WHITE PAPER

GSM OR CDMA:

The Commercial and Technology Challenges for TDMA Operators

The Shosteck Group

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A C K N O W L E D G E M E N T S

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P R E F A C E

The Shosteck Group

THE SHOSTECK GROUP (formerly Herschel Shosteck Associates, Ltd.) is an international telecommunications consultancy, which analyzes and forecasts wireless markets and technologies. The firm has focused on wireless since 1981 – when the industry was in its embryonic state. Since then, it has expanded to encompass the intersect of wireless and the Internet.

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1 An Overview

1.1 Introduction

This white paper reviews and discusses the options open to TDMA/IS-136 network operators for migrating to third generation (3G) wireless technologies. In particular, it addresses the suitability of **CDMA2000**[*] 1X (formerly called CDMA/IS-95-C, CDMA 1xRTT, or cdma2000 1x), and its future derivatives CDMA 1xEV-DO and CDMA 1xEV-DV, as a 3G alternative.

Central to our analysis are the issues of handset availability, handset cost, and economies of manufacturing scale over the short- to medium-term. In evaluating them, we find that in transitioning from TDMA/IS-136 to 3G, the advantage often attributed to mature technologies may not hold.

The Shosteck Group does *not* endorse one technology over another or one 3G-migration path over another. Rather, we point to and discuss possible challenges that TDMA/IS-136 operators may face in deploying GSM and possible advantages that **cdmaOne**™[†] may offer. Based on these possible advantages, we suggest that TDMA operators may find it worthwhile to evaluate CDMA as a 3G option. Among TDMA operators who do so, some may conclude that GSM remains their preferred choice. This may be especially so for those licensed in 1900 MHz frequencies. Other TDMA operators may conclude that CDMA provides a better choice. This may be especially so for those licensed in 800 MHz frequencies. We intend this white paper to raise core issues concerning the 3G transition. The resolution of those issues, to the extent feasible, must take place in discussions between the network operators and their vendors.

As a first step, we clarify what we mean by 3G. The radio component of advanced technologies varies in terms of at least three characteristics.

1. The RF channel width. This can range from 200 kHz for GSM-GPRS to 5 MHz for UMTS.
2. The RF spectrum allocation. This can vary from deployment on currently assigned spectrum at 800 and 1900 MHz for CDMA2000 1X to deployment on newly allocated spectrum at 1900 and 2100 MHz for UMTS. While seldom discussed, this latter spectrum is also suitable for CDMA2000 1X as well.

[*] CDMA2000 is a trademark of the Telecommunications Industry Association (TIA)

[†] **cdmaOne** is a registered trademark of the CDMA Development Group (CDG)

3. The data rate. Depending on technology, this may range from theoretical rates of 115 kbps to beyond 2 Mbps. Some advanced technologies are called 2.5 G; others are called 3G; others are, or have been, called both.

The International Telecommunication Union (ITU) serves as the arbiter of 3G standards. It does not define 3G in terms of channel width or spectrum allocation, but rather data rates. By ITU definition, the 3G RF interface can deliver data rates of 144 kbps or greater. The ITU recognizes W-CDMA (UMTS) and CDMA2000 1X as meeting this criterion.[1]

Higher data rates will enable end-users to experience richer content than is now available and, in conjunction with packet architecture, to gain instant and low cost access to the Internet. Higher data rates, and especially instant and low cost access to the Internet, will expand future network traffic. As network traffic expands, operator revenues will increase. However, independent of the capability of technologies, operators must recognize the economic-commercial trade-off of network costs versus data rates. The higher the data rates, the greater the network costs. Eventually, every operator must optimize the data rate it offers to end-users in terms of the cost to provide it versus the revenues it generates.

Currently, TDMA/IS-136 operators AT&T and Rogers AT&T have chosen to adopt GSM, from there to progress to GSM-GPRS, then to deploy GSM-GPRS-EDGE, and finally to adopt UMTS (also referred to as W-CDMA). This last step takes for granted that spectrum for UMTS will be available. This currently assumed migration path has evolved rather recently. Other TDMA operators are still deciding which migration path to pursue. A year ago, the assumed migration path for TDMA/IS-136 operators was to deploy TDMA-GPRS, then TDMA-GPRS-EDGE, and afterwards—through an ill-defined process—to adopt UMTS. This earlier migration path is no longer being discussed.

In reviewing the migration paths, we focus on the *commercial issues* with which TDMA/IS-136 operators must deal in choosing a 3G alternative. Five sets of issues stand out. These are:

1. To increase average revenue per user (ARPU).
2. To minimize costs of technology deployment To adopt as simple (and, therefore, as painless) a deployment process as possible.
3. To deploy viable commercial services in a timely manner.
4. To maintain a satisfactory end-user experience throughout this process.

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1. "The Road to IMT-2000," http://www/itu.int/imt/what_is/roadto/index.html. More precisely, the 3G standard specifies 144 kbps in a mobile environment, 384 kbps in a pedestrian environment, and 2 Mbps in a fixed environment.

These latter two are especially important. If operators cannot deploy viable commercial services in a timely manner, they run the risk of losing competitive position. If the network and/or handsets deliver a negative end-user experience, they will not only fail to generate revenue, but will encourage churn as well. We pay little attention to the nuances of technology elegance that alternative technologies may or may not provide. For our purposes, the commercial issues are overriding.

Not to be forgotten is the importance of voice. Using compression techniques and more sophisticated bandwidth management, 3G will eventually enable non-voice applications such as full-motion video and multi-media, all in real time. That said, voice will continue to provide operators with the bulk of their revenues into the foreseeable future. This stems from the “data stimulus effect.” Increased data use does not displace voice traffic but expands it. Even the most enthusiastic supporters of non-voice applications recognize this phenomenon.[2]

1.2 Migration Paths and Time Frames for Deployment

In 10 to 15 years, the current issues of 3G migration will be dimming into historical memory. All of today’s 2G operators will have deployed 3G and, possibly, yet more advanced technologies. The deployment challenges, some not yet fully recognized, will have been successfully surmounted.

Today, the critical issues that operators face center on what next generation technology paths they choose for the immediate- to mid-term future—the next one to five years. For operators who now deploy GSM, **cdmaOne**, or PDC, the one to five year evolutionary paths are clear. They are much less so for operators who deploy TDMA/IS-136.

To review, GSM operators, or more precisely those assigned 900 and/or 1800 MHz spectrum, will evolve first to GSM-GPRS and eventually to UMTS. They may or may not deploy GSM-GPRS-EDGE as an intermediary step. Deploying UMTS will require these operators to use newly allocated and assigned 3G (UMTS) spectrum at 1900 (uplink) and 2100 MHz (downlink) in conjunction with their currently assigned GSM spectrum at 900 and/or 1800 MHz. It will also require multi-mode/multi-band GSM-GPRS-UMTS (or GSM-GPRS-EDGE-UMTS) handsets. Such multi-mode handsets will enable handoff from network to network. This will enable seamless provision of basic GSM services (voice and messaging) throughout the network and provision of UMTS in the heaviest traffic parts. This also enables operators to deploy 3G infrastructure only as demand requires, thus minimizing their investment burdens.

The migration path for GSM operators assigned 1900 MHz spectrum (almost all in the Americas) is less clear. Separate 3G spectrum, suitable for UMTS, has yet to be allocated. Until such spectrum is allocated and cleared, this precludes GSM operators at

2. Ian Allison, “Ericsson on the EDGE: Interview,” *Wapweek*, April 9, 2001.

assigned 1900 MHz spectrum from advancing beyond GPRS and EDGE, if the latter becomes commercially available.

cdmaOne operators, whether assigned frequencies at 800 MHz, 1900 MHz, or both, can evolve to CDMA2000 1X using their current spectrum. This obviates the challenge of finding new spectrum. The evolution to CDMA2000 1X requires channel cards and software upgrades to **cdmaOne** base stations and introduction of CDMA2000 1X handsets. All CDMA2000 1X handsets are backward compatible with legacy **cdmaOne** infrastructure. This obviates the need for multi-mode handsets.

In Japan, PDC operators will construct entirely separate UMTS networks on newly assigned 1900 and 2100 MHz spectrum. Subscribers will access those networks with single-mode/single-band UMTS handsets.

During the next one to five years—or through mid-2006—no operator, regardless of whether they are today GSM, **cdmaOne**, TDMA/IS-136, or PDC, will complete the evolution to 3G. Some may fully deploy 3G infrastructure. However, sans massive handset subsidies, all will still have subscribers who continue to use the 2G network. Some operators will advance substantially in making the transition to 3G. This will be particularly so for those who currently deploy **cdmaOne** and adopt CDMA2000 1X. For those who currently deploy TDMA, the evolutionary path is more complex and less clear.

That said, regardless of whether TDMA/IS-136 operators choose GSM or **cdmaOne** as their migration path, they will have to overcome challenges, which the industry has never before faced. Because of this, both paths will prove more complex, expensive, difficult, and time consuming than many initially imagined. However, as we suggest in our following analysis, for at least some TDMA operators, CDMA may prove the less onerous alternative.

1.3 The Dilemma of TDMA Operators

The greater complexity, expense, difficulty, and time will stem from TDMA/IS-136's becoming an "orphan technology." Orphan technologies are characterized by two limitations.

1. They fill only a short-term market need.
2. They offer no basis for further evolution.[3]

Such orphans may be new technologies with only a limited life cycle. High rate circuit-switched data (HSCSD), which was barely deployed before being abandoned, provides an example. They may be mature technologies at the end of their life cycles. TDMA falls into this category.

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3. The Shosteck Group, *Third Generation Wireless (3G): The Continuing Saga*, Wheaton, Maryland, February 2001, pp. 263-264.

By their inherent nature, orphan technologies are being superceded by more functional and/or lower cost alternatives. For this reason, they provide no more than short-lived advantages for network operators and/or end-users. For manufacturers, this means quickly diminishing production volumes and profits. As manufacturers recognize this, they stop R&D investment. This accelerates the orphan status of the technology. With that, it falls more behind newer and more advanced ones. As it falls behind, it provides fewer and fewer benefits for network operators and/or end-users. Eventually, it is abandoned.

Other examples of orphan technologies include the telegraph (superceded by the telephone), telex (superceded by fax, which, in turn, is being superceded by email), and circuit-switched telephony (being superceded by packet telephony).

Worldwide terminal sales attest to the emerging orphan status of TDMA/IS-136. During 2000, 63 percent of terminals sold were GSM, 13 percent were **cdmaOne**, and nine percent were TDMA.[4] The relatively small volume for TDMA has made it the least attractive for manufacturers. The orphaning of TDMA was sealed by the announcement of AT&T Wireless, made in November 2000, that it was abandoning plans to incorporate GPRS and EDGE into TDMA. Instead, AT&T announced that it will overlay GSM onto its current TDMA network.[5] In concept, this will enable AT&T to deploy GSM-GPRS, GSM-GPRS-EDGE, and, assuming available spectrum, GSM-GPRS-EDGE-UMTS as its migration path to 3G.

AT&T's approach is premised on AT&T's taking advantage of the massive R&D efforts that are being devoted to the GSM transition path (i.e., GSM-GPRS and GSM-GPRS-EDGE) and the expected economies of manufacturing scale of GSM, and eventually of UMTS, over time. *Indeed, this premise of long-term economies of R&D and manufacturing scale is the fundamental rationale underlying the choice of GSM as a 3G-transition path.*[6] It defines the central, albeit unspoken, dilemma that each TDMA operator faces. On the one hand, should the operator choose a 3G path with lower short- to mid-term costs but uncertain long-term costs? Or on the other hand, should the operator choose a 3G path with higher short- to mid-term costs but apparently more certain and seemingly lower long-term costs?

A goal of this paper is to clarify these cost issues. Later, we discuss the economies of manufacturing scale. We explain that by deploying dual-mode TDMA-GSM handsets, TDMA/IS-136 operators will be unable to reap the economies of scale commonly associated with adopting GSM as the path to 3G. We also discuss the trade-off between cost-efficient (and potentially profitable) network design and operation and the provision of high data rates.

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4. "Terminal Sales by Technology, World Market, 1992-2000," *Shosteck E-STATS*, The Shosteck Group, Wheaton Maryland, continuous.
5. "AT&T to Ditch TDMA for GSM-Based Data Migration," *3G Mobile*, November 29, 2000, pp. 1-2.
6. Personal communication, informed industry source, Bellevue, Washington, May 25, 2001.

In adopting GSM, AT&T ended any hope for further development of TDMA/IS-136 and a migration to 3G based on it. This means that all TDMA operators must now choose a new migration alternative. While most industry observers have assumed that this would be GSM, it could be **cdmaOne** as well.

Using GSM as a means of reaching 3G is an appealing concept. However, it requires that TDMA/IS-136 operators deploy what, in effect, will be a completely separate 3G network. This will prove a challenging and expensive proposition. It will be especially challenging to TDMA operators that are assigned to the 800 MHz rather than to the 1900 MHz frequencies. For the 800 MHz operators, the availability of GSM infrastructure is still a promise, although Nokia, Ericsson, Motorola, and Nortel, who have made such promises, are credible vendors. Far more important, and still unspoken, will be the timely delivery of 800 MHz GSM handsets at a reasonable cost. As of this writing (June 2001), both their date of delivery and cost remain unknown.

1.4 The Two Steps of 3G Evolution

Regardless of whether TDMA/IS-136 operators choose GSM or **cdmaOne** as a migration path to 3G, they face the same two transition barriers.

1. The challenge and cost of deploying a separate GSM or CDMA network that would parallel their established TDMA network.
2. The challenge and cost of using that separate network to make the 3G transition.

That said, GSM and **cdmaOne** offer substantially different migration alternatives. We explore these in the chapters that follow, looking especially at the issues of timely deployment and cost.

2 *Defining What 3G May Deliver*

2.1 Introduction

The mobile industry has been cursed by its own hyperbole. Whether driven by exuberance or guile, the press releases of manufacturers and network operators alike have set unrealistic expectations of what 2.5G and 3G can *economically and commercially* deliver, especially over the near term. This press release mantra has centered on 384 kbps or more in a pedestrian and/or mobile environment. Such rates would enable the promised full-motion video and multi-media in real time.

Such data rates have not yet been delivered commercially, where costs are an issue and the limitations of a real world radio frequency (RF) environment are real. They can be delivered within idealized test sites or test networks where a handful of friendly users on dedicated spectrum assures that interference from other network traffic or inconvenient geography is minimal. However, in the commercial world, costs must be considered and RF must be transmitted under the imperfect conditions of frequency congestion, background RF noise, challenging geography, and incomplete network coverage. Under these conditions, commercial delivery of consistent and ubiquitous bandwidth at 384 kbps remains to be proven.

Surprisingly, the first commercial network has achieved data rates close to the theoretical ideal. Korea's SK Telecom (SKT) launched CDMA2000 1X service in October 2000. As of late May 2001, SKT had 180,000 CDMA2000 1X subscribers. The network provides data rates of 120 kbps in an ideal RF environment, but more typically 70–90 kbps.[7]

The experiences in Europe and the expectations in North America are more constrained. In both areas, members of the industry, in particular network operators, are beginning to recognize and acknowledge that while the theoretical throughput, and long-term potential, of new technologies may range from 115 kbps to 384 kbps, the near-term reality will be less. In the case of CDMA2000 1X, Richard Lynch, Executive Vice President and Chief Technology Officer of Verizon Wireless, the largest U.S. wireless operator, anticipates mobile data rates of 30–40 kbps over the near term, notwithstanding a theoretical expectation of 144 kbps.[8] In the case of GSM-GPRS, David Williams, Vice President for Strategic Planning for Cingular, the second largest U.S. wireless operator, anticipates near-term data rates of 20–30 kbps, notwithstanding a theoretical expectation

7. Personal communication, informed industry source, Seoul, May 29, 2001.
8. "U.S. Operators Reveal Their Hands for 3G Buildout," *3G Mobile*, April 4, 2001, p. 1.

of 115 kbps.[9] Some European observers look to GPRS delivering up to 50 kbps[10] although others believe that 20 to 40 kbps will be more likely.[11]

Over the long term, the technologies will mature and the networks will be built. With these, the data rates will increase. However, until that time, the advantage of 3G will center not on high data rates but on its packet switched architecture. As we observed in our introduction, in contrast to circuit switching, packet switching enables instant and low-cost IP access to the Web and the plethora of applications and services available from it. As we discuss at the end of this chapter, regardless of the data rates that technologies may be able to deliver, economic and commercial concerns will drive operators to provide data rates that are less.

John Roth, CEO of Nortel Networks, first advanced the cost benefits of packet architecture in February 1999 at the annual convention of the Cellular Telecommunications and Internet Association (CTIA). There, he announced Nortel's goal of using packet architecture

> "to drive the overall cost of operating a mobile network down by an order of magnitude…from 37 cents today to only four cents within five years."[12]

More than two years later, in May 2001, Conrad Labante, Nortel's Director of Wireless Internet Business Strategy Development, reiterated Mr. Roth's expectations, that packet architecture would reduce the costs of delivering data by a factor of 10. However, he still saw that day as at least five years into the future.[13]

Nokia, a leading proponent of 3G, doesn't "believe that the data issue is data rates," but rather relevant applications and services. In the initial stages of GPRS and EDGE deployment, Nokia sees data rates of 20–30 kbps as enabling "a lot for money making applications." Nokia doubts that video will provide "money making applications in the beginning."[14]

In sum, by focusing on high data rates, network operators may be misdirecting their resources. Into the foreseeable future, the key issues in deploying 2.5 and 3G will more likely center on the cost-benefits of given data rates for provisioning services and applications that subscribers will use and, thereby, generate revenues for network operators. We explore this further at the conclusion of this chapter.

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9. Peggy Albright, "Roll Out of the GPRS Handsets," *Wireless Week*, February 19, 2001, p. 18.
10. "Maximum GPRS Speed Set to Stay at 50 kbit/sec for Foreseeable Future," *Wireless Internet*, March 29, 2001, pp. 1-2/6-7.
11. "TDC Uses Netverk Software to Create Six-Fold Increase in Download Speeds," *Wireless Internet*, March 29, 2001, pp. 3-4.
12. Press release, "Nortel Networks Established Benchmark for Wireless Network Cost Performance…," Nortel Networks, New Orleans, Louisiana, February 9, 1999.
13. Nathan Lynch, "South Korea: the Heart and Seoul of 3G – Part II," *WapWeek*, May 29, 2001.
14. Personal communication, informed source, Nokia Networks, Seattle, Washington, May 11, 2001.

2.2 Factors That Constrain High-Bandwidth Transmissions

An issue of cost-benefits aside, multiple factors limit high-bandwidth transmissions in a real-world environment. Most, but not all, stem from technology immaturity. Some factors may be more relevant to one RF interface than to another. Over time and with sufficient R&D efforts, such factors will be overcome. Until they are overcome, such factors preclude consistently achieving anything near the data rates being claimed.

We briefly discuss three of these factors below—power budgets and battery drain, latency, and bit error rate. These discussions are not exhaustive. Rather, they exemplify the range of challenges that wireless vendors and operators must surmount before high-bandwidth transmissions in real time can become a commercial reality.

2.2.1 Power Budgets and Battery Drain

For GSM, conventional voice is transmitted on a “time slot” at 9.6 kbps. High bandwidth is commonly advertised as up to 384 kbps—40 times more than 9.6 kbps. Regardless of RF technology, such transmissions require greater power budgets, and therefore produce more battery drain. This will pose a problem for all new technologies, albeit less so for CDMA2000 1X and UMTS than for GSM, GPRS, and EDGE.

The transmission power required for all CDMA technologies, including CDMA2000 1X and UMTS (also a CDMA technology), is continuously adjusted to the bits being transmitted. If, at a particular moment, few bits are being transmitted, as in a short message, less power is used. If more bits are being transmitted, as in a video clip, more power is used. This is commonly called a variable data rate. Thus, CDMA2000 1X and UMTS are more efficient, in that they allocate only the RF power needed to deliver the bits being transmitted. Battery drain will vary accordingly. That said, average battery drain will be relatively less than for non-CDMA technologies.

GSM technologies, including GPRS and EDGE, also vary their power output to match the number of bits being transmitted. However, they are less adaptive in how they match power output to bits rates. In concept, they can add or subtract up to eight time slots, depending on the nature of the transmission. Because of this less refined matching of power output to bit rate, the battery drain will generally be higher than for CDMA-based technologies that transmit the same content. This phenomenon is apparently occurring on the GPRS network recently launched by BT Cellnet, where subscribers are complaining about battery drain.[15]

15. “Teething problems for GPRS, as Network Availability is Not up to Scratch,” ZDNet News, April 14, 2001.

2.2.2 Latency

Latency describes the delay of a transmission from the time it enters the network until the time it leaves. Low latency means short delays. High latency means long delays. Latency may occur in the handset or in the network. Latency that occurs in the handset or between the handset and the base station is called access latency. Latency that occurs from the base station through the network is called network latency. Low latency is essential for real-time transmissions. These include live voice conversations (but not voice mail messages, which are time insensitive) and live two-way video (but not entertainment video clips, which also are time insensitive).

Latency is *not* a phenomenon only of mobile networks. It is an outcome of all the networks, terminals, and devices through which transmissions may pass and the bottlenecks (and, therefore, delays) they may encounter. At home, users of broadband Internet connections experience latency as delays in downloading websites during peak traffic hours (often in early evenings and during inclement weather). Such delays are due to overloading bandwidth at the network periphery.

More important are delays due to overloading bandwidth at the network core. A user in New York may download a website that is hosted in Seattle. Depending on traffic loading and transmissions costs at the moment, the download may travel from Seattle to Los Angeles to Denver to Houston to Chicago and finally to New York. It may use fiber networks owned by Qwest, AT&T, and/or Verizon. At each switching point, and in particular at the juncture of each network, it will encounter delay. Each of these delays increases the latency. This means that even if a mobile network is configured to provide low latency, the operator cannot guarantee low latency for end-users who use their mobile devices to access other networks or who use their terminals in a noisy, and thereby latency inducing, RF environment.

2.2.3 Bit Error Rate

Voice is more forgiving of transmission errors or high bit error rates (BER) than is data (also called non-voice content).[16] The reason for this forgiveness comes from the ability of the human brain to reconstruct the missing parts of conversations. If a syllable or even a word is dropped, the brain assumes the missing information from the context of the conversation and reconstructs it. This enables people to communicate through the noise or the break-up of a marginally understandable mobile radio call.

16. Within the telecommunications industry, the term "data" typically refers to the *content* of transmission. Content may be either "voice" or "data" (sometimes called "non-voice"). Within the computing industry, "data" typically refer to the *form* of transmission, whether digital or analog. When we use "data" in the present discussion, we refer to the content being transmitted. In all cases, whether voice or non-voice, such content will be in digital form. See: "Chapter10: The 3G Technologies," *Third Generation Wireless (3G): Why, When and How It Will Happen,* The Shosteck Group, Wheaton Maryland, November 1999, pp. 209-210.

The transmission of data does not provide this reconstruction advantage. If non-voice content is lost, it can only be recovered, if at all, through sophisticated error correction algorithms. Such error corrections add overhead to RF transmissions. This overhead slows the true data rate, or transmission rate, of the desired content. The greater the number of errors, the more error correction required and the slower the true data rate. Thus, in an imperfect RF environment, any RF technology will deliver but a fraction of its theoretical peak data rate. In addition to complaints of excessive battery drain on its GPRS system, BT Cellnet is also experiencing lower than expected throughput on its GPRS system, in some cases as low as 8 kbps.[17] As we observed earlier, as other operators follow BT's lead, slower than expected data rates will be the norm, not the exception.

To one extent or another, each of these issues applies to all transitional and 3G technologies. We present them as considerations, which may be useful for network operators in evaluating their migration alternatives.

2.3 The Cost to Deliver Theoretical Data Rates

Into the foreseeable future, the cost to deliver theoretical data rates will prove economically and commercially unsustainable. To provide anything near ubiquitous and consistent 384 kbps in real time will require enormous investment by operators. Not to be forgotten, *operators must expand RF capacity to provide such data rates for non-voice content without compromising the RF capacity needed to carry conventional voice traffic.* If a network is at capacity, adding data capabilities without expanding network capacity will undermine the quality of service for conventional voice users.[18] If data traffic causes voice service to degrade, it will alienate voice subscribers.

In the case of CDMA2000 1X, the costs of networks capable of carrying high data rates without degrading voice quality have not been published. The UMTS costs have been published as an outcome of the "beauty contests" for 3G licenses. Without shared networks, these would be as much as $400 per population covered, although $200 per population covered might be sufficient.[19] Such costs would be three to five times those needed to provide acceptable voice service. By way of comparison, from 1983 through December 2000, the *cumulative* investment of all U.S. operators (up to seven per market) had reached $89.6 billion.[20] Given a population of 276 million, this equated to $325 per population covered.

17. "Teething Problems for GPRS, as Network Availability Is Not up to Scratch," ZDNet News, April 14, 2001 and David Neal, "Data Transfer Rates of 30 kbit/s Are Just a Pipe Dream for Now, *IT Week*, May 26, 2001.
18. Ian Channing, "Not So Fast!," *Mobile Communications International*, April 2000, p. 30.
19. *Third Generation Wireless (3G): The Continuing Saga*, The Shosteck Group, Wheaton Maryland, February 2001, pp. 133-136.
20. *CTIA's Semi-Annual Wireless Industry Survey*, CTIA, Washington DC, continuous and estimates by The Shosteck Group.

At present, capital expenditures of $200 to $400 per population covered are commercially non-viable. Given the flight of capital from the telecommunications industry, this situation is unlikely to change soon. Thus, into the foreseeable future, mobile operators will invest less in 3G infrastructure than required to deliver 384 kbps on a ubiquitous and consistent basis. This precludes providing the publicized nirvana of full-motion video and multi-media in real time.[21] This means that over the near term, the commercial relevance of ubiquitous 3G must stem from something other than high bandwidth. In most respects, this will focus on the cost perspectives of Nortel and the applications and services perspectives of Nokia. Other vendors may or may not share these perspectives.

2.4 An Alternative to the High Data Rate 3G Business Model

In 10 years and beyond, the general provision of high-bandwidth wireless traffic will plausibly become commercially viable. However, over the next five years, and likely longer, the high costs of the required infrastructure will preclude operators from providing 384 kbps, or anything near it, on a ubiquitous and consistent basis. This will prevent ubiquitous and consistent delivery of full-motion video and multi-media in real time.

The business case for 3G will not come from providing massively high bandwidth. Rather, it will come from providing (1) cost-efficient mixed voice and data traffic and (2) immediate, open, and low cost connectivity to the Internet.

The latter will provide access to infinite sources of infinite applications and services. Most will be available through relatively low bandwidth. The success of NTT DoCoMo's I-Mode points to this potential. Notwithstanding data rates of only 9.6 kbps, I-Mode has been adopted by most of DoCoMo's subscribers. Average revenue per user (ARPU) has increased by up to 30 percent or more.[22]

This is not to say that a data rate of 9.6 kbps will be sufficient. Over time, it will not be. As 3G networks and their 2.5G proxies are launched, they will enable bandwidths greater than 9.6 kbps, albeit at less than the rates promised by industry hyperbole. As we pointed out earlier, operators who have spoken, place these in the range of 20–40 kbps. Into the foreseeable future, this may emerge as an industry benchmark. Data rates greater than this will prove an extra dividend.

At present, SKT is unique among world operators as the only one with meaningful experience in the operation of a commercial 3G network. Based on this experience, SKT is perhaps more aware and more thoughtful than other operators over the trade-off between the provision of commercially feasible services, on the one hand, and high data rates, on the other.

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21. The possible exception may be certain heavy-traffic pico- and micro-cells, likely located in the urban core.

22. *Third Generation Wireless (3G): The Continuing Saga,* pp. 13-26.

As we observed earlier, SKT is now delivering 70–90 kbps to 180,000 commercial CDMA2000 1X subscribers. This is out of an approximate customer base of 12 million. Notwithstanding this technical achievement, SKT understands that economics and not technology will limit the data rates that its customers eventually experience. SKT observes that with only 180,000 3G customers, it does not yet have sufficient traffic to experience problems with loading or deployment. However, SKT foresees an eventual trade-off in voice versus data capacity. For this reason, SKT foresees economical data rates of 30–50 kbps—what it will be able to deliver cost-effectively for every customer while maintaining acceptable quality of service. SKT believes that this will be the case whether on its CDMA2000 1X network or on a UMTS network. SKT does not see cost differences between the infrastructure for the two 3G technologies. SKT's 3G problem is not technical but commercial "converting 3G services to money." To do so, it is striving to provide "reasonably good" quality of voice and data services in order to "satisfy…customers reasonably not absolutely." SKT perceives that attempts to provide high data rates and absolute customer satisfaction are dangers. To do so, it would spend too much money, thus reducing its chance for profits.[23]

In sum, SKT sees the central 3G issue not as high data rates but as profitable data rates. SKT believes that a focus on data rates, and the technologies that may deliver them, detracts from what for SKT is their basic issue—to generate profits through providing 3G services.

To the extent that other operators recognize and adopt this point of view, they may shift their long-term perspective. Rather than focusing on a distant and commercially uncertain goal of data rates of 144 kbps and beyond, they may refocus on an immediate and commercially profitable goal of data rates at 30–50 kbps. To the extent that this refocus takes place, current TDMA/IS-136 operators may pay greater attention to **cdmaOne** as a transition to 3G.

23. Personal communication, informed source, Seoul, May 29, 2001.

3 A Review of Conventional 3G Migration Paths

3.1 Introduction

To understand the 3G migration options open to TDMA/IS-136 operators, we begin by examining the currently conceived migration paths for the major 2G technologies: GSM, **cdmaOne**, and TDMA/IS-136. This chapter reviews and expands parts of our earlier discussions. Following this review, we examine the possibility of CDMA2000 1X as a migration alternative for TDMA. We do not review PDC, a 2G technology that is unique to Japan and which will be superceded by UMTS and CDMA2000 1X.

One assumed migration for TDMA/IS-136 posits an initial transition to GSM, subsequent adoption of GPRS and EDGE and final deployment of UMTS, the generally accepted 3G standard for GSM.

Examining this assumed path uncovers what may be possible barriers to TDMA operators who deploy GSM. Because of these, some TDMA operators may find it useful to reevaluate the full cost benefits of the GSM option and to consider CDMA2000 1X (also called CDMA 1xRTT) as an alternative for enabling 3G services. This will be particularly so for operators who are assigned to 800 MHz spectrum.[24]

3.2 The Migration Path for Current GSM Operators[25]

The migration path for current GSM operators envisions GPRS and EDGE enhancements to GSM technology followed by the transition to UMTS on new spectrum. The deployment of GPRS and EDGE may take place on 900, 1800, and/or 1900 MHz spectrum, on which GSM is, at present, deployed. The migration assumes the availability of multi-mode/multi-band handsets that will enable seamless interoperability between GSM (including GPRS-EDGE) and UMTS, which, into the foreseeable future, will be deployed on 1900 and 2100 MHz spectrum.

24. “The radio spectrum is that portion of the electromagnet energy spectrum used by radio waves. ‘Radio services’ are categories of radio use. Setting aside frequency ranges, or bands, in the radio spectrum to or radio services is a government function called spectrum allocation or frequency allocation.” From Bennett Z. Kobb, *Spectrum Guide,* New Signals Press, Falls Church, Virginia, 1994, p. 8. In this white paper, we use the terms “spectrum” and “frequency” interchangeably.

25. The Shosteck Group, *Third Generation Wireless (3G): Why, When, and How It Will Happ*en, Wheaton Maryland, November 1999, pp. 194-205.

3.2.1 General Packet Radio Service

General Packet Radio Service (GPRS) is considered the first step in the 3G transition. GPRS enhances the GSM *network* by overlaying packet architecture onto the current circuit switched architecture. It enables GSM operators to gain experience with operating packet networks, billing for packet traffic, and delivering packet-based IP applications in what will be a mixed circuit switched-packet environment. In theory, GPRS enables mobile networks to connect to the Internet at speeds of up to 115 kbps. As we observed in our previous chapter, the likely reality will be rates of 10–40 kbps, although 50 kbps may be possible. As we observed in our previous chapter, BT is now experiencing data rates of only 8 kbps. This, however, should increase as the technology matures.

The cost to deploy GPRS is but a fraction of the cost to deploy UMTS. In concept, GSM operators will be able to incorporate GPRS infrastructure into future UMTS systems. This will mitigate the risk of GPRS becoming an orphaned technology and a stranded investment. In effect, this makes GPRS infrastructure (albeit not terminals) appear "free" to GSM operators who are planning the 3G transition. GPRS requires a dual-mode GSM-GPRS terminal. Once economies of manufacturing scale are reached, the earlier classes of GSM-GPRS terminals will be only marginally more expensive than conventional GSM terminals.[26]

3.2.2 Enhanced Data [Rate] for Global Evolution

Enhanced Data [Rate] for Global Evolution (EDGE) is being positioned as a complement to GPRS. EDGE would enhance the *air interface* to the GSM Network. In theory, EDGE integrated with GPRS would enable data rates as high as 384 kbps. In the TDMA/IS-136 world, EDGE would likely be deployed as an integral part of a new GSM network. For this reason, deploying a "greenfield" GSM-EDGE network would, in concept, be simpler than integrating EDGE into an established GSM network.

However, deploying EDGE would require more than a software upgrade. EDGE has different modulation characteristics from either TDMA or GSM. Because of this, GSM-EDGE may require changes and/or additions to the hardware sub-systems of cell sites. These could include amplifiers, combiners, and isolators. EDGE may also require changes to established reuse patterns. This would imply changes to base station antennas. Of particular importance, EDGE has a 4–7 dB weaker link budget than GSM.

26. GPRS terminals are defined in terms of "classes." Each class specifies a permutation of up-link and downlink time-slots, which the terminal aggregates to provide higher data rates. The GPRS standard specifies 29 different classes, although this number will not be manufactured. The earlier classes of GPRS terminals will specify lower data rates and, once produced in volume, will likely cost little more than GSM handsets. The later classes will specify higher data rates, which will require more components. These will likely cost more noticeably more than GSM handsets.

Compensating for this would require additional base stations.[27] For such reasons, the implementation of EDGE may be more complex than some may have initially envisioned.

EDGE would use the same frequencies as GSM-GPRS and would require a tri-mode GSM-GPRS-EDGE handset. Some observers point to the engineering challenge of imposing a packet architecture onto aggregated GSM time slots. The extent of this challenge is suggested by the delayed deliveries of commercial GPRS handsets and their so far limited data throughput. Not inconsistent with this observation, no vendor has yet demonstrated a prototype EDGE handset. For these reasons, it remains uncertain of how soon, if at all, EDGE handsets would become commercially available and if they become available what data rates they would deliver.[28] There is the further issue of how much GSM-GPRS-EDGE handsets would cost.

Given the above, even assuming that EDGE handsets become commercially available, some GSM operators will not adopt EDGE, but will migrate from GSM or GPRS directly to UMTS.

3.2.3 Universal Mobile Telephone Service

Universal Mobile Telephone Service (UMTS) is the accepted 3G standard for GSM operators. UMTS requires paired 5 MHz RF channels, four times as wide as the paired 1.25 MHz channels required for CDMA2000. For this reason, UMTS is sometimes referred to as “wideband CDMA” (W-CDMA). By migrating to UMTS, operators will gain access to additional spectrum as well as the greater capacity and expanded functionality of the new technology. UMTS incorporates a more efficient variable vocoder (codec). In common with CDMA2000 1X, this vocoder will increase the voice capacity of a given amount of spectrum. As we have already noted, outside of the Americas, UMTS is being deployed on the 1900 MHz (uplink) and 2100 MHz (downlink) frequencies. Because of this, some operators, primarily those in the Americas who now use the 1900 MHz frequencies for PCS, would be unable to migrate to UMTS.[29] Allocation of other frequencies for UMTS may or may not be possible. The well-publicized failures of U.S. operators to acquire frequencies at 700 MHz (occupied by TV broadcasters), 1700 MHz (occupied by the military), or 2500–2600 MHz (occupied by educational broadcasters) provide examples.

With the sole exception of Japan (which is constructing stand-alone UMTS networks), UMTS operators will use multi-mode and multi-band terminals. Such terminals will enable seamless handoff between what will be fully deployed GSM-GPRS (or GSM-GPRS-EDGE) networks and partially deployed UMTS networks. Seamless handoff will

27. “EDGE400 Compensates EDGE’s 4-7dB Weaker Link Budget,” Slide presentation, (GSM400General.PTT/ver 2.0 3.1.2000, Jla), Nokia, Helsinki, 1999.

28. “Handsets Hold the Key to Survival of Edge,” *3G Mobile*, December 12, 2000, pp. 1-2.

29. Only part of the allocated PCS frequencies overlap the allocated UMTS frequencies. Depending on frequency assignment, some PCS operators may be able to deploy UMTS at 1900 MHz and others not.

enable operators to buildout UMTS networks as the technology matures and as demand evolves, much as 800 MHz operators in North and South America built out digital networks as extensions to their analog networks during the mid- to late-1990s.

In sum, the transition to UMTS will enable the advantage of a gradual infrastructure investment closely tailored to demand. However, it will introduce the disadvantage of complex and expensive terminals.

3.3 The Migration Path for TDMA/IS-136 Operators

Originally, the migration from TDMA/IS-136 to 3G was to parallel that of GSM to 3G. TDMA operators were to have overlaid packet based GPRS onto their TDMA infrastructure. Following this, they were to have introduced an EDGE RF Interface. However, with AT&T's adoption of GSM, that migration path changed. Currently, it is assumed that TDMA operators will first deploy a GSM network on to their currently assigned 800 and/or 1900 MHz spectrum. This will overlay or parallel their established TDMA network. Following, they will take the path of GSM operators and migrate their GSM networks to GPRS, possibly to EDGE, and finally to UMTS. In theory, this change in migration path will enable TDMA operators to benefit from the R&D advances and economies of scale enjoyed by the GSM world.

In concept, this approach makes sense. However, it presents at least four implementation challenges. All four apply to TDMA/IS-136 operators who occupy the 800 MHz frequencies. Two apply to TDMA operators who occupy the 1900 MHz frequencies.

1. GSM equipment is, at present, available only for the 900, 1800, and 1900 MHz frequencies. Neither infrastructure nor terminals are yet available for the 800 MHz frequencies on which major TDMA/IS-136 operators have deployed. Nokia, Ericsson, Motorola, and Nortel have promised GSM 800 infrastructure. However, they have yet to produce it. This means that TDMA operators assigned to the 800 MHz spectrum cannot begin their 3G migration until vendors deliver GSM 800 infrastructure and, more importantly, GSM 800 terminals. In the U.S., this challenge would most affect Cingular, which of the TDMA operators holds the most 800 MHz spectrum. In Latin America, it will affect virtually all TDMA operators.
2. Because of cost and complexity, manufacturers are unlikely to produce AMPS-TDMA-GSM terminals. For example, the Siemens S47, due to be launched in the U.S. during the fourth quarter of 2001, will offer multi-band and dual-mode TDMA-GSM capabilities. Because of costs, it does not offer analog AMPS capability.[30] Siemens has no plans to produce AMPS-TDMA-GSM

30. Press release, "Siemens Challenges U.S. Mobile Phone Market with GSM/TDMA Handset to Capitalize on Carriers' Interest in Globally Dominant GSM Standard," Siemens AG, Las Vegas, March 21, 2001.

phones.[31] However, many 800 MHz TDMA/IS-136 operators have not extended their TDMA/IS-136 networks into rural areas to provide the same coverage as their analog networks. As an example, as of year-end 2000, Canada's Rogers AT&T Wireless reported analog coverage for 93 percent of Canada's population, but digital coverage for only 83 percent.[32] More importantly, in urban areas, the digital coverage of AMPS-TDMA networks may be incomplete. This is due to the greater attenuation of discernible voice conversations, which is characteristic of GSM and TDMA/IS-136. In such digital "holes," whether rural or urban, as the TDMA call degrades, subscribers may hand off from TDMA to AMPS. Without analog capabilities, GSM-TDMA phones will preclude such hand-off. As a consequence, 800 MHz TDMA operators may have to deploy more dense (and, therefore, more expensive) GSM cell coverage than initially anticipated. Without such deployment, they may risk providing their new GSM subscribers with inferior service. Siemens acknowledges this challenge. However, Siemens foresees that TDMA operators will quickly build out GSM systems to cover such holes.[33] This coverage issue does not arise with **cdmaOne**. The CDMA RF link was designed to provide coverage equal to or greater than that of AMPS. Field tests have confirmed the design.[34]

3. There is no current way to transfer the rich portfolio of GSM applications and services to a TDMA/IS-136 network. Thus, even with multi-mode GSM-TDMA phones, GSM subscribers will be unable to use their GSM services when they roam onto TDMA networks. Vendors and operators are exploring means of overcoming this challenge, under the acronym of GAIT. However, the question remains of if and when the necessary GAIT infrastructure and, especially, the GAIT handsets will be delivered. We discuss this further in our next chapter.
4. In most countries of North and South America, where TDMA/IS-136 is primarily deployed, the lower part of the 1900 MHz spectrum, which elsewhere is allocated to UMTS, is being used or is reserved for Personal Communications Services (PCS). This means that no spectrum is available for TDMA operators, whether using 800 or 1900 MHz, which would enable them to migrate beyond GSM-GPRS-EDGE to UMTS. Brazil is an exception. There, ANATEL, Brazil's regulatory body has allocated PCS to the 1800 MHz GSM frequencies. While ANATEL has made no formal decision on 3G, its allocation of PCS services to 1800 MHz has left the 1900 and 2100 MHz frequencies open for UMTS.

AT&T, which precipitated the move of TDMA/IS-136 operators toward GSM, may be a special case. Unlike Cingular, the other major TDMA operator in the U.S., AT&T has amassed a disproportionate amount of 1900 MHz spectrum in the 12 largest

31. Personal communication, Martin Fichter, Director of Products Marketing, U.S., Siemens, San Diego, California, April 19, 2001.
32. *2000 Annual Report 2000*, Rogers-AT&T Wireless, Toronto, 2001, p. 1.
33. Personal communication, Martin Fichter, Director of Products Marketing U.S., Siemens, San Diego, California, April 19, 2001.
34. Personal communication, Dr. Charles Wheatley, Senior Vice President – Technology, QUALCOMM Inc., San Diego, California, May 25, 2001.

metropolitan areas.[35] AT&T holds 1900 MHz licenses in 9 of these 12 largest markets.[36] Cingular holds 1900 MHz licenses in only four of them.[37] Thus, in adopting GSM as its migration path to 3G, AT&T may be responding to what it recognizes as a competitive advantage, one which Cingular, a major competitor, cannot match.

In sum, the concept of adopting GSM as the 3G migration path for TDMA/IS-136 is clear. However, in practice, there are barriers to doing so. For 800 MHz TDMA operators, there is the uncertain availability of GSM 800 equipment, in particular handsets, and the potential need for an unexpectedly dense GSM network. For both 800 and 1900 MHz TDMA operators, there is the potential inability of subscribers to use their GSM services when roaming on to TDMA networks. In addition, there is the uncertain future availability of spectrum on which UMTS can be deployed.

Not to be overlooked are the issues of handset costs. Dual-mode GSM-TDMA handsets will be inherently expensive. They will be useful for only a niche market. As such, they will not benefit from the economies of scale, which, in general, will be enjoyed by the GSM community. We discuss these economies in our next chapter.

3.4 The Migration Path for cdmaOne Operators

The initial migration path for **cdmaOne** operators extends from the current **cdmaOne** (also called CDMA/IS-95 or CDMA/IS-95-A), optionally to CDMA/IS-95-B (deployed only in Japan, Korea, and recently Peru), and then to CDMA/IS-95-C or CDMA 1xRTT (One Times Radio Transmission Technology). CDMA 1xRTT is frequently abbreviated to CDMA2000 1X or sometimes CDMA2000 1x.

The next evolutionary step is to CDMA2000 1x EV-DO (Evolution-Data Only). While the timing of its deployment is not yet firm, Sprint anticipates its commercial availability in early 2003. Sprint is cautious in approaching EV-DO, wishing to observe how the data market may unfold before making a commitment.[38] Others anticipate that EV-DO will become commercially available in late 2002. CDMA2000 1x EV-DV (Evolution-Data and Voice) lies further in the future. During the first quarter of 2001, Motorola demonstrated the technology and together with Nokia, Philips Semiconductors, and Texas Instruments proposed a standard. At that time, the group anticipated that the standard would be set in May 2001.[39] The end of year 2001 now appears more likely.

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35. These include Atlanta, Baltimore, Boston, Chicago, Dallas, Detroit, Houston, Los Angeles, New York, Philadelphia, San Francisco, and Washington DC.
36. Personal communication, informed source, AT&T Wireless, Seattle, Washington, May 31, 2001.
37. Personal communication, Jeff Cannon, Director of Investor Relations, Cingular, Atlanta, Georgia, May 31, 2001.
38. Personal communication, Oliver Valente, Chief Technology Officer, Sprint PCS, Kansas City, April 24, 2001.
39. Press release, “Motorola Successfully Demonstrates Industry-First CDMA 1xEV-DV Solution in Lab,” Motorola, Inc., Arlington Heights, Illinois, March 19, 2001 and “Motorola Transmits Live Video in CDMA 1xEV-DV Test,” *RCR Wireless News*, March 26, 2001, p. 33.

3.4.1 cdmaOne/IS-95-A

cdmaOne/IS-95-A supports circuit-switched voice and circuit- or packet-switched data at speeds of up to 14.4 kbps. Due to the early focus of vendors and operators on voice, **cdmaOne**/IS-95-A historically has been used exclusively for circuit-switched voice and recently for a small amount of circuit-switched data.

3.4.2 cdmaOne/IS-95-B

cdmaOne/IS-95-B supports circuit-switched voice and packet-switched data. KDDI in Japan and SK Telecom in Korea have deployed it since 1999. It provides theoretical data rates of up to 115 kbps, with generally experienced rates of 64 kbps. **cdmaOne**/ IS-95-B is now being superceded by the higher capacity and faster CDMA2000 1X and is unlikely to be deployed elsewhere.

3.4.3 CDMA2000 1X

CDMA2000 1X was historically called phase one of the 3G-migration for **cdmaOne**. As we observed in Chapter One, the ITU considers it to be 3G. It supports circuit-switched voice and packet-switched data on the same RF channel. Theoretically, CDMA2000 1X, Release A, enables data rates of up to 307 kbps or above, depending on RF environment. The former is a 10-fold increase over the 14.4 kbps provided by **cdmaOne** and complies with the accepted performance standard for 3G.

In October 2000, Korea's SK Telecom (SKT), using Samsung equipment, launched the world's first commercial CDMA2000 1X service on its currently occupied 800 MHz spectrum. At that time, it announced plans to cover all urban regions of the country during the second quarter of 2002.[40] In May 2001, Korea's LG Telecom (LGT) and Korea Telecom Freetel (KTF) launched commercial CDMA2000 1X on their currently occupied spectrum. At that time, LGT stated that it would cover the entire country by year-end.[41] In the U.S., Verizon and Sprint PCS will deploy CDMA2000 1X by year-end 2001.[42]

The Korean launches illustrate both the flexibility and full commercial availability of CDMA2000 1X. SKT and KTF have received 3G licenses to deploy UMTS on 1900 and 2100 MHz spectrum. Nonetheless, pending commercial delivery and testing of UMTS infrastructure and handsets, they are first deploying CDMA2000 1X on their current spectrum.

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40. Hung Song and John S. Csapo, *3G in Korea*, CDG Digevent Series, Samsung, Seoul, April 17, 2001.
41. Nathan Lynch, "South Korea Delivers on 2.5G Promise," *WapWeek*, May 3, 2001.
42. Dan Meyer, "Sprint Says It Has Ample Spectrum for 3G Services," *RCR Wireless News*, March 26, 2001, p. 34.

3.4.4 CDMA2000 1x EV-DO

CDMA2000 1x EV-DO supports packet-switched voice and packet-switched high-speed data on separate RF channels. The voice channel facilitates the low latency necessary for transmitting two-way conversations. The data channel enables the flexible routing and low-cost transmission advantages of a packet network. CDMA2000 1x EV-DO provides theoretical data speeds of up to 2.4 Mbps. In concept, using separate channels for voice and data requires more bandwidth than using a combined channel. In practice, the spectrum disadvantage diminishes as data traffic increases. This will be especially so for operators with larger spectrum assignments and large data throughput.

Of particular value—and in some cases not fully recognized—the migration of **cdmaOne** to CDMA2000 1X and beyond provides a more flexible use of spectrum compared to the migrations from GSM to UMTS and TDMA/IS-136 through GSM to UMTS. Under present concepts, GSM will not be available for the 1900 and 2100 MHz frequencies allocated to UMTS. UMTS will not be available for the 800, 900, 1800, and 1900 MHz frequencies allocated to GSM. However, operators can deploy CDMA2000 1x EV-DO (and eventually EV-DV) either on newly available 1900 and 2100 MHz spectrum and/or on currently assigned 800 and/or 1900 MHz spectrum.[43] As we observed earlier, SKT, LGT, and KTF in Korea have deployed CDMA2000 1X on current spectrum. The Japanese operator KDDI intends to deploy CDMA2000 1X on newly available spectrum. Most operators will deploy CDMA2000 1X on current spectrum.

This flexible use of spectrum is an advantage of CDMA2000 1X. By enabling operators to use their current spectrum, CDMA2000 1X can save them the overt costs of bidding for new 3G spectrum or, in the case of “beauty contests,” the covert costs of petitioning for it. The latter can be considerable, especially when they include onerous conditions for network construction. Sweden, for example, did not charge for 3G licenses. However, it did require each license recipient to spend what would have been $3 billion or more for constructing *full* nationwide networks within *two years* of the license award.[44] (The regulator has since eased this burden by allowing the license recipients to share up to 70 percent of the 3G infrastructure.)

Operators who deploy CDMA2000 1X on currently assigned spectrum do not gain the added capacity that new spectrum provides. However, this disadvantage is to some extent overcome by the more efficient coding algorithm, which CDMA2000 1X deploys. This algorithm doubles the theoretical capacity of **cdmaOne**, although in practice the capacity gain without voice degradation will be closer to 50 percent.[45] EDGE and UMTS will also deploy a more efficient coding algorithm and realize the associated capacity gains. Because GPRS is a network architecture, not an RF interface, it cannot provide capacity gains.

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43. In the unique case of Korea, currently allocated spectrum is at 1700 MHz.

44. Almar Latour, “Sweden Shocks Telia by Rejecting Its Bid for New Wireless Licenses,” *The Wall Street Journal*, December 18, 2000.

45. Personal communication, informed source, Seoul, Korea, May 29, 2001.

3.5 CDMA2000 1X as an Alternative for TDMA/IS-136 Operators

Our preceding discussion has briefly compared the currently assumed 3G migration paths for TDMA/IS-136 and **cdmaOne**. It uncovered four potential barriers for TDMA operators who may adopt GSM.

1. The uncertain availability of GSM 800 infrastructure and, especially, TDMA-GSM terminals.
2. The uncertainty of whether TDMA-GSM terminals will enable access to GSM applications and services on TDMA networks.
3. The possible need to deploy a denser GSM network than initially envisioned.
4. The uncertain availability of spectrum at 1900 and 2100 MHz that would enable migration to UMTS.

TDMA/IS-136 operators who occupy the 800 MHz frequencies will face all four barriers.

For TDMA/IS-136 operators who occupy the 1900 MHz frequencies, GSM infrastructure is available and Siemens, at least, is promising TDMA-GSM terminals by year-end. These operators have deployed networks to provide acceptable digital coverage. However, in common with TDMA 800 operators, even when TDMA-GSM terminals become available, it is uncertain whether they will enable subscribers to access GSM applications and services on TDMA networks. Likewise, TDMA 800 operators face the uncertain availability of UMTS spectrum.

By enabling the 3G transition on currently occupied spectrum, whether at 800 or 1900 MHz, CDMA2000 1X overcomes these uncertainties. CDMA2000 1X infrastructure and terminals are available for 800 and 1900 MHz frequencies. All CDMA2000 1X terminals for 800 MHz have an analog mode, thereby assuring coverage of non-digital network holes. Operators already hold their spectrum. Finally, the 50 percent or greater efficiency of CDMA2000 1X and its derivatives provides capacity for higher bandwidth applications as well as more voice.

These are meaningful advantages. For these reasons, TDMA/IS-136 operators may find it useful to reevaluate the full cost-benefits of GSM versus **cdmaOne** and to consider **cdmaOne** and its derivatives for enabling 3G services.

Our following chapter compares the GSM and **cdmaOne** alternatives in further detail.

4 Comparing the Migration Paths

4.1 Introduction

In our previous chapter, we described four potential barriers and the ensuing uncertainties that currently face TDMA/IS-136 operators who may choose GSM as a migration path to 3G. We consider two of these especially important.

1. The uncertainty regarding when vendors will develop and deliver 800 MHz GSM infrastructure—in particular 800 MHz GSM handsets. This will affect TDMA operators assigned 800 MHz spectrum.
2. The uncertainty regarding when and at what frequency(ies) UMTS spectrum may eventually become available. This will affect TDMA operators assigned both 1900 and/or 800 MHz spectrum.

In this chapter, we examine further the time that may be needed to develop and deploy infrastructure and handsets for GSM 800. We introduce the sometimes overlooked issue of the backward compatibility of **cdmaOne** base stations with legacy TDMA/IS-136 switches and how that may impact the cost of the 3G transition. Finally, we discuss plausible handset costs.

In some cases, we find apparent advantage for **cdmaOne**. In other cases, we find apparent advantage for GSM. Overall, we maintain the conclusion of our previous chapter, that the uncertainties of the transition warrant TDMA operators reviewing CDMA as an alternative path to 3G

4.2 The Time Required to Develop and Deploy Infrastructure

In February 2000, Nokia announced that it would begin “system deliveries…[of GSM technologies at 800 MHz] during the second half of [2001].”[46] Similar announcements from Ericsson, Motorola, and Nortel followed. This new GSM alternative expanded the migration options for TDMA/IS-136 operators using the 800 MHz frequencies.

However, the deployment of GSM 800 faces challenges. All vendors must decide how to allocate their finite resources. The wave of recent staff reductions has not eased this decision. This raises two questions.

1. Can vendors deliver GSM 800 infrastructure in a timely manner?

46. Press release, “Nokia Expands GSM Success with GSM 800 to Secure Solid Evolution to 3G,” Nokia, New York, February 6, 2001.

2. More important, can vendors effectively overlay and integrate GSM infrastructure onto established TDMA/IS-136 networks in a timely manner?

These are not trivial questions. If vendors fail to deliver and integrate GSM 800 infrastructure in a timely manner, the operators left waiting lose competitive position to their **cdmaOne**- and GSM-based rivals.

4.2.1 Delivering the Infrastructure

Nokia points out, correctly, that the GSM standard is exceptionally rigorous. Nokia characterizes "down banding" from 900 to 800 MHz as "fairly trivial." However, Nokia cautions that subsequent system testing takes time. As of May 2000, Nokia anticipated that it would deliver GSM 800 base stations during the fourth quarter of 2001. This is not inconsistent with its original announced date of deployment.

Given that Nokia announced GSM 800 only in February 2001, this timeframe may seem optimistic. However, while Nokia will not divulge the timing of its R&D cycles, it acknowledged that it initiated the GSM 800 program during 1999 and that it was in a "fairly major stage" of development by the February announcement.[47] Given this, Nokia's target of a fourth quarter infrastructure delivery is not unrealistic.

Ericsson's perspectives are not dissimilar from those of Nokia. Ericsson points out that a great deal of R&D has already been invested in defining EDGE for 800 MHz TDMA/IS-136. Most of that R&D is applicable to GSM 800. As of May 2000, Ericsson, in common with Nokia, anticipated delivering initial volumes of GSM 800 infrastructure during the fourth quarter of 2001 and larger volumes during the first quarter of 2002.[48]

Other industry sources have corroborated these initial deployment dates.[49] On the basis of these reports, it appears that Nokia and Ericsson, at least, will be shipping GSM 800 infrastructure by the end of 2001.

4.2.2 Deploying the Infrastructure

However, as we observed earlier, shipping GSM 800 infrastructure in a timely manner resolves only half of the infrastructure challenge. The remaining half centers on successfully overlaying that infrastructure onto established TDMA/IS-136 networks.

This may take longer than vendors foresee. The reason would center on the unique complexity of RF engineering in the 800 MHz spectrum. In contrast to mobile spectrum allocated to other frequencies (450, 900, 1500, 1700, 1800, and 1900 MHz), the 800 MHz spectrum in North and South America differs in two regards.

47. Personal communication, informed source, Nokia Inc., May 11, 2001.
48. Personal communication, informed source, Ericsson Inc., May 1, 2001.
49. Personal communication, informed industry source, May 25, 2001

1. It is on average more crowded.
2. Together with the 1900 MHz frequencies, it is uniquely the host to multiple RF technologies.

Combined, these two factors pose considerable challenges to deploying any overlay technology, but especially GSM.

The crowding of the 800 MHz spectrum stems from differences in spectrum allocation among countries and services. In the U.S., and most countries of North and South America, the allocation for 800 MHz mobile service is relatively narrow (2×25 MHz). In comparison, the European allocation for mobile services at 900 MHz provides more than half again as much spectrum (2×39 MHz). The PCS allocation at 1900 MHz provides more than twice as much (2×60 MHz).

The crowding at 800 MHz increases the RF engineering challenges of introducing a new technology to supplement or replace TDMA/IS-136. This would hold for either GSM or **cdmaOne**. To make room for the new technology, the cellular reuse structure of the TDMA network must be disassembled while that of the new technology must be put in place. The challenge would be greatest during the initial deployment. Due to issues of interference and required "guard bands," CDMA would need an initial 1.8 MHz while GSM would need an initial 2.5 MHz.[50] In theory, CDMA's need for less spectrum would make its initial deployment less difficult.

The engineering difficulties of such a deployment translate directly into a marketing challenge. By removing TDMA/IS-136 channels to support a new RF technology, operators run the risk of degrading service. *Degraded service will dissatisfy customers and risk stimulating churn.*

Depending on the bandwidth an operator has available, the initial spectrum needed to deploy **cdmaOne** or GSM may or may not be important.

The issue of multiple RF technologies at 800 MHz may prove as challenging as the issue of crowded spectrum and possibly more so. With the exception of systems at 1900 MHz, GSM has always been exclusively deployed on dedicated spectrum at 900 and 1800 MHz. No other RF technologies co-share the spectrum—and, thereby, generate the potential of cross-technology interference. GSM engineers who work in the 900 and 1800 MHz frequencies have ample experience in dealing with interference among adjacent GSM channels. They have no experience in dealing with interference from adjacent TDMA/IS-136 and/or **cdmaOne**.

50. To deploy the first CDMA2000 1x channel would require clearing 1.79–1.25 MHz for the RF carrier plus two 270 kHz guard bands. To deploy the first GSM channel would require clearing 2.50 MHz–200 kHz for the RF carriers × 3 (for 3 sectors per cell site) × 4 (for a 4 times cell reuse pattern) plus two 50 kHz guard bands. In theory, a TDMA/IS-136 operator could deploy a first GSM channel on 700 kHz by using only a single 200 kHz RF channel for each of three cell sectors, plus two 50 kHz guard bands. However, this deployment would not provide sufficient useable GSM bandwidth to be commercially relevant.

An argument can be made that GSM, TDMA/IS-136, and **cdmaOne** occupy the same spectrum at 1900 MHz. Because of this, GSM engineers have experience in deploying GSM in a TDMA and CDMA world.[51] Up to a point, this argument is valid. However, as we observed earlier, less spectrum is available at 800 MHz than at 1900 MHz. Because of this, the GSM experience at 1900 MHz has not dealt with the frequency congestion common to 800 MHz. In addition, the specialized mobile radio (SMR) bands are adjacent to the 800 MHz mobile frequencies in the U.S. and Canada and in some cases elsewhere in the Americas. These introduce the further challenge of dealing with interference from the iDEN technology deployed on those bands. Nor should operators overlook the continuing prevalence of 800 MHz AMPS and its potential for interference.

The deployment of TDMA/IS-54 (the predecessor of IS-136) serves as an example of initial promise versus eventual reality. At the time of TDMA's introduction, operators were told that its deployment would require only replacing a 30 kHz AMPS radio channel with a 30 kHz TDMA radio channel at the base station. The reality proved different. RF engineers discovered that useful TDMA signals attenuate more rapidly than AMPS signals. This phenomenon required a time consuming re-balancing of the networks as TDMA was introduced. In addition, TDMA experienced adjacent channel interference with AMPS. Overcoming these problems of network re-balancing and interference minimization proved a long and costly process. The same phenomena occurred in the UK and Europe as network operators made the transition from TACS to GSM.[52]

If past experience serves as a guide, problems of interference and network re-balancing will lead to a more difficult integration of GSM onto TDMA networks than vendors anticipate. Should this be the case, the successful deployment of GSM 800 infrastructure would extend well beyond the fourth quarter of 2001.

This is not to say that **cdmaOne** will not pose similar challenges. It will. However, in contrast to GSM, CDMA engineers have five years of experience in deploying CDMA in the 800 MHz frequencies. GSM engineers have none.

4.3 The Time Required to Develop and Deploy Handsets

If the availability of GSM 800 infrastructure is critical for the transition plans of TDMA/IS-136 operators, the availability of GSM 800 handsets is even more so. Without handsets, networks cannot function. Idle networks strand operator investment. When handsets are available, they must be fully functional. If not, end-users will reject them, and revenues to operators will fail to materialize.

51. Personal communication, informed source, Nokia Inc., May 11, 2001.

52. Personal experience, Herschel Shosteck, The Shosteck Group, 1991 through 1995.

4.3.1 The "Reality Gap" in Handset Delivery

Historically, the availability of handsets has always lagged the deployment of infrastructure. We call this the "reality gap." It consists of two dimensions. On the one hand is the difference between the *performance* that handset vendors promise and the capabilities of their initial products. On the other hand is the difference between when vendors promise *delivery* and when they actually do so. As our examples illustrate, the reality gap is universal.

The first GSM network was officially launched in Helsinki in July 1991. Due to chronic handset shortages and malfunctions, GSM was officially "re-launched" in Berlin in July 1992. The first TDMA/IS-54 (the predecessor of IS-136) handsets could not transmit calls to other TDMA handsets. The first **cdmaOne** handsets were characterized by an embarrassingly rapid battery drain.[53]

More recently, WAP handsets have proven a universal disappointment, failing to provide anything near the performance promised by the marketing hyperbole. British Telecom (BT), among the most enthusiastic promoters of WAP, has suffered. Purloined internal figures show total visits to BT's WAP site fell from 115 million in January 2001 to 40.5 million in April 2001, a decline of 65 percent. Over the same period, total Web use fell from 36 million minutes to 12 million, a decline of 67 percent.[54] No information has been reported regarding how many customers have churned because of their poor WAP experiences.

GPRS is repeating the process of delayed availability and disappointing performance. In July 1999, Nokia promised that "GPRS services will be launched…in the second half of…2000, at which time GPRS terminals will also be available."[55] As of May 2001, Nokia planned to "begin shipping commercial GPRS phones during Q3 [2001] and in volume (multi-millions) during Q4."[56] This would be at least nine months later than originally announced.

GPRS handsets that are already available from other vendors, most prominently Motorola, are not performing well. Anite Telecoms, a vendor of network performance equipment, has independently monitored BT's GPRS network. Anite finds that current handsets are delivering data rates of only 8 kbps. This is but one-third of the 30 kbps expected and less than the 9.6 kbps provided by GSM.[57]

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53. Personal experience, Herschel Shosteck and Jane Zweig, The Shosteck Group, continuous.
54. Ben Rosier, "BT's Mobile Web Access Slumps," *Independent Digital (UK) Ltd.* May 27, 2001.
55. "Nokia 2nd Quarter 1999 Conference Call. Review by Martin Sandelin, VP, Investor Relations, Nokia Inc., undated, http://www.nokia.com/investor/1999/2Q/review.html.
56. Personal communication, Megan Matthews, Director Corporate Communications, Nokia Inc., Irving, Texas, May 22, 2001.
57. David Neal, "Data Transfer Rates of 30 kbit/s Are Just a Pipe Dream for Now," *IT Week*, May 26, 2001.

Overall, the reality gap suggests that, in common with all other technologies, GSM 800 handsets will come to market later than vendors first promise.

4.3.2 The Delivery of GSM 800 Handsets

In discussing handset delivery, we must first ask what kind of handsets? In concept, TDMA/IS-136 operators, such as AT&T and Cingular, could construct their GSM networks rapidly and provide their subscribers with nation-wide coverage through roaming on VoiceStream's GSM network. Under this scenario, TDMA operators could, in concept, require only GSM 800/1900 MHz handsets. This, however, is unlikely. More likely, TDMA operators will require dual-mode/dual-band handsets. Such handsets will enable their subscribers to hand off from GSM to TDMA networks and back again. This is the path that AT&T will follow.[58]

The advantage of the dual-mode approach is that it provides subscribers with continuous coverage, giving TDMA/IS-136 operators time to construct their GSM networks. The disadvantage centers on the time it will take for vendors to develop and deliver dual-mode/dual-band handsets and, as we suggest later, higher handset costs.

As of May 2001, only Nokia would go on record regarding when GSM 800 handsets might be available. Nokia observed that given its experience in producing 900/1800 MHz GSM, "it's almost a trivial thing" to down band from 900 to 800 MHz.[59] A separate Nokia source, while making no commitment, pointed out that handset delivery usually follows infrastructure delivery by "6 to 12 months."[60] By inference, this suggests that, at present, Nokia intends to deliver GSM 800 handsets somewhere between the second and fourth quarters of 2002.

However, the reality gap raises the question of whether Nokia (or any other vendor) can devote the resources to deliver GSM 800 handsets when, by inference, it has promised them. This question becomes especially acute because providing dual-mode/dual-band TDMA-GSM handsets requires developing and integrating two, and possibly three, separate technologies.

1. Down-band GSM from 900 to 800 MHz.
2. Integrate GSM and TDMA/IS-136 into a single dual-mode device.
3. Uncertain at this point in time, would be to develop "GSM-ANSI Interoperability Team" or GAIT capabilities.

We referred to GAIT in our last chapter. GAIT is a proposed network standard that translates MAP network signals into ANSI-41 signals and vice-versa. By so doing, GAIT

58. Personal communication, informed source, AT&T Wireless, Redmond, Washington, May 14, 2001.
59. Personal communication, informed source, Nokia Inc., May 11, 2001.
60. Personal communication, second informed source, Nokia Inc., May 11, 2001.

would enable TDMA-GSM handsets mobile subscribers to access their full portfolios of personalized services regardless of whether they would be on a TDMA/IS-136 or GSM network. Without GAIT, subscribers to GSM systems could use only their voice and possibly SMS capabilities when handing off to TDMA systems. This would abrogate a major attraction of GSM—its ability to access a rich portfolio of personalized subscriber applications and services. A number of infrastructure and terminal manufactures are studying GAIT, as well as AT&T Wireless, Cingular, and VoiceStream.[61] As of May 2001, no vendor had publicly announced its intention to develop a GAIT handset. However, while it has made no public comments, Nokia states that it will do so.[62]

Given the complexity of a dual-mode/dual-band GSM 800 handset, the likelihood of a reality gap between promised and actual delivery appears substantial. That said, one could posit that AT&T and Cingular,[63] as the second and third largest operators in the U.S., will command attention from the handset vendors. This is possible, but we think that it is too U.S.-centric a view.

The established world market—primarily devoted to GSM 900 and 1800—is five to six times as large as that of the U.S. Given this size difference, handset vendors will continue to place the needs of Europe and Asia-Pacific first. These center on GSM 900/1800 for Europe and Asia and **cdmaOne** and CDMA2000 1X for Asia (and the Americas). AT&T and Cingular, demanding GSM 800/1900, will fall to the end of the handset supply line. Smaller TDMA/IS-136 operators, such as those in Latin America, will fall with them.

Other frequencies, unique to the Americas, show the diminished attention that handset vendors pay to them. In early 2001, while Motorola was shipping its GPRS-enabled Timeport 260 to Europe, it was not shipping GPRS models to the U.S.[64] A glance at a manufacturer's website illustrates that fewer models for the Americas are available. Ericsson, for example, lists over 50 models each under its categories of GSM 900 and GSM 1800, but only 19 models under its category of GSM 1900 phones.[65] Fewer models may actually be sold. Nokia, the world's largest vendor of handsets, sells only five GSM 1900 models in the U.S.[66]

We see little likelihood that the forces favoring GSM 800 will strengthen. In 12 to 18 months, the pressures on handset vendors to focus on GPRS, EDGE, and/or UMTS will

61. Sam Omatseye, "GAIT to Open GSM-TDMA Door," *RCR Wireless News*, May 14, 2001, pp. 1/46.

62. Personal communication, informed source, Nokia Inc., May 11, 2001.

63. As of May 2001, Cingular had not made a formal commitment to adopt GSM 800. Should Cingular adopt CDMA2000 1x, instead, the pressure on vendors to forego GSM 800 handsets would intensify.

64. Peggy Albright, "Roll Out the GPRS Handsets," *Wireless Week*, February 19, 2001, p. 18.

65. http://www.ericsson.c…/spg.jsp?page=W1.6.1&NetID=383&CatID=50&SubName=Networ. These numbers are as of May 25. Multi-band phones are multi-listed under each band in which they will operate.

66. Personal communication, Virve Virtanen, Manager, Media Relations, Nokia Inc., Irving, Texas, May 29, 2001.

be greater than at present. In light of this, resources to produce an initial multi-mode TDMA-GSM 800 handset, let alone multiple models, will be more constrained than they are now.

In sum, under best of circumstances, handsets for GSM 800 will not be available until the second to fourth quarters of 2002. However, if the historical reality gap serves as a guide, they will not be delivered until later.

4.4 The Delivery of CDMA2000 1X Handsets

By comparison, handsets for CDMA2000 1X are in production and being used on all three Korean networks. As of early May 2001, as many as ten different handset models were available from four different manufacturers. Samsung led the pack with its SCH X100, X110, X120, X130, X200, and X1000 models, followed by two models from SK TeleTech, one from LG, and one from Motorola.[67]

And vendors are introducing more models. Samsung has begun marketing what it calls "the world's first [CDMA2000 1X] mobile handset with the capability to receive motion pictures in color" and capable of reproducing "clear motion picture images in 200,000 different color shades."[68] This has increased the number of available models to 10. By the year-end 2001, SKT expects additional vendors to enter the market, including Nokia. Together, they will produce 26 additional CDMA2000 1X models, bringing the total available to 36.[69] This is a meaningful lead over GSM 800, for which models will not be available until Q2 to Q4, 2002, at the earliest and, given the reality gap, not until much later.

More handset variety stimulates market demand. In addition, more handset manufacturers drive down handset prices.[70] This further stimulates demand. We will examine handset prices in greater detail later in this chapter.

4.5 Backward Compatibility with Legacy Networks and the Full Cost of Infrastructure

Unlike the original North American standards—AMPS, TDMA/IS-136,[71] and **cdmaOne**—Europe's GSM standard has always specified the interface between mobile switches and base stations.[72] This means that GSM base stations and switches produced

67. http:/www.cdg.org/ProdPavilion/subscriber_products_3g.asp.
68. Press release, "Samsung Electronics Markets Mobile Phone with Color Motion Picture Capability," Samsung Electronics, Seoul, May 15, 2001.
69. Personal communication, informed source, Seoul, Korea, May 29, 2001.
70. Personal communication, informed source, Seoul, Korea, May 29, 2001.
71. Technically, the original North American TDMA standard was designated IS-54. This evolved into the currently deployed IS-136.
72. Proponents of **cdmaOne** have been moving in this direction, with the publication of IS-633, which defines the interface between the base station and the switch.

by any one vendor can interoperate with the base stations and switches produced by any other. In addition, although the total number of CDMA infrastructure vendors may be greater, more major vendors—notably Nokia, Siemens, and Alcatel—supply GSM infrastructure than supply CDMA infrastructure.

As a consequence, measured on a hardware-to-hardware basis, the nominal price of GSM infrastructure is less than that of CDMA infrastructure. Discounting the substantial arguments concerning the relative performance benefits of the two technologies, this provides an apparent pricing advantage to GSM as a migration path from TDMA/IS-136 to 3G. This apparent advantage may remain, albeit to a lesser degree, even when GPRS and EDGE are incorporated into the GSM infrastructure pricing.

That said, **cdmaOne** may hold infrastructure price advantages that are not as readily apparent. Two appear plausible.

1. The possibility of using CDMA base stations with legacy TDMA/IS-136 switches.
2. The possibility of incorporating CDMA into the subsystems and service platforms of legacy TDMA networks. These would include home and visitor location registers, voice mail, and short messaging services (SMS), among others.

These possible advantages stem from the fact that TDMA/IS-136 and **cdmaOne** employ a common network signaling (American National Standards Institute-41 or ANSI-41). Network signaling drives the subsystems and service platforms. However, GSM employs an incompatible network signaling (Mobile Application Part or MAP). MAP's incompatibility with ANSI-41 precludes incorporating GSM into TDMA switches or other TDMA network elements.

The extent to which the reuse of TDMA/IS-136 infrastructure may prove feasible will depend on the vendor and the willingness of the vendor to assure interoperability between its legacy TDMA switches and current **cdmaOne** base stations. Nortel appears to enable such adoption the easiest.

> "We can configure a single MTX [switch] to simultaneously support CDMA and TDMA cell site equipment. This is a viable method to transition from a TDMA network configuration to a CDMA network."[73]

Lucent's 5ESS switch, executive cellular processor/inter-message switch (ECP/IMS), and applications processor (AP) are capable of handling both TDMA and CDMA base stations simultaneously. However, to ensure full interoperability, Lucent would have to undertake integration testing. Lucent would do so if customers expressed sufficient

73. Personal communication, Christopher Daigle, Senior Manager Marketing, Wireless Internet, Nortel Networks, Richardson, Texas, May 11, 2001

demand.[74] Ericsson can also support TDMA and CDMA base stations on the same switch, but not simultaneously. For this reason, Ericsson would use one set of switches to support TDMA and another set to support CDMA. In concept, Ericsson could provide "commercial credits" for operators making the migration.[75]

The extent to which new **cdmaOne** infrastructure could reuse the switches or other elements of a legacy TDMA/IS-136 network would also depend upon the extent to which specific vendors have designed interoperability into their products. Motorola, Samsung, and Ericsson, for example, produce base stations intended to operate on the switches produced by Lucent and Nortel.

This is not to imply that incorporating **cdmaOne** into TDMA/IS-136 infrastructure will be without problems. It will not. No one has yet done it. Without the engineering experience, unexpected challenges will surely arise. However, as we observe below, their magnitude should not be as great as those that will arise in overlaying GSM onto TDMA.

The discussion of backward compatibility reintroduces the issue of deploying GSM 800 onto a TDMA/IS-136 network and integrating the two technologies—in particular the MAP and ANSI-41 signaling systems. Even if a TDMA operator decided to build an entirely separate GSM 800 network, it would still need the two networks to communicate with each other.

The most obvious need would be in the realm of billing. Can the MAP signaling system integrate into an ANSI-41 driven billing system? If not, the network operator will be forced to use two separate billing systems, one for its GSM 800 network and the other for its TDMA network. Nokia acknowledges this issue, characterizing the initial reality as being two billing systems.[76] If this will be the case, how, if at all, will operators render a single bill to end-users? And, if separate bills are required, how will end-users respond?

What about packet-based mobile-to-mobile calls? European and U.S. landline operators have more than 30 years of experience in developing translation gateways to carry circuit switched calls between incompatible signaling systems. They have 15 years of experience in carrying circuit switched calls between the incompatible signaling systems of mobile networks. There is no equivalent experience with packet calls. What little there is has centered on implementing GPRS. To date that has not been good. How then, will packet calls be carried between MAP-based GSM 800 and ANSI-based TDMA? True, GAIT is intended to deal with the MAP-ANSI translation. However, the issue remains—regardless of GAIT's theoretical elegance or long-term success, engineers will first go through a long and arduous applied learning process.

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74. Personal communication, informed source, Lucent Technologies, April 30, 2001.

75. Personal communication, Phillip Hester, Director of Product and Technical Marketing, CDMA Systems, Ericsson, Inc., San Diego, California, April 30, 2001.

76. Personal communication, informed source, Nokia Inc., May 11, 2001.

The above will prove central issues for TDMA/IS-136 operators who might deploy GSM 800. They will prove less so for those who might deploy **cdmaOne**.

4.6 The Costs of Handsets

The cost of handsets has proven the Achilles heel of all new mobile technologies. For each new generation of technology, the high initial cost of handsets has slowed end-user adoption. Only when operators subsidized handset prices have they motivated end-users to adopt the new technology. And only as economies of manufacturing scale developed, have handset prices declined. This has held true for GSM, TDMA/IS-136 (originally IS-54), and **cdmaOne**.

It is well recognized that for any new technology, the handset price is always greater than the handset price for established technologies. It is also well recognized that as technologies mature and gain economies of manufacturing scale, handset prices decline. However, it is less well recognized that the handset prices of the newest technologies tend to remain above those of the more mature ones.

Table 4–1 illustrates this phenomenon. It compares the wholesale prices of GSM and **cdmaOne** handsets in the U.S. market from 1998 through 2000. GSM, first introduced in Europe in 1991–1992, is the more mature technology. CDMA, first introduced in Hong Kong, Korea, and the U.S. in 1995–1996, is the newer one. Based on surveys of the U.S. wireless market, they represent the average low wholesale price for all classes of CDMA and GSM handsets. (See notes in Table 4–1.) For years 1998 and 1999, they are the averages of four quarters. For 2000, they are the averages of the June and December quarters.

Table 4–1. The Wholesale Price of Mobile Handsets, U.S. Market, 1998–2000

Year	Technology		
	GSM ($)	CDMA/IS-95 ($)	Difference ($)
1998	117	191	74
1999	89	135	46
2000	95	120	25

Notes:

Source: "Wholesale Prices of Digital Portable Terminals, by Technology and Band, U.S. Market, Recent Quarters, "*Shosteck E-STATS,* The Shosteck Group, Wheaton, Maryland, continuous.

Values represent the un-weighted average for all classes of phone for each technology. In the case of IS-95, these classes are (1) CDMA 800-AMPS 800, (2) CDMA 1900, (3) CDMA 1900-AMPS 800, and (4) CDMA 800/1900-AMPS 800. In the case of GSM, these classes are (1) GSM 1900 and (2) GSM 1900-AMPS 800. For the years 1998 and 19999, the values are based on the averages of four quarters. For the year 2000, they are based on the averages of two quarters. The values for TDMA/IS-136 were $154 for 1998, $117 for 1999, and $98 for 2000. the GSM average of $89 for 1999 may reflect selling of obsolete inventory at distressed prices during March and September.

Table 4–1 documents that from 1998 through 2000 the average wholesale price of GSM handsets fell from $117 to $95. During the same time period, the wholesale price of **cdmaOne** handsets fell from $191 to $120. The price difference between GSM and CDMA handsets diminished from $74 in 1998 to $25 in 2000. Between 1999 and 2000, the price of CDMA handsets declined by 11 percent. Assuming that this rate of decline continues, it points to an average wholesale price of $106 during 2001.

Our estimate of $106 as the current wholesale price for **cdmaOne** handsets is consistent with those of other sources. Ericsson places the current price at $95 to $110.[77] QUALCOMM places it at $110 to $140.[78] Lucent sees it as $100 to $129.[79] Using our own estimates and the midpoints of the Ericsson, QUALCOMM, and Lucent ranges, these prices average to $112.

However, our core interest centers on the likely wholesale price of CDMA2000 1X handsets. A number of our sources were willing to share this information with us. Sprint placed the price at "several tens" of dollars more than that of **cdmaOne** and did not dispute our inference that this indicated an incremental increase of $30 to $50.[80] Added to the $112 price of **cdmaOne**, this indicates that CDMA2000 1X handsets will range from

77. Personal communication, informed source, Ericsson, Inc., May 23, 2001.
78. Personal communication, Irwin Jacobs, CEO, QUALCOMM, Inc., San Diego, California, May 24, 2001.
79. Personal communication, informed source, Lucent Technologies, May 21, 2001.
80. Personal communication, informed source, Sprint PCS, April 24, 2001.

$142 to $162. Consistent with this, Lucent reports a price of $149.[81] Ericsson estimates $130 to $140. Using the midpoints of the ranges, these estimates average to $145. Assuming an annual 11 percent price decline, the price would fall to $129 during 2002.

How does this compare with the prices of the dual-mode TDMA-GSM phones that AT&T, at least, intends to use as it makes the transition from TDMA/IS-136 to GSM? One source, speaking not for attribution, holds that “a phone like that will never be cheap enough” for end-users to afford or for network operators to subsidize.[82] This source observed that any dual-mode phone, whether TDMA-CDMA or TDMA-GSM, would be an interim product that could never develop long-term volume. Without long-term volume, such phones would always demand a price penalty. Implicitly, this source differentiated such phones from dual-mode AMPS-digital phones, which did realize long-term volumes.

Given a price penalty for dual-mode, what might it be? At this juncture, Nokia is most advanced in developing GSM 800 products. Nokia was extremely reluctant to provide specific prices. However, it affirmed “we know that we can” produce “in a profitable way” a dual-band GAIT phone for under $200. Such a phone would be similar to its present 5165. However, Nokia emphasized that, depending on functionality, the [initial] price of such a phone could be higher or lower.[83] We infer from this that the initial price would be higher.

In sum, the likely wholesale price of GAIT phones would be $200 or more compared to the likely wholesale price of CDMA2000 1X phones, which would be $129. The minimum price difference would be $71. Likely, it would be more, plausibly much more. Operators who choose the GAIT alternative would have to compete under this price penalty.

4.7 The Issue of Dual-Mode TDMA-CDMA Handsets

At this point, readers must raise the issues of dual-mode TDMA-CDMA handsets. Would not the same challenges that arise with TDMA-GSM handsets arise with TDMA-CDMA handsets? The answer is yes. However, dual-mode TDMA-CDMA handsets may not be produced. As of this writing, QUALCOMM is studying developing TDMA-CDMA chips. However, it has not yet committed to them.[84] This suggests that such dual-mode phones may not be needed.

This viewpoint may make economic and commercial sense. It assumes that operators and end-users benefit more by the operators’ spending their money to deploy infrastructure rather than to subsidize handsets.

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81. Personal communication, informed source, Lucent Technologies, May 21, 2001.

82. Personal communication, informed source, May 23, 2001.

83. Personal communication, informed source, Nokia Inc., May 11, 2001.

84. Personal communication, Irwin Jacobs, CEO, QUALCOMM Inc., San Diego, California, May 24,2001

Under this assumption, TDMA/IS-136 operators who may choose CDMA2000 1X would deploy a parallel CDMA2000 1X network as quickly as possible. Once it provided sufficient area coverage, they would begin to migrate their subscribers to it. In concept, there is no reason why TDMA operators who may choose GSM could not do the same thing. Doing so would avoid the price penalties of dual-mode phones.

Rapidly building out a network may not be as onerous a task as may at first seem to be the case. Critically, the civil engineering in terms of cell sites is already in place. The backhaul transmission is in place, as well. The new network would have few initial subscribers. Thus, it would be initially designed to provide wide coverage, not high capacity. For this reason, the initial deployment of a parallel network, whether CDMA2000 1X or GSM, would require relatively few base stations. More importantly, it would be deployed quickly and at relatively low cost.

In sum, the option of quickly deploying a fully parallel CDMA2000 1X network, and completely foregoing dual-mode handsets may prove economically more attractive to operators than shouldering the continuous stream of subsidies required for dual-mode handsets. This economic advantage would apply to the paths of **cdmaOne** and GSM, alike.

5 Summary and Conclusions

This white paper provides an overview of options open to TDMA/IS-136 operators as they choose a migration path to third generation (3G) and addresses issues in choosing a path. It specifically compares GSM and **cdmaOne**/CDMA2000 1X as migration alternatives.

Perhaps its most important value lies in identifying the implementation challenges that may hinder that migration. By identifying such challenges, operators can be more watchful of transition pitfalls and question their vendors more closely concerning viable means of avoiding those pitfalls and implementing cost-effective alternatives.

We warn operators (and vendors) against focusing on high data rates. As SK Telecom emphasizes, *the issue is not high data rates, but profitable data rates.* Over the short- to mid-term, these may well be in the range of 30 to 50 kbps. Looked at in this context, for operators to choose—or for vendors to promote—technologies because of their ultimate speeds becomes self-defeating.

We note the daunting engineering challenges inherent in deploying EDGE and, because of them, the possibility that EDGE may never reach commercial fruition. Or should it reach fruition, we point to the likelihood that some GSM operators will bypass it to migrate directly to UMTS.

We describe and document the historical “reality gap” between when vendors promise handsets and when they actually deliver. Tied to the complexity and expense of dual-mode handsets, this virtually ensures their delay to market and a high price tag when they eventually arrive. The dual-mode nature of these phones precludes the economies of scale, which a single-mode device would provide. This will apply to TDMA-GSM 800 handsets and, if produced, TDMA-CDMA handsets, as well. In contrast, single-mode CDMA2000 1X handsets are already available and being offered at low and declining market prices. Single-mode GSM handsets, when and if produced, will be available at low prices, as well.

Of special importance, we reiterate that UMTS spectrum has not been licensed in the Americas. This means that TDMA/IS-136 operators who choose GSM have no foreseeable migration path to full 3G. In contrast, CDMA2000 1X is becoming available, is enabling 3G services on present spectrum, and is providing capacity increases of 50 percent or more.

We note that AT&T, which precipitated the move of TDMA/IS-136 operators toward GSM, may be a special case. Unlike Cingular, AT&T’s major TDMA rival, AT&T holds 1900 MHz spectrum in 9 of the 12 largest markets. Cingular holds 1900 MHz spectrum in only four. This enables AT&T to migrate using GSM 1900. With little 1900 MHz spectrum, Cingular is much more constrained.

We pay close attention to what may be required to deploy GSM onto a TDMA/IS-136 network. In addition to the challenge of developing dual-mode TDMA-GSM handsets, two seldom-discussed factors emerge.

1. The crowding of the 800 MHz spectrum. No one in the world has experience in deploying GSM at 800 MHz and in dealing with the potential interference from different RF technologies. Two of these, AMPS and iDEN, are unique at 800 MHz. Good engineers will overcome such interference. However, doing so will take time and money.
2. The challenge of integrating the incompatible MAP signaling used by GSM with the ANSI-41 signaling used by TDMA/IS-136. Again, no one in the world has ever done this. It would be disingenuous to think that it will prove an easy process.

Not to be overlooked is the question of whether to use dual-mode handsets at all. A powerful argument can be made to forego dual-mode handsets and use only "pure" CDMA2000 1X or GSM 800. This bypasses many, but not all, of the issues of network integration. By building a pure network, operators would spend money on infrastructure rather than handset subsidies.

Throughout our analysis, we return to the themes of costs and profits—or the phrase we sometimes use ,"commercial" relevance. Related to costs and profits is the theme of maintaining a satisfactory end-user experience throughout the transition. A poor end-user experience creates churn. In addition to being costly humiliations, the failed promises of WAP and GPRS alienated end-users to the operators' detriment.

Overall, we indicate the possible challenges that TDMA/IS-136 operators may face in deploying GSM and the possible advantages that **cdmaOne** may offer. Based on these possible advantages, we suggest that TDMA operators may find it worthwhile to consider **cdmaOne**/CDMA2000 1X as a migration path.

Depending upon their specific circumstances, some TDMA/IS-136 operators may choose CDMA2000 1X as the better path for them. This may happen more for those who are licensed primarily to 800 MHz spectrum. Others may choose GSM. This may happen more for those who are licensed primarily to 1900 MHz spectrum.

In sum, we are not endorsing CDMA2000 1X as the transition technology from TDMA/IS-136 to 3G. Rather, we are saying that it appears to offer a promising story that some TDMA operators will find worth considering.