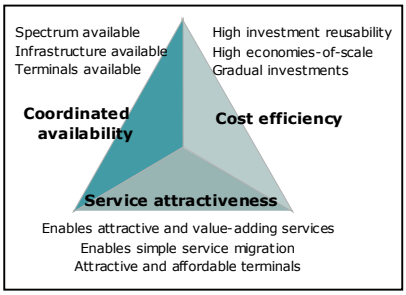
We conclude that a GSM operator with spectrum to deploy WCDMA will choose the WCDMA evolution path. Investment reusability, gradual investments, simpler service migration, more attractive services (primarily roaming) and a better long-term terminal market, combine to make this a simple decision. GSM operators who face difficulties in finding spectrum for a WCDMA deployment, for example in North America, should use EDGE as bridging technology until spectrum for WCDMA becomes available, rather than choosing a CDMA2000 evolution.

For a CdmaOne operator the generally preferable path is to evolve its network to 1X (which has similar service-enabling capabilities to GPRS) and then on to DO and/or DV. Spectrum availability, investment reusability, gradual investments, simpler service migration and lack of CDMA/WCDMA terminals, combine to make this a straightforward decision. In some cases, specific market conditions or operator ownership structures may call for a WCDMA evolution.

For a TDMA operator we view both WCDMA- and CDMA-based evolution paths as feasible. High economies-of-scale, more attractive services (primarily roaming) and a more attractive long-term terminals market all speak for WCDMA. Against these factors stand the prospects of simpler spectrum management, gradual investments enabled by AMPS/CDMA terminals (for AMPS-intensive operators) and higher investment reusability, which speak in favour of CDMA2000. Whichever option is adopted a TDMA operator will have to make sure it has the solid backing of its suppliers to provide it with confidence in making this difficult decision.

Independent of 3G paths chosen, we conclude that GSM/GPRS will continue to dominate the global market for years. WCDMA dominance is likely to follow, albeit in the long term.

Contents



An evaluation framework developed by Northstream is used when assessing feasibility of different network evolution paths

1 Introduction

The last couple of years have been interesting for players involved in technology evolution strategies for the mobile telecom industry. Back in 2000, it was clear that the entire GSM community, leading American TDMA operators and leading Japanese PDC operators would deploy GSM-based networks with the WCDMA radio access as '3G' radio interface (albeit later in the Americas than elsewhere due to spectrum shortage). Northstream, along with most other industry observers, regarded WCDMA as the unrivalled future global radio interface, around which future developments would focus.

Now, in the beginning of 2003, when the mobile industry has faced its biggest crisis ever, one may ask whether the crisis has substantially affected technology evolution to '3G'. Some analysts indeed suggest that the playing field has fundamentally changed: The financial difficulties of many operators, having purchased over-priced spectrum (and the knock-on effects on their vendors when operator investments have been frozen), the inability of the GSM community to make available ARPU-boosting GPRS handsets and services, the lower-than-target uptake of NTT Docomo's WCDMA service, and the technology shift in Korea and Japan from cdmaOne to CDMA2000 1X are examples of facts used to motivate statements of a change in the market place.

We believe that the questions remain: What is the outlook for the technology evolution in the mid- to long-term perspective? Have the sensible options available to operators fundamentally changed due to the last couple of years' downturn, or have they not? In this report, we give Northstream's independent view on the matter, assessing GSM, CDMA and TDMA operator technology evolution options to WCDMA or CDMA2000[1]. We do it through systematically analysing the factors involved in technology evolution decisions, and by trying very hard to put the public news flow in its correct perspective. In doing so, we make use of a few key observations, central to our view of the matter but not always acknowledged by all parties discussing technology evolution:

- A technology evolution path decision should be driven by the future profitability impact that the decision will have: with which technology can the operator maximise revenue? Which path requires least additional investment, considering the legacy situation?
- A technology evolution path decision is a long-term decision. Because a technology generation shift is generally very expensive it cannot be done often, and therefore it is irrelevant what is gained in the short term if the 5-10 year profitability impact is negative.
- Bad services do not mean bad networks. The introduction of data services decouples the service offering from the network technology. This means that an operator can easily fail to offer compelling services despite having an excellent underlying network technology, and hence such failures cannot be used as arguments against the technology as such. Likewise, a good service is not always the result of a superior network technology (but naturally a proof that the technology has certain *service-enabling capability*).
- Higher data rates as such are not a main driver for data services uptake. The services envisaged for mass-market adoption of mobile data are typically *not* data rate demanding. The network technology behind the biggest success of advanced mobile data so far is PDC-P (9.6 kbps). As discussed later, fast uptake of 1X in Japan is due to other factors than the technology and its data rate. We thus view short-term data rate capabilities as irrelevant for a technology evolution decision. s For long-term needs, any of the 3G standards can be evolved for sufficient data rates when the market demands it.

With these observations in mind, we can more easily distinguish relevant facts from over-simplistic or invalid arguments, all of which exist in the current evolution discussion.

[1] In this report 'CDMA2000' is used as a general reference to 1X, DO and DV technologies. When a specific technology is referenced, it is marked by 1X, DO or DV.

1.1 Methodology

For analysing the options facing GSM, CDMA and TDMA operators, we have made use of Northstream's own framework for evaluating technology evolution alternatives. As shown in Figure 1, the framework includes three basic aspects that should be fulfilled by the preferred technology:

Co-ordinated availability. A basic pre-requisite for choosing an evolution path is the availability of appropriate spectrum, a supply of infrastructure from a sufficient mass of vendors and terminals capable of supporting the bearer. The availability of these different items needs to be well co-ordinated in time.

Cost efficiency. A preferred technology should ideally allow high degree of reuse of already made investments, it should have high future economies of scale to minimise cost, and the evolution scenario available should allow gradual investments (avoiding high up-front costs such as network capex and new handset subsidies).

Service attractiveness. Intimately related to revenue potential, a preferred technology should *enable* an attractive service offering to the end-user. The service migration should be simple, preferably transparent, to the user. Finally, to maximise service attractiveness, the terminal portfolio should be rich and attractive and be available at non-prohibitive prices.

To be able to properly assess these factors, we first summarise the current state of the mobile industry in Section 2, with emphasis on facts that relate to the factors discussed above. Similarly in Section 3, we predict the general future of the two main '3G' technology families WCDMA and CDMA2000. With the groundwork laid out, we finally assess the WCDMA and CDMA2000 evolution paths for GSM, CDMA and TDMA operators respectively.

A final reminder is probably appropriate here: While we believe that the analysis in this report adequately reflects rational arguments for and against evolution paths, there are also "soft" factors in place, such as vendor relationships, availability of support and politics, that could play a key role in an individual operator's choice of evolution path. To be able to analyse such factors, a market-by-market study would have to be carried out, which is beyond the scope of this report.

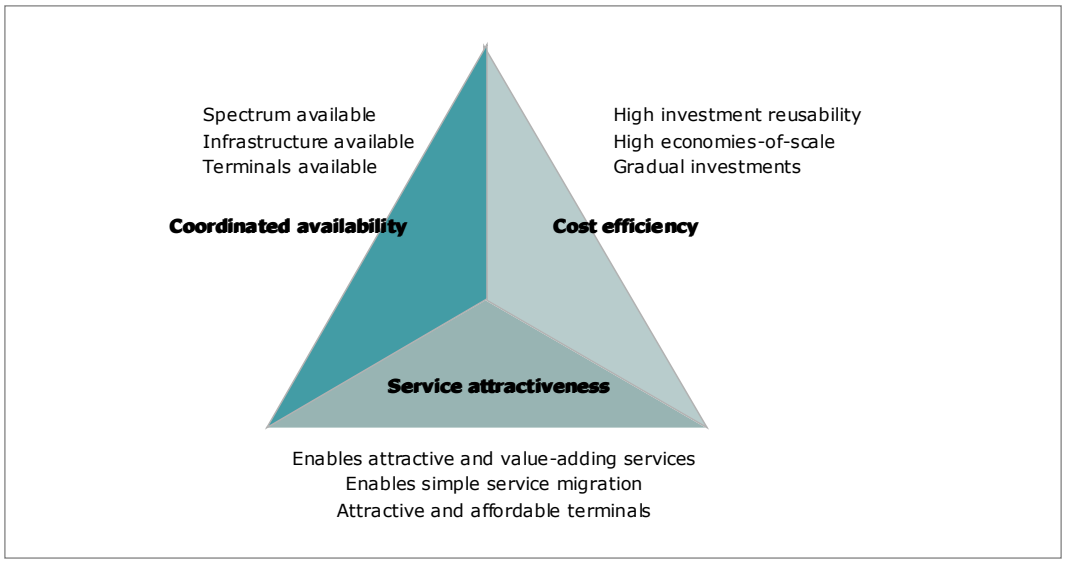


Figure 1. Key aspects of a technology, used when assessing feasibility of different network evolution paths. An evaluation framework developed by Northstream.

2 Current status of the mobile market

2.1 Global usage of mobile technologies

The current status of mobile networks in terms of spectrum allocation, technologies they use and user distribution is generally well known, but key information is included here as background to the later analysis. As illustrated by Figure 2, GSM is the dominant cellular technology worldwide with 69% of the total number of subscribers at the end of September 2002. CDMA represented 12% of the total number of subscribers at the same date.

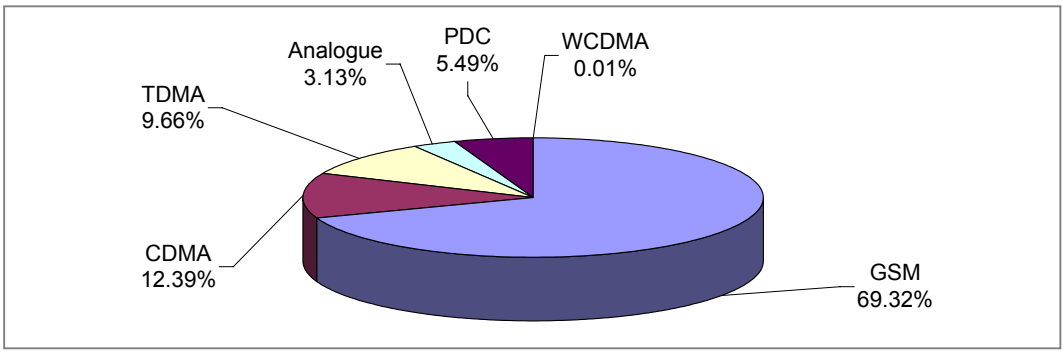


Figure 2. Distribution of worldwide mobile subscribers per technology (September 2002)[2]

GSM and cdmaOne networks are rapidly being upgraded to packet data capabilities, through GPRS and CDMA2000 1X. Packet data subscriber numbers are still insignificant in most markets, making current packet data subscriber statistics less useful for analysing future developments. To get a view of the emerging sizes of packet data enabled deployments using different technologies, of more interest is the number of commercial networks with packet data capabilities. Figure 3 shows the number of commercially deployed GPRS and CDMA2000 1X networks by December 2002 according to EMC. (Other sources have indicated different numbers, for example "more than 140 data enabled GPRS networks commercially deployed with a further 40 currently in construction"[3] and "33 CDMA2000 1X commercial networks and 19 scheduled to be deployed in the next year"[4].) These numbers show a substantial dominance of GPRS networks over CDMA2000 1X networks, as expected considering the dominance of GSM operators worldwide. It can thus be assumed that once the packet data market matures also in other markets than Japan and Korea, the share of the packet data subscribers using GPRS will likely follow the proportion of GSM subscribers in the 2G market.

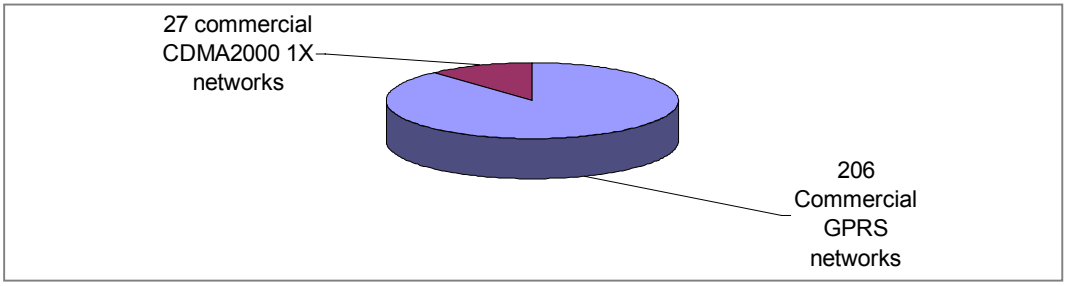


Figure 3. Numbers of commercially deployed GPRS and CDMA2000 1X networks in December 2002[5].

[2] Source: EMC
[3] Source: GSM Association Press Release, 1/16/2003
[4] Source: CDMA Development Group Web Site, 1/16/2003
[5] Source: EMC

The spectrum allocation situation is intimately related to network evolution strategies. In many countries, spectrum bands are even explicitly associated with specific technologies. Spectrum regulation together with various market-related factors has lead to a regional distribution of mobile subscribers as shown in Figure 4.

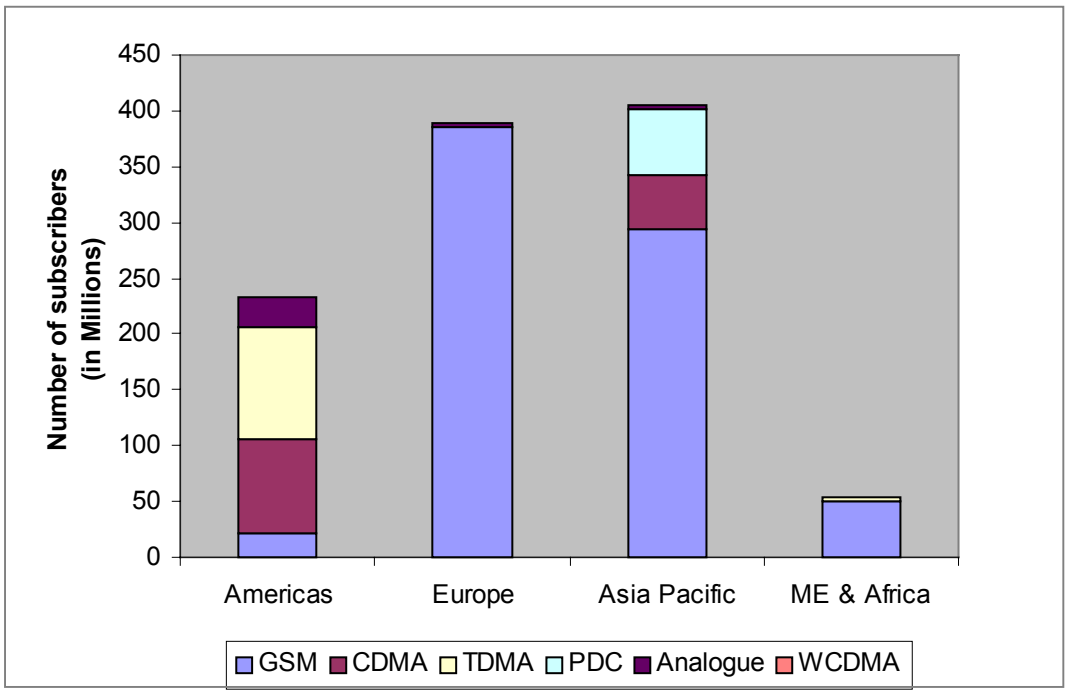


Figure 4. Distribution of mobile subscribers per technology, per region (September 2002)[6]

Europe's primary wireless technology is GSM, which uses the 900 and 1800 MHz bands. The IMT-2000 2GHz band has in most countries been allocated to operators for WCDMA (with some specific spectrum for UMTS/TDD mode in many countries).

In **North America** the current major CDMA, TDMA & GSM technologies use the 800 MHz cellular band and the 1900 MHz PCS band, the latter blocking the IMT-2000 2GHz band and causing a shortage of spectrum. In November 2002, the US telecom regulator FCC published a document discussing rules to allocate 90 MHz in the 1700 and 2100 MHz bands for the provision of Advanced Wireless Services, and recently it allocated another 30 MHz in parts of the 2000 MHz and 2100 MHz bands. However it is anticipated that the actual licensing process will take time and as a consequence the availability of additional spectrum is still uncertain. Operators must thus consider a scenario without additional spectrum in the near to mid term when deciding on their technology evolution strategies.

Related to spectrum and technology usage in the US is the fact that the spectrum cap imposed on operators has been removed as of January 2003. A possible result of this is a consolidated wireless US market with a smaller number of big operators, which in turn should in turn lead to easier accommodation of 3G technologies within the 800/1900 MHz bands since the 'new' operators will control bigger chunks of spectrum.

In **Central and South America** wireless technologies are dominated by analogue and 2G operations in the 800 MHz band using AMPS/TDMA, with some GSM and CDMA coverage. In most countries e.g. Chile, Mexico & Argentina, 1900 MHz spectrum has been allocated, in accordance with the US allocation. The biggest market Brazil has allocated 1800 MHz rather than 1900 MHz, leaving IMT-2000 2Ghz band available for the future.

[6] Source: EMC

AMPS and TDMA networks are progressively being migrated to either GSM or CDMA. In the Americas, 28 TDMA operators[7] have decided to migrate to GSM whilst 12[8] have opted for the CDMA2000 1X path. The TDMA operators in the Americas that have formally announced their decision to migrate to GSM so far account for about 68% of all TDMA subscribers in the Americas[9].

In **Asia Pacific**, GSM using the standard 900 and 1800 MHz band is the dominant current technology outside Japan and Korea. The IMT-2000 2GHz band is generally available.

In the important Chinese market[10], GSM prevails, being offered by the two existing cellular operators China Mobile and China Unicom in the 900 MHz and 1800 MHz bands. China Unicom also offers cdmaOne[11], in the 800 MHz band and has announced its plan to upgrade it to CDMA2000 1X. Technologies to be used in the IMT-2000 2GHz band remain unclear: the paired part of this band is going to be used for WCDMA and CDMA2000, whereas the unpaired part of the band is reserved for TD-SCDMA. The Chinese authorities have also reserved substantial additional spectrum for 3G networks, in the 1800 and 2300 MHz bands. However, the exact conditions under which 3G licenses will be allocated in China (in particular the technologies to be used) are not expected until late 2003.

In South Korea, cdmaOne and CDMA2000 1X are being used in the 800 and 1700 MHz bands. Of the three licenses granted in the IMT-2000 2GHZ band, SK Telecom and KTF subsidiary KTI will use WCDMA, whereas LG Telecom will use CDMA2000.

In Japan, operators generally use PDC primarily in the 800 MHz band. For the IMT-2000 2GHz band, NTT Docomo and J-Phone has opted for WCDMA, whereas KDDI has launched a CDMA2000 1X network.

In **Middle East and Africa,** GSM is the prevailing technology, being used in the standard 900 and 1800 MHz bands.

2.2 Terminal, service and economical aspects

Below we highlight key facts regarding the status of terminals, services and economics for current mobile networks, which provides a useful background when assessing 3G evolution paths.

Key terminal aspects

GSM terminal models for 900 and 1800 MHz bands are available in very large numbers. For the 1900 MHz band, a large number of terminals are available as well: 75 terminal models

[7] AWS (US), Cingular (US), Telcel (Mexico), Rogers AWS (Canada), Cable&Wireless (pan-Caribbean and Central American Operations), Dobson (US), Triton PCS (US, AWS affiliate), Edge Wireless (US, AWS affiliate), Observer Cellular (Antigua and Barbuda), Telecom Personal (Argentina), Unifon (Argentina), BTC Mobility (Bermuda), Telefonica CTC (Chile), Comcel (Columbia), Conecel (Ecuador), TSTT (Trinidad & Tobago), TSKL (Kiribati), TIM (Brazil), Oi (Brazil), Telefonica (Brazil), SETAR (Aruba), Batelco (Bahamas), Entel Movil (Bolivia), ICE (Costa Rica), Curacao Telecom (Netherlands Antilles), Setel (Netherlands Antilles), TelCell (Netherlands Antilles), CCPR (Puerto Rico). Source: EMC.

[8] Bell Mobility (Canada), BellSouth International (Ecuador, Panama, Chile, Venezuela, Columbia), Movilnet (Venezuela), US Cellular (US), Verizon Wireless Puerto Rico, Cellular One (Bermuda), Otecel (Ecuador) and Western Wireless (US). Source: EMC and CDG.

[9] Source: 3G Americas

[10] EMC estimate gives 216 million subscribers in China at the end of 2002 accounting for nearly 19% of the World subscriber base.

[11] According to Global Mobile, at the end of September 2002, China Unicom had 36.14 million GSM susbcribers and 2.28 cdmaOne subscribers.

were either shipped or announced by the beginning of November 2002[12]. In addition, during 2002, Motorola, Nokia, Siemens, and Sony Ericsson released GSM terminals for the 850 MHz band. Around 110 GPRS devices from than 30 manufacturers were reported to be available in January 2003[13]. The first EDGE handset, the GSM 800/1800/1900 from Nokia, was announced in November 2002 with a release date of Q1 2003 in the US. Motorola have also announced an EDGE terminal T725 which will be up for shipment in H2 2003. EDGE terminal support is hence still very limited. For CDMA, cdmaOne terminals for the 800 and 1900 MHz bands are available in large numbers. More than 200 CDMA2000 1X devices from more than 30 manufacturers were reported to be available by November 2002[14].

While quoting global numbers of models above to give an overview, we also note that direct comparisons should always be market-specific: In the global numbers above we expect some double-counting, since several variants of the same product are sometimes accounted for as distinct models. Specifically, the largely proprietary service networks of CDMA operators lead to operator-specific terminals, increasing the global count of devices. Recently, a trend towards operator-specific terminals has been observed also among some GSM operators.

Enabling gradual rollout of GSM over TDMA, three GSM/TDMA (GAIT) terminals started shipping in 2002, from Nokia, Siemens and Motorola[15]. The availability is thus limited. To our knowledge, there is no CDMA/TDMA terminal available on the market; but many of the CDMA terminals support AMPS which enables gradual CDMA rollout for operators with significant AMPS capacity still available.

Qualcomm announced in March 2002 the availability of the Removable User Identity Module, (R-UIM)/UIM Toolkit (UTK) system software which can help to support future SIM roaming between GSM and CDMA networks. For the World Cup in Korea in 2002, South Korean CDMA operator KTF and Chinese GSM operator China Mobile signed a roaming deal whereby China Mobile subscribers could insert their SIM cards into KTF handsets provided upon arrival[16]. Such SIM roaming arrangements are likely to remain a small niche activity.

A GSM/GPRS/CDMA chipset, the MSM6500, became available from Qualcomm in November 2002. However, it is still unclear when, if at all, dual mode GSM/CDMA2000 handsets will appear on the market. See further the roaming discussion in Section 3.2.

Service characteristics

All 2G technologies in the analysis (GSM, TDMA, CDMA) support basic end-user services such as voice and text messaging. Regarding more advanced data services, these are generally less dependent on the network technology; they rely more on the availability of specific features in handsets and on the corresponding service platforms. A notable difference between GSM and CDMA is that in GSM, the service network layer is largely standardised: For example, regarding picture messaging, MMS is being launched for GSM as a global solution, whereas for CDMA, a number of proprietary variants exist even within national markets. From a service characteristics viewpoint, proprietary solutions often lead to fast service launch but also generally cause poor interoperability between operators.

One difference between current packet data technologies is that currently CDMA2000 1X (defined as a '3G' technology by ITU, but from a service capability point-of-view

[12] Source: 3G Americas
[13] Source: GSM Association
[14] Source: EMC
[15] : Nokia 6340 (GSM 1900 – TDMA 800/1900 – AMPS), Siemens S46 (GSM/GPRS 900/1900 – TDMA 850/1900) and Sony Ericsson T62u (GSM 850-1900 – TDMA 800/1900 – AMPS
[16] Source: http://www.chinamobile.com/english/readennews.asp?id=5466

comparable with GPRS) provides higher practical data rates, around 40-60 kbps, than the 20–30 kbps of GPRS. However, this type of difference does not dramatically change the way users perceive existing data services (except possibly web browsing or file transfer for laptop and PDA users) or enable the take-up of new types of services.

Because of its dominance in terms of geographic footprint across the world (it is estimated that at the end of 2002, GSM was available across 190 countries[17]), GSM has a fundamentally different existing roaming base than other technologies. This is true not only in terms of number of countries where GSM is present but also in terms of the extensive roaming infrastructure in place (i.e. clearing houses, standardised service network layer, inter-operability testing, and general charging agreements).

Impact of technology on revenues and costs

Revenues are mainly affected by other factors than network technology. Factors where network technology does have an influence include service offering, roaming and the availability of terminals that enable and support usage of services. As discussed in the previous paragraphs, there is little difference between GSM/GPRS and CDMA2000 1X in terms of terminal availability and general service offerings. The major differentiator is the substantially higher revenue potential from roaming with GSM/GPRS.

Regarding costs, we observe that volumes matter: GSM today has a high volume of terminals leading to lower costs per unit produced, in turn implying lower prices assuming constant supplier profit margin. As data services mature in other markets than Japan and Korea, we expect to see this effect for GSM/GPRS over CDMA2000 1X devices as well. Similarly, greater economies-of-scale should lead to lower network infrastructure prices for GSM/GPRS over CDMA2000 1X.

Note that CDMA2000 1X, when terminal penetration becomes significant, can help operators reduce their expansion capital expenditure by providing enhanced voice capacity (compared to a cdmaOne-based capacity expansion).

[17] Source: GSM Association

3 Future market developments

This chapter outlines key general differentiators between the two major 3G technology families that will prevail, the WCDMA technology and CDMA2000 DO and DV (CDMA2000 1X status was discussed in Section 2 together with GPRS). Aspects considered include projected market size, terminal availability and price, and service capability.

3.1 Future usage of mobile technologies

General 3G evolution options

Figure 5 highlights the evolution paths that are discussed in this report, and also highlights our estimates of timing of the different technologies. The timelines reflect the availability of equipment (including terminals, radio and core network equipment) for the operators. The feasibility of these evolution paths are analysed in Section 4.

What is apparent is that two main future technology communities will co-exist, based on WCDMA and CDMA2000 technologies. GSM, TDMA and CDMA (and PDC) networks will eventually deploy either of those technologies.

As a market-specific addition, we note the interest for TD-SCDMA technology in China. It is heavily pushed by Chinese authorities and vendors Datang and Siemens, and Chinese operators may be forced to deploy it as a part of the 3G licence requirements. While TD-SCDMA thus constitutes a third evolution path for Chinese operators, we see the likelihood of the technology spreading to other markets as limited, and it is not put forward as a globally available evolution option in this report.

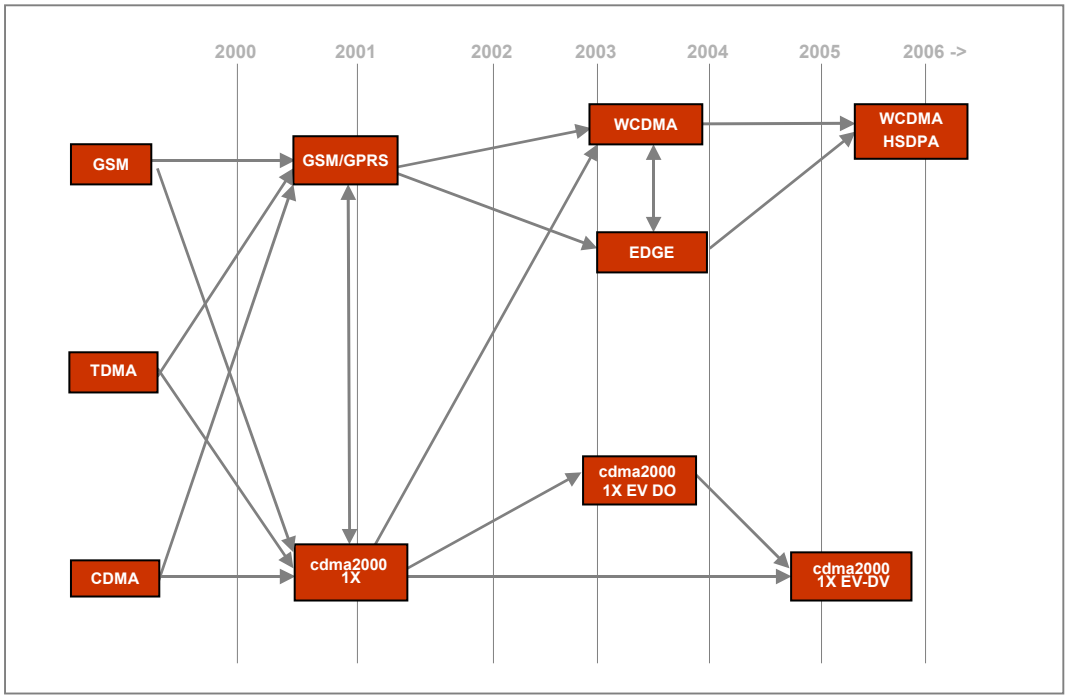


Figure 5. Network evolution path options facing CDMA, TDMA and GSM operators. Timeline indicates equipment availability. (When an evolution step is taken, the previous network technology typically stays with the operator for a long time; these 'legacy' networks are not shown in the picture.)

User and technology share predictions worldwide

In many markets, network evolution paths are already quite clear. In other markets, operators' choices remain to be made. By combining public announcements, an appreciation of the overall market size of the technologies can still be obtained.

As starting point for a future market size discussion, we use the widely known Ovum predictions, presented as the relative number of mobile users worldwide per technology 2002-2007 in Figure 6. In the figure, '3G' includes WCDMA, EDGE, CDMA2000 1X and DO while 'GSM' includes GPRS. The definition enables an indication of the amount of "3G" users in the world, but does not draw conclusions about the technology shares of 3G.

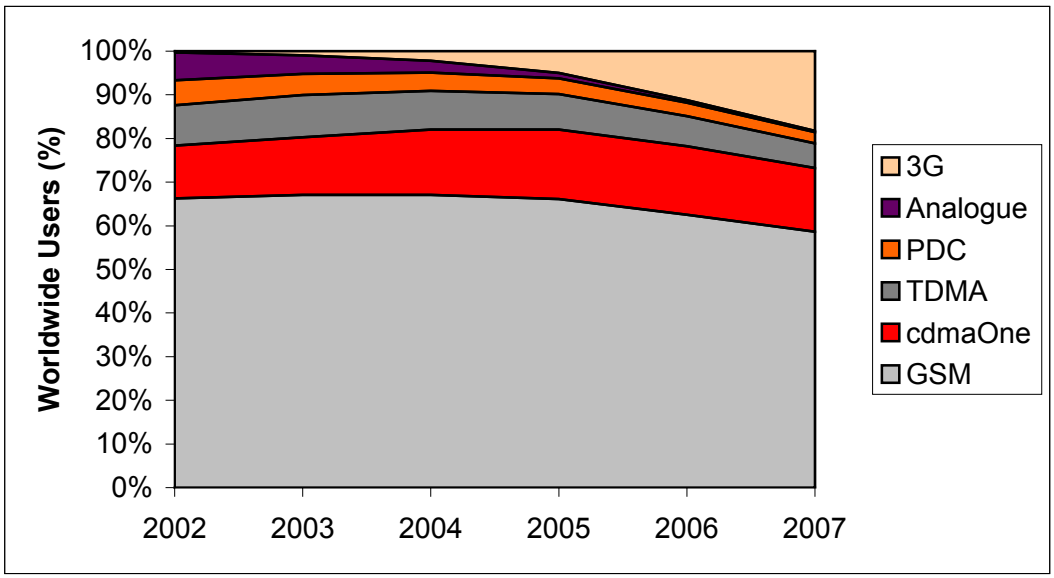


Figure 6. Worldwide mobile users per technology 2002-2007 (January 1)[18]

There is little reason to doubt the prediction that GSM (including GPRS) is and will continue to dominate globally over the next five years. The drop of GSM user share beyond 2005 is attributed to the migration of subscribers to WCDMA networks. As most leading GSM/GPRS operators have stated their intention to become WCDMA operators, we believe that WCDMA will dominate the global market in a similar way as GSM. However, as shown by the Ovum predictions, a global market dominated by WCDMA is only a long-term scenario.

The predicted decline of TDMA subscribers is attributed to network operators gradually phasing out their networks in favour of GSM or CDMA2000. Announcements during 2002 of many AMPS/TDMA operators adopting either GSM or CDMA2000 may suggest that the rate of decline will be faster than Ovum predicted.

Regarding the technologies within '3G', it is still premature to predict exact shares of each technology. Specifically regarding the CDMA2000 paths, the operator views on DO and DV options are still unclear. We have to date found three DO vendor contracts. While many CDMA2000 operators are testing DO networks, it remains open how many operators will actually deploy DO and not wait until DV becomes available.

[18] Ovum Forecasts: Global Wireless Markets 2002-2006, 2002

3.2 Terminal, service and economical aspects

Future mobile terminals

It is envisaged that the following terminal trends will mould the 3G market development and 3G take-up for CDMA2000 and WCDMA technologies.

It is clear that most WCDMA terminals will, unlike the current NTT Docomo WCDMA terminals, be dual mode with both GSM/GPRS and WCDMA access capabilities. This will be instrumental to ensure global roaming and permit gradual deployment of WCDMA networks from the first day of launch.

We believe that the mass market for CDMA2000 terminals will concentrate on 1X (as opposed to DO) and will continue focusing more on service support and enhanced features such as multimedia message, camera, and video support. The data rate advantage that DO provides over 1X is mainly suited for services targeted at niche user segments, which means that operators may be reluctant to dedicate DO carriers. Where deployed, the DO market is believed to focus on small selected user segments, reducing terminal model availability[19]. The emergence of the DV technology will likely increase the number of enhanced data terminals both in numbers and in variety.

There has been some publicity around multimode chipsets for cdmaOne, CDMA2000, GSM/GPRS and WCDMA[20]. However we question that these chipsets will ever develop to dual, triple or quadruple mode terminals, given the lack of incentives to sign roaming agreements (see the roaming discussion in the service capability section below).

Service capability evolution

In this section, important service aspects of WCDMA and CDMA2000 are compared. We reiterate that the main service differentiators offered by operators are currently not related to network technology: the market currently sees services being pushed via application and terminal technologies such as picture messaging, colour screens, in-built cameras and GPS. We believe that these aspects will continue to drive the service offerings, while network developments should be seen as enabling tools for the operator to exploit and improve their service offering.

Both WCDMA and CDMA2000 offer 64 kpbs circuit switched data. The maximum packet data rate is initially to the advantage of CDMA 2000 1X EV-DO (comparable with initial deployment of WCDMA). However to compare offered end-user data rates is more complex. In WCDMA, each user will have its own data channel where 384 kbps is, in practice, the highest implemented data rate. In DO, all users in one cell share a packet data channel and at any given instant the entire bandwidth is dedicated to a single user. Therefore average speeds depend on load and location in the cell. Simplified, a DO carrier has roughly an average downlink data throughput of 800-1000 kbps (although maximum theoretical speed is 2.5 Mbps) which all users share, e.g. with four users on a carrier simultaneously receiving on the downlink the average speed per user would be around 200-250 kbps. Given that DO only offers a data connection, operators will have to support 1X and wait until DV functionality is available to offer simultaneous voice and high rate packet data. Approximately coinciding in time with DV, a further development for WCDMA networks will be available (High Speed Downlink Packet Access, HSDPA) providing higher maximal data rates (up to 8-10 Mbps in its first release).

[19] According to the December 2002 edition of Signals to Noise by Deutsche Bank, SK Telecom currently have 9 ev DO models identified, 4 commercially available and 5 currently being tested

[20] Qualcomm proposes the support of CDMA2000 1x and GSM/GPRS in their MSM 6500 series and WCDMA/GSM/GPRS and CDMA2000 1x in their MSM 6600 series)

One main difference between WCDMA and CDMA2000 DO (and possibly DV) networks is that the latter currently uses a priority based QoS mechanism for its packet access, while WCDMA and GPRS networks define four QoS classes having particular well-defined QoS characteristics[21]. We find the ability to offer advanced QoS, including guaranteed data rates, short latency, seamless packet handover, and controlled trade-off with bit error ratio of the data flow, to be a key enabler of more advanced data services, much more so than higher maximum data rates.

From a standardisation viewpoint, recent developments in 3GPP2 have helped to reduce the functionality gap between WCDMA and CDMA2000. In the last six months 3GPP2 has identified the support of intelligent network (IN) interaction for packet networks, MMS and QoS schemes. It is not yet clear when these functionalities will be available for the operator. The current proprietary service network layers of CDMA will in the short term continue to limit interoperability between operators, thus reducing attractiveness of services such as multimedia messaging where inter-operator support is important. However, in the long term we believe that the systems will be similar in most of these respects.

A key service differentiator that will remain in the future is the support of extensive international roaming. The support of roaming requires certain infrastructure and contractual agreements between operators. Furthermore, terminals need to work with the visited networks' technologies and spectrum bands, or the visited operator need to lend terminals to the roaming user (here referred to as 'SIM roaming'). The ubiquity of GSM networks and fully established roaming agreements globally means that subscribers can be guaranteed GSM coverage almost anywhere[22]. WCDMA reuses the established roaming framework introduced in GPRS and GSM networks, although a GSM-like roaming coverage for WCDMA data services is a long-term scenario. The well-defined QoS in WCDMA networks also enables consistent end user service experience whilst roaming, which would otherwise rely on the visited operator's network dimensioning. CDMA on the other hand does not have strong roaming framework[23], nor does it have the ability to learn from substantial packet data service roaming experience. This, together with CDMA's absence in many key markets will keep the roaming offering limited for CDMA operators also in the future. We do not see that this situation will be aided by inter-technology roaming to any significant extent: there is simply little incentive for WCDMA operators to spend effort on CDMA roaming agreements given the GSM and future WCDMA global presence[24].

During 2002 there have been certain drivers to try and align the developments of the two 3G standards groups, 3GPP and 3GPP2. This harmonization work has been mainly targeted at a common approach to the evolution of networks to an all-IP architecture. Similar developments in 3GPP (developing the IP Multi-media Subsystem (IMS) and 3GPP2 (the IP Network Architecture Model) have lead to an agreed joint development to be continued within 3GPP. Other areas of harmonisation between the two access technologies have also been studied, although with minimal results. We believe that this harmonisation work will only act in improving efficiencies for companies developing similar features within parallel standards bodies and mapping those developments onto their respective products. We do

[21] Note however that 3GPP2 has identified various QoS schemes for cdma networks (to provide QoS classes and provide various QoS "streams" for the same connection (in a similar way that 3GPP defines the QoS for GPRS)) but it is unclear exactly how this will be introduced over their current CDMA2000 packet network.

[22] Major operators in Germany, Italy, UK and Sweden have GSM roaming with between 110 and 180 countries each (Source: Northstream research, Sep 2002).

[23] CdmaOne roaming is currently supported via a mechanism called cellular interconnection billing exchange record (CIBER) and is currently limited to Canada, North America, some parts of South America and Asia. (Source: CDG).

[24] The only exception would be in the case of common operator interest, for example such as potentially Vodafone and Verizon.

not envisage that the joint development will increase the number of inter-technology roaming agreements or influence operators' network evolution path plans.

Impact of technology on revenues and costs

The main aspects concerning costs in deploying a mobile network are related to the access network and terminals. Reduced costs in one aspect may be offset by higher costs in the other.

Market sizes of both WCDMA and CDMA2000 appear to become big enough for infrastructure suppliers to make attractive products available. However, a greater market volume would probably lead to higher volumes per supplier, translating into lower manufacturing cost per produced unit as fixed costs are shared between more units. A lower cost structure naturally opens up for lower unit prices, but also higher possible investments in R&D, creating a potential for a quicker product evolution in the longer term. Given the likely higher number of future WCDMA subscribers, we believe that the long term fixed costs will be considerably less per unit than for CDMA DO/DV terminals leading to lower WCDMA unit prices.

As mentioned, data rates differ between WCDMA and CDMA2000 DO and DV. However, from the packet data service take-up in Japan and Korea, we see that the data service access as such is a main key enabler, not the data rate. Subscriber numbers and ARPU increase as a consequence of the new enabled data services and more advanced terminal features (camera, GPS, etc), and not due to high data rates. Similarly, we view the WCDMA and CDMA2000 DO and DV data rate differences as irrelevant from a revenue potential perspective.

Finally international roaming as a revenue generator is an area gaining importance with the increase in travelling and of household incomes. The previously mentioned long term global roaming ubiquity of WCDMA is predicted to lead to significant revenue potential advantages in three respects: firstly, a WCDMA operator competing with CDMA2000 in the same market will offer a stronger value proposition to high-paying travel-intensive user segments boosting subscriber growth; secondly, WCDMA operators will gain revenue from their own subscribers visiting other networks; and thirdly, revenues will come from incoming roamers from other networks.

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4 Operator options for 3G evolution

Strategies for evolving 2G networks to 3G have been on operator agendas for a number of years. While most leading operators have expressed their plans for evolution of their networks, some uncertainties remain, most importantly in parts of East Asia and in the Americas. In the important Chinese market, 3G technologies for use in the IMT-2000 spectrum band have not yet been decided. In the Americas, the evolution path for some of the TDMA operators is not yet clear. In addition, the expected operator consolidation following the removal of the spectrum cap in the US may, in case cross-technology mergers take place, destabilise the seemingly stable 3G plans in that market, which may in turn affect Latin America due operators ownership structures and the region's tendency to adapt to the North American evolution.

In this chapter, we analyse the rationale for different evolution paths to 3G, for GSM, TDMA and CDMA operators respectively, using the evaluation framework presented in Section 1.1. WCDMA and CDMA2000 are seen as the two main options, although the parallel TD-SCDMA technology developments have been considered in the analysis. AMPS operators are discussed within the TDMA section, as are the TDMA operators that have already launched GSM/GPRS and thus in a strict sense are also GSM operators.

4.1 GSM operator options

Rationale for a WCDMA-based evolution

As mentioned in Section 3.1, WCDMA deployment is already a de facto evolution for many GSM operators. In Europe WCDMA is unanimously preferred, with many commercial contracts and trials in place. The evolution in this region has great impact on other GSM operators globally. For spectrum-limited GSM operators, as well as for other operators needing to make best use of its spectrum, EDGE can be included as a complement in the overall WCDMA-based path to provide data rate-demanding services in a cost efficient way.

Using the analysis framework presented in Section 1.1, we conclude that the following are key decisive factors speaking for a WCDMA-based evolution for GSM operators. In addition to those, strong GSM vendor commitment and European regulation should be mentioned as important reasons why WCDMA evolution has become the preferred evolution path for GSM operators.

Higher investment reusability: WCDMA evolution requires substantial new investment for a GSM operator, since a new radio access network (UTRAN) needs to be deployed. Still, major effort has been put in standards and products to make reuse possible of many of the service network components, as well as other peripheral systems and operator competence. We hence see significant investment reusability advantages with the WCDMA path.

Gradual investments: The WCDMA path provides step-by-step evolution towards 3G for a GSM operator. The support of service continuity across technologies allows controlled gradual deployment of the WCDMA network hence allowing initial infrastructure and terminal investments to be kept to a minimum. (The CDMA2000 path would force operators to deploy a complete network rapidly due to lack of inter-technology handover capabilities, leading to higher initial investments.)

Simple service migration for the user: GSM to WCDMA evolution provides similar user experience and service continuity across both generations of technologies. Operators can build on existing service portfolios and provide seamless introduction of new services from GSM/GPRS (and EDGE) to WCDMA.

Enables attractive, value-adding services: WCDMA has a strong service capability profile, but as discussed in Section 3.2, CDMA2000 is closing many of the gaps through recent developments. One remaining fundamental differentiator is roaming capabilities, where GSM/GPRS/WCDMA roaming is going to be enabled on an entirely different scale than for CDMA2000, as pointed out in Section 3.2. This should create substantial revenue advantages for the WCDMA path, both in terms of the richer service offering attracting users to the networks, and from plain roaming charges.

Attractive and affordable terminals: As mentioned in Section 3.2, GSM/GPRS/WCDMA-capable terminals will be a mass-market product, distributed by a large number of vendors for a global market. We believe that this will create high competition which will drive terminal attractiveness and push prices down. For comparison, a terminal incorporating both GSM and CDMA2000 (which would be needed for a smooth user migration) will be a niche product at best, with unclear support from terminal vendors. Furthermore, the costs involved in setting up distribution channels for terminals in markets where CDMA technology and vendors are not currently present, may substantially increase the initial deployment costs.

Rationale for a CDMA2000-based evolution

The evolution of GSM to CDMA2000 would theoretically suggest two possible paths: either the development of a parallel CDMA2000 network with an already deployed GSM network, or the integration of CDMA access network within the GSM network (sometimes referred to as GSM 1X).

We believe the only reason a GSM operator would consider either of these CDMA2000 paths would be market-specific requirements, including regulatory or political factors. We have seen very few indications in this direction: China Unicom has deployed a complete CDMA network in parallel to its GSM system. The network is using a large number of Chinese manufacturers as suppliers, plus five of the major foreign suppliers, which gives an indication of the industry political nature of this evolution decision. Another CDMA2000 1X overlay on GSM is done by Telstra in Australia, where the extremely low population density, making high coverage a key characteristic, apparently has motivated this deployment despite the costs of deploying and running double networks. Notably, Telstra markets the two networks with the same services, apart from coverage: CDMA is for the domestic traveller whereas GSM is for the international traveller due to the roaming support.

Using the framework presented in Section 1.1, we have found one general decisive factor speaking for a CDMA2000 evolution path, which is applicable to a subset of all GSM operators, particularly in North America:

Spectrum available: CDMA2000 evolution has some mid term spectrum management advantages for a GSM operator. A deployment of a CDMA 2000 DO network would require minimum two carriers (~3 MHz), whereas WCDMA deployment requires ~5MHz of spectrum. For GSM operators with mid term limits on spectrum availability, this is a quite significant argument. However, the argument is not valid in the short term: For a short-term spectrum-limited GSM operator, EDGE is more easily integrated in existing spectrum than CDMA 2000. Likewise, it is not a long term sustainable argument: as 3G capacity demand increases after a completed migration, the spectrum issue is transformed from initial deployment needs to spectral efficiency, where we have found no advantage of CDMA2000 over WCDMA.

One argument sometimes claimed as a benefit of CDMA2000 over WCDMA for a GSM operator, is a difference in support of high data rates. As we point out in Sections 2.2 and 3.2, while there currently is a difference between GPRS and CDMA2000 1X, we see it as

irrelevant from the service-enabling perspective which in the end is what makes an operator successful or not. As we point out, data rates are insignificant in the explanation of the current uptake of CDMA2000 1X (and GPRS). We thus do not view data rates as a decisive factor for a GSM operator choosing a 3G evolution path.

Conclusion for GSM operators

We conclude that a GSM operator that has spectrum to deploy WCDMA will choose the WCDMA evolution path according to Figure 7. Higher investment reusability, gradual investments, simpler service migration, more attractive services including roaming and better long term terminal availability (highlighted in Figure 8), combine to make such a decision rather simple.

GSM operators who face difficulties to find spectrum for a WCDMA deployment, for example in North America, will likely be using EDGE as bridging technology until spectrum for WCDMA becomes available, rather than choosing a CDMA2000 evolution. As mentioned in Section 2.1, the widely expected consolidation among North American operators may also contribute to freeing up larger portions of spectrum per operator, which makes a WCDMA deployment easier.

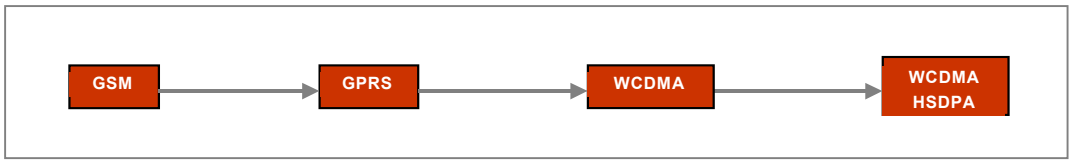

Figure 7. GSM operator evolution path to WCDMA

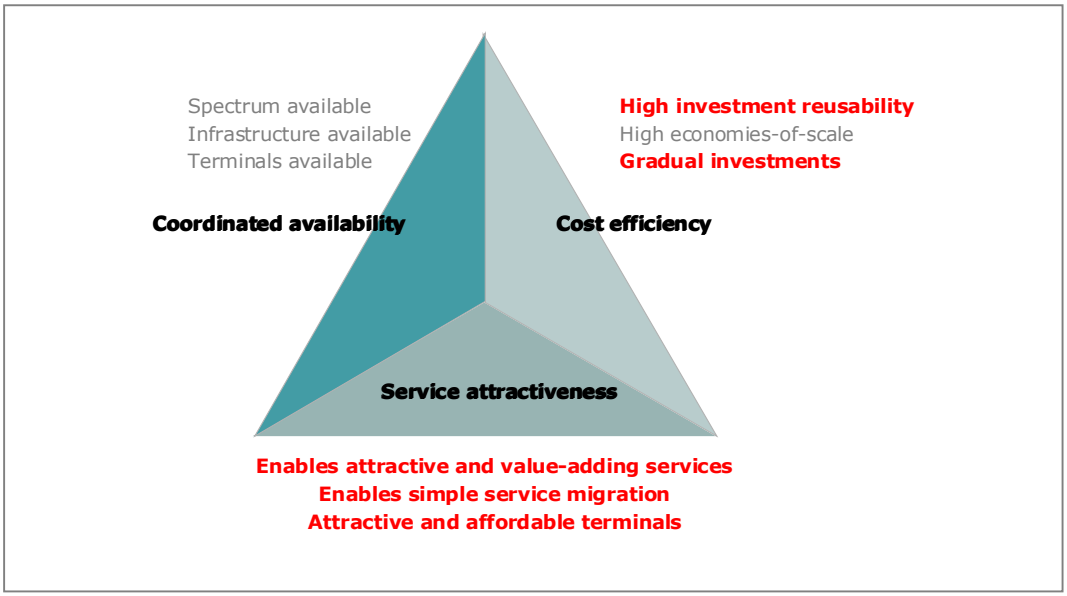

Figure 8. Key decisive factors for GSM operators to evolve their networks to WCDMA

4.2 CDMA operator options

Rationale for a CDMA2000-based evolution

As mentioned in Section 2.1, evolution of cdmaOne networks to 1X is already taking place on significant scale. We believe that this evolution will spread across many of the remaining cdmaOne networks in the near to mid term.

By CDMA2000 evolution, we here refer to the subsequent evolution steps for a current cdmaOne or 1X operator: The evolution to DO appears technically straightforward: DO deployments have already commenced, as pointed out in Section 3.1, and many trials are ongoing. Commercial launches so far have not been great success stories however, and we tend to believe that the subsequent evolution step to DV should offer more attractive capabilities. Hence, we may see a tendency to move directly from 1X to DV, as indicated by Sprint PCS.

Using the analysis framework presented in Section 1.1, we conclude that the following are key decisive factors speaking for a CDMA2000-based evolution for CDMA operators.

Spectrum available: Straightforward spectrum management is possible for the CDMA2000 path. DO can be added to a CDMA2000 1X network by evacuating one carrier (1.25MHz) of spectrum, whereas extensive re-farming or more likely new spectrum would need to be acquired to accommodate the minimum 5 MHz that WCDMA deployment would require. DV can be introduced by upgrading a 1X carrier.

High investment reusability: Deployment of DO in an existing CDMA2000 1X network requires some upgrades and replacements of equipment, mostly in the radio access network, but these are still fairly limited. We hence see substantial investment reusability advantages over the WCDMA path, which would require a full network overlay. Similarly, also DV deployment should allow higher reusability than WCDMA for a CDMA2000.

Gradual investments: The CDMA2000 path provides step-by-step evolution to 3G. This allows controlled gradual deployment of the network hence allowing initial infrastructure and terminal investments to be kept to a minimum. (The WCDMA evolution path would force CDMA2000 1X operators to deploy a complete network rapidly due to lack of inter-technology handover capabilities and dual mode handsets, thus leading to higher initial investments.)

Simple service migration for the user: cdmaOne to CDMA2000 evolution provides service continuity across both generations of technologies. Operators can build on existing service portfolios and provide seamless introduction of new services. (By comparison, the WCDMA path would require a separate service offering to the end user, as in NTT Docomo's PDC to WCDMA evolution.)

Attractive and affordable terminals: As mentioned in Section 3.2, CDMA2000 DO terminals will be produced on a significant scale. It is believed that the volumes will be sufficient to keep the terminal market alive, with characteristics and prices fairly comparable with WCDMA competition for the foreseeable future. DV support is still uncertain, but as we view this as a more favourable step than DO, we assume that once products become available, a market will be created. By comparison, a terminal incorporating cdmaOne and WCDMA (which would be needed for the cdmaOne to WCDMA path) will be a niche product at best, with unclear support from terminal vendors.

Rationale for a WCDMA-based evolution

A WCDMA-based evolution for a cdmaOne or CDMA2000 1X operator would in practice imply a completely new WCDMA network being overlaid on the existing CDMA installed base. There would in principle be the additional option of first deploying a GSM/GPRS network, and then supplement it with WCDMA later (similar to what some TDMA operators are currently doing). We believe that either of these evolution variants seems generally unlikely, and we have not established that CDMA operators are planning for this evolution path, other than in a few exceptional cases.

SK Telecom and the KTF affiliate KTI in Korea have decided to deploy WCDMA networks in parallel to their CDMA2000 1X networks. Out of the 3G licences made available by the Korean regulator (two for WCDMA, one for CDMA2000), these two operators favoured the WCDMA ones. At the time of these decisions, the future service capabilities and the service creation environment of WCDMA (QoS, All-IP, OSA, roaming, etc) was much stronger than that of CDMA2000, which may have been a factor in this decision. As pointed out in Section 3.2, while roaming will continue to be a WCDMA strength, some of the other gaps are now closing.

Partly owned by the Vodafone Group, Verizon in the US is an additional interesting case. Vodafone has started to command strong integration of its operators, with centralised service development and common technology platforms. This suggests that Vodafone may aim to eventually own WCDMA operations in the US, implying either forcing Verizon onto this evolution, or perhaps more likely, change its operator stakes in the widely expected US operator consolidation to come.

Using the framework presented in Section 1.1, we have found one decisive factor speaking for a WCDMA evolution path for cdmaOne and CDMA2000 1X operators:

Enables attractive, value-adding services: WCDMA has a strong service capability profile, but as discussed in Section 3.2, CDMA2000 is closing many of the gaps through recent developments. One remaining fundamental differentiator is roaming capabilities, where GSM/GPRS/WCDMA roaming is going to be enabled on an entirely different scale than for CDMA2000, as pointed out in Section 3.2. This should create substantial revenue advantages for the WCDMA path, both in terms of the richer service offering attracting users to the networks, and from plain roaming charges.

However, we do not believe this advantage to be sufficient for cdmaOne operators to deploy WCDMA on a significant scale.

Conclusion for CDMA operators

We conclude that the generally preferable path for a CdmaOne operator is to evolve its network to 1X and then on to DO and/or DV, which is outlined in Figure 9. Spectrum availability, investment reusability, gradual investments, simpler service migration and better terminal availability (highlighted in Figure 10), combine to make this a straightforward decision.

We do not currently see it being rational for a CDMA operator to deploy WCDMA in parallel. In the cases where that evolution takes place, the context in which it occurs is specific with regards to the market or the operator ownership structure.

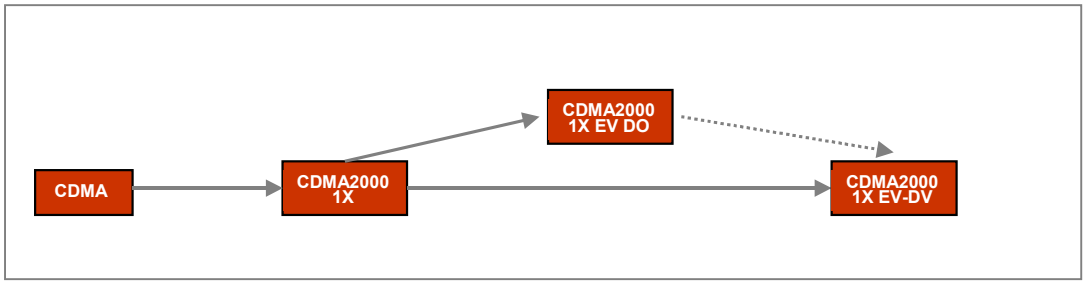

Figure 9. CDMA (IS-95) operator migration path to CDMA2000

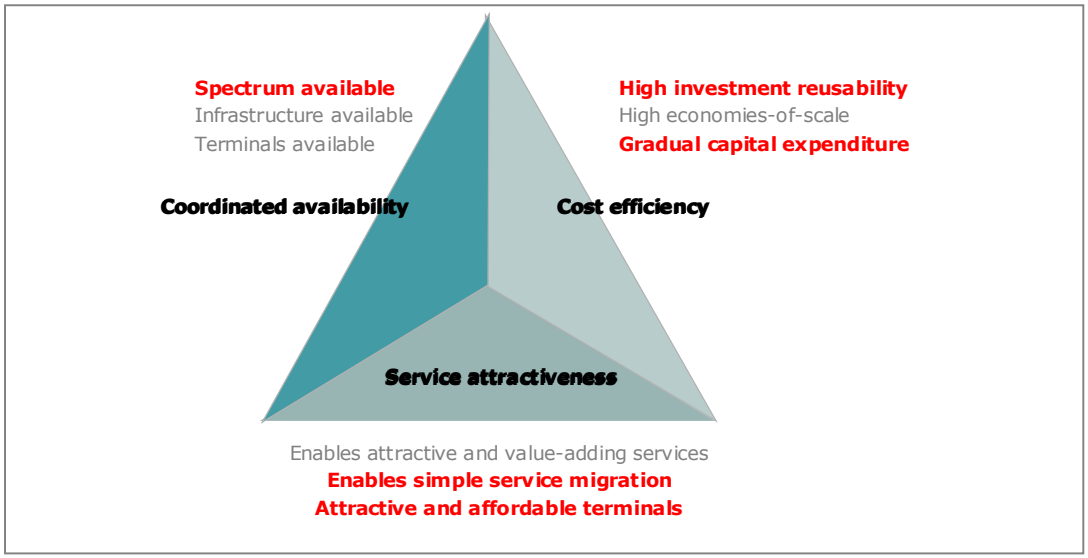

Figure 10. Key decisive factors for CDMA operators to follow the CDMA2000 evolution path

4.3 TDMA operator options

The TDMA evolution is controversial, as TDMA network operators cannot stay on a 'default TDMA path' to 3G but must choose between a CDMA-based path and a GSM-based path. In either case, substantial effort is required succeed in managing the technology shift and the migration of users onto the new technology.

Rationale for a WCDMA-based evolution

A WCDMA-based evolution for a TDMA operator is a multi-step process, implying a first step of deploying a GSM/GPRS network as a parallel overlay on the existing TDMA network. An optional simultaneous or subsequent step is to upgrade the radio access network to support EDGE, increasing data rates for the packet data network. Then, as spectrum allows and service capabilities and capacity needs arise, a WCDMA radio access network is deployed connecting to an evolved GSM/GPRS core network. In theory, a TDMA operator could move directly to WCDMA, but as this would delay the migration of users, we believe this option is not a practical one.

The GSM/GPRS/EDGE/WCDMA path has wide support among leading TDMA operators, as highlighted in Section 2.1. Influential and/or big operators such as AT&T Wireless Services, Cingular and Telcel. Generally, the backing is focused on the earlier step of GSM/GPRS/EDGE deployment, whereas the subsequent use of WCDMA is less certain due to the spectrum situation.

Our evaluation framework presented in Section 1.1 leads to the following key factors in favour of a GSM/WCDMA-based evolution for TDMA operators.

High economies-of-scale: The investment required for either evolution path is substantial. As discussed in Section 2.2, it is envisaged that short-term investment will be less for the TDMA to GSM steps than for a CDMA2000 1X.Similarly, in the long term, we predict that WCDMA products will have significantly better scale benefits than those of CDMA2000.

Enables attractive, value-adding services: WCDMA has a strong service capability profile, but as discussed in Section 3.2, CDMA2000 is closing many of the gaps through recent developments. One remaining fundamental differentiator is roaming capabilities, where GSM/GPRS/WCDMA roaming is going to be enabled on an entirely different scale than for CDMA2000, as pointed out in Section 3.2. This should create substantial revenue advantages for the WCDMA path, both in terms of the richer service offering attracting users to the networks, and from plain roaming charges.

Attractive and affordable terminals: As highlighted in Section 3.2 the GSM/GPRS/WCDMA terminal market will over time be a global mass market. With the increasing presence of GSM in the Americas, and with tri-band and quad-band becoming commodity features in terminals, TDMA operators deploying GSM and later WCDMA will in the long term have access to a very big selection of terminals, substantially bigger than that of CDMA2000. In the short term the advantage is seen as limited.

An advantage sometimes claimed for GSM/GPRS/WCDMA evolution path over the CDMA2000 path for TDMA operators is the existence of the GAIT terminals (see Section 2.2). This enables smooth migration of the user base from TDMA to GSM. However, firstly there are limited numbers of such terminals available. Secondly, current evolutions to GSM (such as that of AWS) take place without a key role of the GAIT terminals. Operators requiring a more gradual update, generally have a more significant presence of AMPS, enabling use of AMPS/CDMA terminals in a transition to CDMA2000. This combined, we

do not regard GAIT terminals as a key decisive factor for TDMA operators to choose a WCDMA-based evolution over CDMA2000.

Rationale for a CDMA2000-based evolution

Evolution of TDMA to CDMA2000 involves upgrading the TDMA circuit switched core network and deploying a new CDMA2000 1X radio access network in parallel to the TDMA radio access.

This evolution path has significant proponents among TDMA operators, as highlighted in Section 2.1. Based on announcements to date, we believe that evolution to CDMA will continue to have support from vendors, albeit not being the path followed by the main part of the TDMA community.

Using the framework presented in Section 1.1, we have found the following decisive factors for a CDMA evolution for TDMA operators:

Spectrum available: CDMA2000 evolution has spectrum management advantages for a TDMA operator. In a first evolution step CDMA2000 1X can be deployed within ~1.5 MHz, whereas the corresponding step of GSM/GPRS/EDGE requires at least ~2.5 MHz. For the later evolution steps, the difference is more accentuated: the upgrade to DO/DV would require minimum one more carrier (~1.5MHz), whereas WCDMA deployment requires ~5MHz additional spectrum. For TDMA operators with short-term limits on spectrum availability, this is a quite significant argument. It is however a short term advantage: as 3G capacity demand increases after a completed migration, the spectrum issue is transformed from initial deployment needs to spectral efficiency, where we have found no advantage of CDMA2000 over WCDMA.

Terminals available: For some TDMA operators wishing to evolve their networks gradually, the CDMA path has an advantage over the GSM/WCDMA path, through the widely available AMPS/CDMA terminals mentioned in Section 2.2. These allow the deployment of CDMA2000 to be gradual, relying on AMPS as fallback technology. For operators having AMPS in significant portions of their spectrum, this can be very useful. For TDMA operators where AMPS usage is insignificant or completely phased out, this terminal type is not useful since it paradoxically would force additional AMPS investments (!), but we believe that this latter situation is rare among TDMA operators that are still to choose their evolution path.

Gradual investments: Assuming that a TDMA operator has significant AMPS capacity and usage in its network, it can benefit from the AMPS/CDMA terminal availability mentioned above to introduce its CDMA overlay gradually. Infrastructure and terminal investments will then be gradual as well. Naturally, network-wide service launches are delayed, which delays revenue potential, so this approach is merely useful in less advanced markets. However, leading TDMA operators such as AT&T Wireless Services have shown a clearly different strategy, to deploy their (GSM) overlay network as fast as possible, implying high upfront investments but also enabling service launches sooner.

High investment reusability: The CDMA2000 1X deployment reuses the circuit switched core network of the TDMA network, and moderate advantages can be claimed over a GSM/GPRS/EDGE path where a complete network must be deployed. More significant is the next steps, where DO/DV can be introduced with moderate investments. By comparison, a WCDMA deployment implies the deployment of a new radio access network, and more changes in other parts of the network. Both steps combined, the CDMA2000 deployment should provide better infrastructure investment reusability than the complete WCDMA path.

Conclusion for TDMA operators

We view both WCDMA- and CDMA-based evolution paths, illustrated in Figure 11, as feasible for a TDMA operator. High economies-of-scale, more attractive services including roaming and a more attractive long-term terminals market all speak for WCDMA. Against these factors stand the prospects of simpler spectrum management, gradual investments enabled by AMPS/CDMA terminals (for AMPS-intensive operators) and higher investment reusability, which speak in favour of CDMA2000. These factors are summarised in Figure 12.

In addition to these rational arguments, each market has its specific requirements. This, as well as ownership structures, pressure from lobby groups and the actions of the leading TDMA operators will have major impact on the choices made by the remaining TDMA operators.

Whichever option is adopted the operator will have to make sure it has the solid backing of its vendors to provide it with confidence in making this difficult decision.

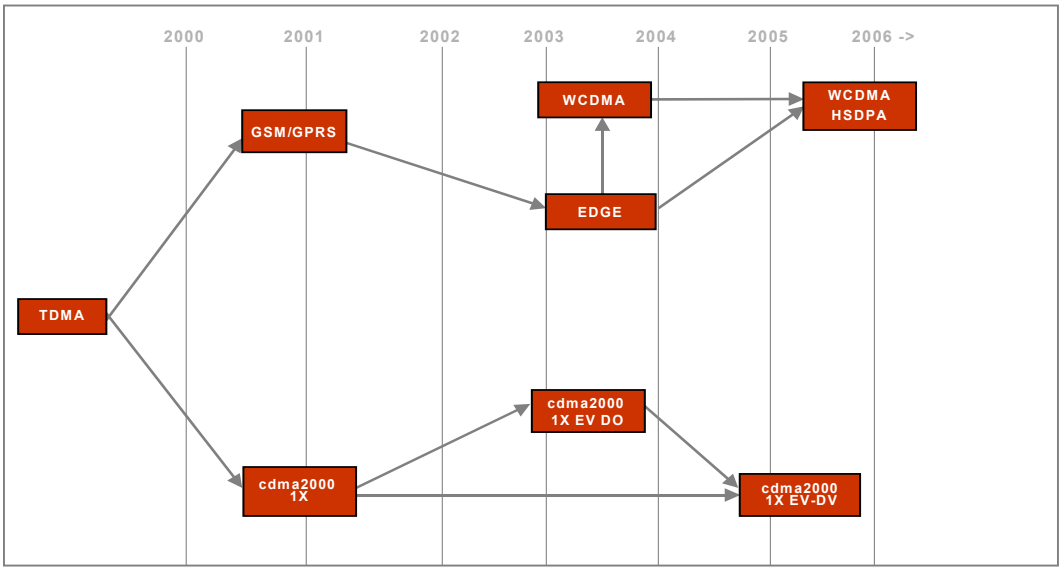

Figure 11 TDMA operator evolution paths – either to GSM/GPRS/EDGE/WCDMA or to CDMA2000

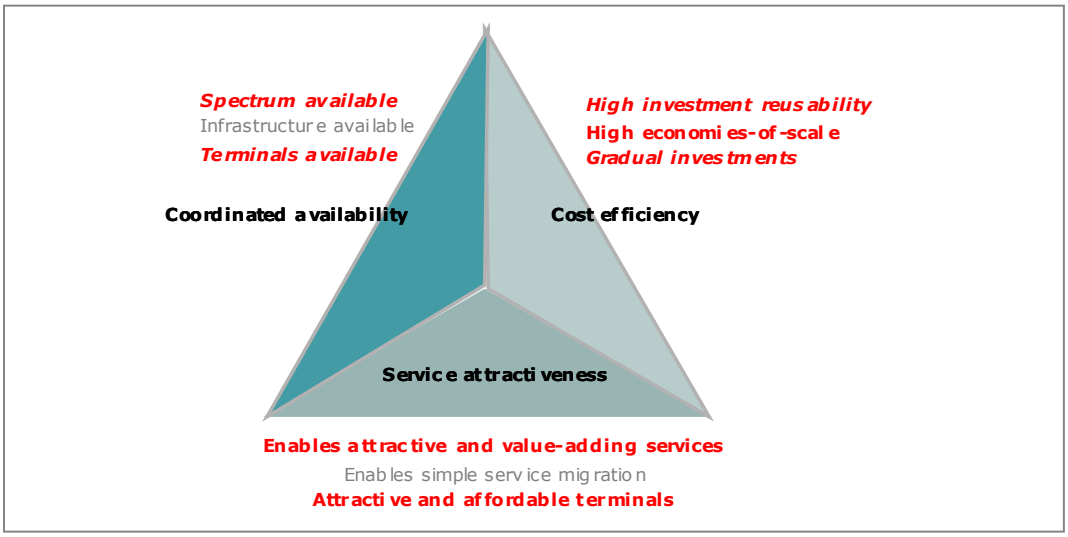

Figure 12. Key decisive factors for TDMA operators when deciding between GSM/EDGE/WCDMA and CDMA2000 evolution paths. Highlighted factors in italic speak for CDMA2000, whereas non-italic highlighted factors speak for WCDMA. (The arguments sometimes apply only to a subset of TDMA operators; please refer to the analysis of each path for the full rationale.)

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