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Telecoms

At the starting line - The race to mobile broadband

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Two basic platforms compete for hearts...

There are two main technologies competing to become the dominant global platform for mobile broadband delivery - WiMAX and HSPA (based on 3G). WiMAX has been heralded by some as 4G, leaving traditional 3G standards in its wake in terms of technical capabilities and techno-economic merits. In this report, we explain WiMAX and HSPA, what the two can do, what they cannot do and what kind of an impact WiMAX will have on the wireless industry.

...but we believe HSPA will win minds despite WiMAX´s spectral efficiency

We believe that WiMAX will have a clear role in the wireless industry's future, but is unlikely to challenge 3G evolution path in *mobile* cellular network services. In our view, WiMAX technology, arguably, has slightly more spectrally efficient radio interface than 3G evolution. However, as we have seen in other battles (eg, GSM vs CDMA), the telecom industry is often driven by factors beyond decibels, link budgets and data rates. In real life, the network-related decisions are based more on techno-economies: affordability, availability, scalability, ruggedness, and politics. Based on our research, we believe these seem to favour incumbent 3G-based technologies such as HSPA because USD500bn investments have already been sunk into existing cellular technologies, serving over 2.6bn subscribers globally.

We forecast 450m HSPA-enabled terminal shipments by 2010

While some operators (many new entrants or fixed line only operators) will be willing to test the mobile WiMAX technology, we believe the real benefit lies in fixed-wireless rather than truly mobile applications. With regard to infrastructure, we believe WiMAX will post a '05-'10 CAGR of c.50% versus 27% for WCDMA (3G). However, the relative bases should be put in context – c.USD600m for WiMAX in 2006 versus USD21bn for WCDMA. On the terminal side, we believe that the WiMAX is likely to focus on the annual laptop market of c.82m units in 2006 and we forecast that the total WiMAX terminal market to reach 29m units. In comparison, we forecast almost 450m HSPA terminals will be shipped by 2010.

Nokia and Ericsson are likely to be main beneficiaries of HSPA

As for the companies that we cover, we expect no major impact from the WiMAX market entry. The cellular equipment market is expected to remain intact, with little shake-up in the Ericsson, Nokia Siemens Networks (NSN) and Alcatel-Lucent dominated pack. Nokia may benefit from WiMAX entry, as the new technology may force the potential WiMAX operators to knock on its door in the hopes of cheaper and interoperable handsets, in line with what happened with Sprint Nextel. We believe that Nokia (with NSN) will, to a large extent, rely on subcontracted R&D with profit-sharing agreements in order to outsource a good deal of the WiMAX risk, but much of the profit potential may be lost to development costs of WiMAX-capable terminals. With regard to HSPA, we feel Ericsson will be a prime beneficiary of the software upgrades that will accrue over time.

Emerging Themes

Top picks	
Ericsson (ERICb.ST),SEK27.40	**Buy**
Alcatel-Lucent (ALU.PA),EUR9.87	**Hold**
Nokia (NOK1V.HE),EUR16.96	**Buy**

Companies featured			
Ericsson (ERICb.ST),SEK27.40			**Buy**
	2006A	2007E	2008E
DB EPS (SEK)	1.46	1.52	1.74
P/E (x)	17.7	18.0	15.8
EV/Sales (x)	1.6	1.6	1.5
Alcatel-Lucent (ALU.PA),EUR9.87			**Hold**
	2005A	2006E	2007E
DB EPS (EUR)	0.51	0.31	-0.10
P/E (x)	19.5	32.3	–
EV/Sales (x)	1.2	1.1	1.2
Nokia (NOK1V.HE),EUR16.96			**Buy**
	2005A	2006E	2007E
DB EPS (EUR)	0.78	1.01	1.14
P/E (x)	16.9	16.7	14.9
EV/Sales (x)	1.4	1.5	1.1

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Investment thesis

Outlook

This report sets out to assess the merits of two of the key technology platforms competing for hearts and minds in mobile broadband, Worldwide Interoperability for Microwave Access (WiMAX) and High Speed Packet Access (HSPA). WiMAX, similar to Wi-Fi before it, is a standard (802.16) designated by the Institute of Electrical and Electronics Engineers (IEEE) and designed to offer high speed data transfer in unlicensed spectrum. This note concentrates on the mobile variant of WiMAX (802.16e). HSPA on the other hand, is a software overlay to existing 3G-WCDMA networks developed by the 3G Partnership Project (3GPP) which boosts the data speeds of these networks.

Our research concludes that while WiMAX enjoys technical advantages with regard to radio transmission, the value proposition of HSPA is more compelling in terms of the economics of broadband mobile provision. Both technologies are seeing some early acceptance with Vodafone in particular as a proponent of HSPA, already rolling out 80% of its 3G network (which has 60% coverage in Europe). We view the main benefits of HSPA as:

- **Backward compatibility**. The fact that HSPA utilizes existing networks is a material benefit to operators keen to maximize the returns from sunk costs of WCDMA investment (over E150bn in Europe alone).
- **Standardisation.** Related to the first point, operators and equipment vendors have joined together to define set standards for HSPA while WiMAX has adopted a different physical layer for its mobile compared with its fixed-mobile variants.
- **Licensed spectrum.** While the WiMAX camp cites the fact that it utilizes unlicensed spectrum as a positive due to its lack of costs, it suffers from interference and also if demand for the service is strong. HSPA, however, is offered on WCDMA networks, based on licensed spectrum.
- **Availability of infrastructure and terminals.** Vodafone recently cited that it would launch an additional 10 HSPA handsets in 2007 and there are concerted efforts by telecom equipment suppliers to provide a greater range of terminals to its core client base. In addition, the infrastructure for HSPA is already in place in many markets (WCDMA in Europe) requiring just a software upgrade.

Valuation

It is extremely difficult to determine the main beneficiaries from the emergence of broadband mobile with the exception of the consumer. We expect no major impact from the WiMAX market entry. The cellular equipment market will remain intact, with little shake-up in the Ericsson, Nokia Siemens Networks (NSN) and Alcatel-Lucent dominated pack. Nokia may benefit from WiMAX entry, as the new technology may force the potential WiMAX operators to knock on its door in the hope of cheaper and interoperable handsets, in line with what happened with Sprint Nextel. With regard to HSPA, we feel Ericsson will be a prime beneficiary of the software upgrades that will accrue over time.

Risks

The main ongoing risk to the infrastructure suppliers remains possible capex cuts at the key operator customers and a possible hiatus in 3G spend. On the terminal side, the main downside risks to the incumbent vendors include the entry of new players.

Evolution of WiMAX from fixed to portable to mobile

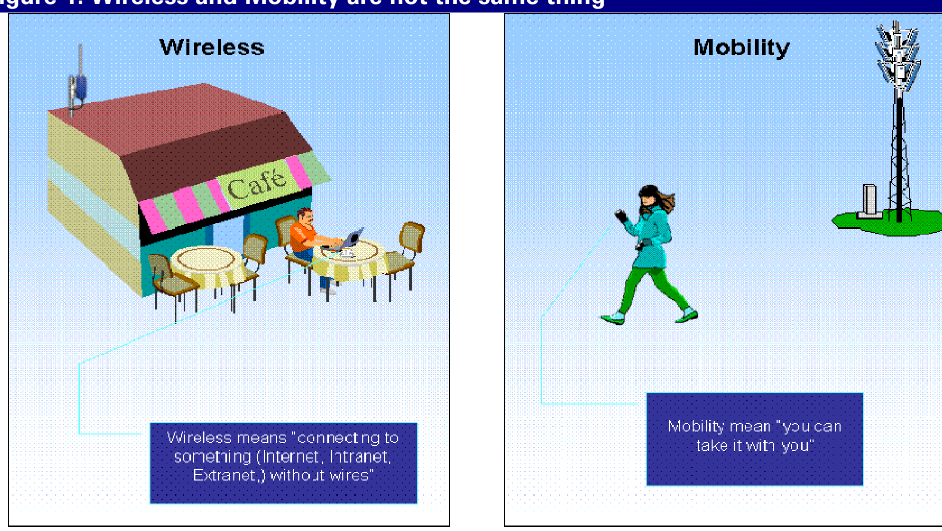
Broadband Wireless access and Mobile broadband access are different

Understanding why broadband wireless access is compelling means knowing what it is—and what it's not. While Mobility and Wireless are often used interchangeably, they are not the same thing.

Mobility & Wireless are often used interchangeably, but they are not the same thing. Wireless means, as the name suggests, without wires. Mobility means being able to take something with you.

Wireless means, as the name suggests, without wires. This may seem obvious but it´s one of those terms that is not truly or fully understood by the vast majority of the industry — or at least is understood differently by various factions in the market. Mobility, on the other hand, means being able to take something with you. It also implies motion, and in the context of telecommunications, to be able to use that something to communicate while being on the move.

Figure 1: Wireless and Mobility are not the same thing



Source: Deutsche Bank

Broadband Wireless Access (BWA) means "broadband-like" data speeds delivered over a geographical area without wires. While the user is free to conduct his/her affairs without being tethered, it still implies confinement to a specific geographical location whether it is a home, an office, a hotspot or a city-wide hot zone, which is discussed later.

It is clear the real appeal of wireless is the ability to move and what seekers of telecoms killer application often fail to realize is that mobility itself is the "killer app".

Mobile broadband wireless access, on the other hand, means having the freedom and convenience to access all subscribed communication services while on the move and without the restriction of having to remain within the confines of a geographic location. That is, the user is free to move or roam across different administrative domains and access services whether they are local, portable or even global.

It is clear that the real appeal (and therefore value) of wireless communications is the ability to move. What seekers of telecoms killer application often fail to realize is that mobility itself is the "killer app" – just as flight was the killer app for aviation or as digital storage is the killer app for multimedia.

Why didn't broadband wireless access take off before?

Broadband Wireless Access systems held great promise when they were first introduced in the early 90s (under the guise of Local Multipoint Distribution Services) and were heralded as the "wireless fibre" alternative for high bandwidth delivery that would unblock the bandwidth bottleneck in the last mile. So what went wrong?

- Operating at frequencies above 15 GHz brings its own unique set of challenges. At these frequencies, the propagated signal range is limited to a local radius of about 2-3km and therefore installations extensively utilized multi-cell designs (which were expensive), and relied on line-of-sight (LOS) conditions to ensure proper operation.
- Electronic components above 15GHz were scarce and immature, which led to relatively high costs.
- At these frequencies the signal is more susceptible to weather conditions like rain and fog; so the propagation distance for reliable communications decreases. This necessitates the over-engineering of the radio link and/or requires that more base stations be deployed to provide the same coverage and performance.
- The radio spectrum is a finite resource. This limits the number of wireless users and the amount of spectrum available to any user at any moment in time. The amount of spectrum available equates almost directly to data bandwidth, with 1Hz of spectrum typically yielding some 1bps of throughput depending on various factors, such as the type of modulation used and environmental factors.
- Finally, LMDS operators were over-marketing their service as "Wireless Fibre" with all that this particular connotation would suggest. However, in their over-zealous haste to get to market quickly, during the fever of the telecom/dotcom era, they over-promised and under-engineered their networks.

In the end, the combination of lack of economies in silicon, expensive equipment, poor deployments, weather conditions, and ultimately, over-hyping and under-delivering on performance plagued the nascent BWA market.

In the end the combination of factors as just discussed plus the lack of economies in silicon, expensive equipment, poor deployments, weather conditions, and ultimately, over-hyping and under-delivering on performance plagued the nascent BWA market. In short, it failed to be seriously considered as a viable means of providing broadband access and consequently was shelved.

WiMAX – Broadband Wireless Access emerges from the LMDS ashes

A new generation of BWA technologies has re-emerged from the LMDS ashes, backed by the giant chipset maker Intel and a host of equipment vendors (most notably former LMDS and MMDS equipment providers), which promises to match the combination of cost, performance, quality and reliability characterized by wireline broadband networks.

It is defined as Worldwide Interoperability for Microwave Access (WiMAX) or in its technical *nom de plume* as IEEE 802.16. As the OECD states, "WiMAX is not a technology *per se*, but rather a certification mark, or 'stamp of approval' given to equipment that meets certain conformity and interoperability tests for the IEEE 802.16 family of standards".

As the OECD states "WiMAX is not a technology per se, but rather a certification mark....

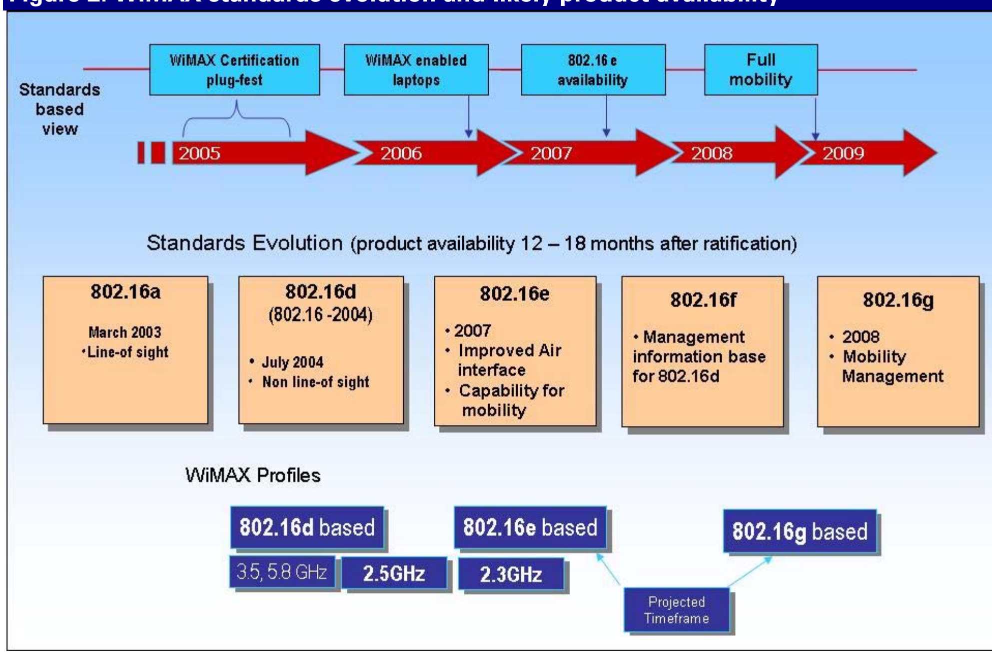
There is a great deal of confusion today, much of which is instigated by wireless equipment vendors, about what the various versions of WiMAX are, what they can do, and when they will be available. Accordingly, to understand Broadband Wireless the relationship between IEEE 802.16 and WiMAX needs to be fully understood.

WiMAX became known to the world in Dec 2001, but began in earnest to be recognized as a standard IEEE 802.16 in 2003 and, as such, attempted to obtain the flow-on effects that emanate from that status. As a standard, it would: encourage economies of scale, lower development costs, achieve volume economics, reduce technical barriers, promote compatibility and result in significant cost savings that will ultimately benefit consumers.

Since 2001, the 802.16 standard has been released in several versions.

- The first addressed Extremely High Frequency Line of Sight (LOS) operation, 11GHz and above. This was to address the Fixed Broadband Wireless Access market previously addressed by LMDS.
- The next major upgrade addressed the lower frequency operations, and this is where the WiMAX Forum is focused. This version, known as 802.16d or 802.16-2004, only addresses fixed, nomadic and portable operation, not mobile.
- It is 802.16e, the mobile variant of the standard (still being formulated scheduled for release sometime in 2007, which is the subject of our analysis later in the report.

Figure 2: WiMAX standards evolution and likely product availability



Source: WiMAX forum

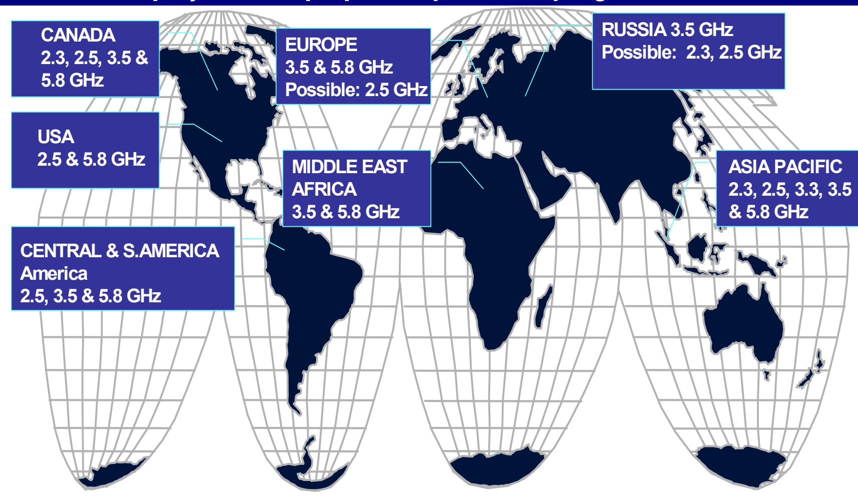
Throughout this paper we will identify the mobile variant as WiMAX (802.16e) or mobile WiMAX; if we only state WiMAX, it's the family of 802.16 fixed/portable standards to which we refer. The reasons will become clear as we go along.

Emergence of unlicensed spectrum a non technological breakthrough

WiMAX offers a great deal of design flexibility – including support for licensed and license-exempt frequency bands. This means that potentially both Private and Wireless Internet Service Providers (WISP) carrier systems have a choice of using licensed or unlicensed Industrial, Scientific and Medical (ISM) spectrum. The use of frequencies below 7GHz means that WiMAX doesn't have as many of the propagation issues (Line of Sight [LOS], shorter distances, weather, etc) as previous BWA systems, and equipment can use inexpensive off-the-shelf components.

WiMAX can potentially also use the license-exempt Unlicensed National Information Infrastructure (UNII) bands in the higher 5.15-5.35GHz and 5.725-5.825GHz range designed to allow for higher data rates, but those frequencies require line of sight and work only at shorter distances negating the potential coverage value of WiMAX.

Figure 3: WiMAX projection of proposed spectrum by region



Source: WiMAX Forum

The use of unlicensed spectrum is often touted as a great advantage because it allows new Wireless Internet Service Provider (WISP) service providers to deploy BWA quickly and alleviate the need to pay enormous amounts for spectrum license fees upfront.

The unlicensed band has its own disadvantages like interference, increased competition, and limited power, as well as limited availability.

But unlicensed band has its own disadvantages like interference, increased competition, and limited power. Since license-exempt bands can be used by other users and appliances, there is a high probability of interference. It is also very difficult to use license-exempt bands and guarantee service levels. Consequently, it is more likely that WiMAX will be deployed in the licensed spectrum, which means operators will have to pay for their licenses. While using licensed spectrum means having to pay for spectrum, it does give operators the right to use greater output power and therefore greater coverage.

NLOS operation a major technological breakthrough

One of the clear advantages of WiMAX, setting it apart from its microwave predecessors, is its ability to operate under blocked or obstructed line-of-sight (LOS) conditions which are commonly referred to as NLOS.

Historically, microwave radio signals have been used in clear, unobstructed scenarios with high confidence. Engineered properly, these links can achieve wire-line-like quality and reliability. We typically refer to any impeded direct path between the two end points of the radio link as blocked *line-of-sight* (LOS), non-LOS (NLOS) or obstructed LOS. Obstacles may take the form of trees, man-made objects such as buildings or geographic features such as hills. Because dissimilar materials absorb microwave radiation at very different rates, some obstructions will have more significant effects than others. For instance, due to its high water content, foliage soaks up microwave signals virtually like a sponge.

One of the clear advantages of WiMAX, setting it apart from its microwave predecessors, is its ability to operate under blocked or obstructed line-of-sight (LOS) conditions which are commonly referred to as NLOS. Wireless Internet Service Providers (WISP) do not have to engage in detailed cell planning using high resolution, three-dimensional data that takes into account terrain, rain data and the footprint, location and height of buildings, and foliage. Accordingly, BWA links that use such technology can serve a greater number of sites.

Radio Physics 101

NLOS means the radio link will retain a high degree of performance and reliability even though the Fresnel zone is partially blocked. However, it does not mean the link can penetrate mountains or buildings.

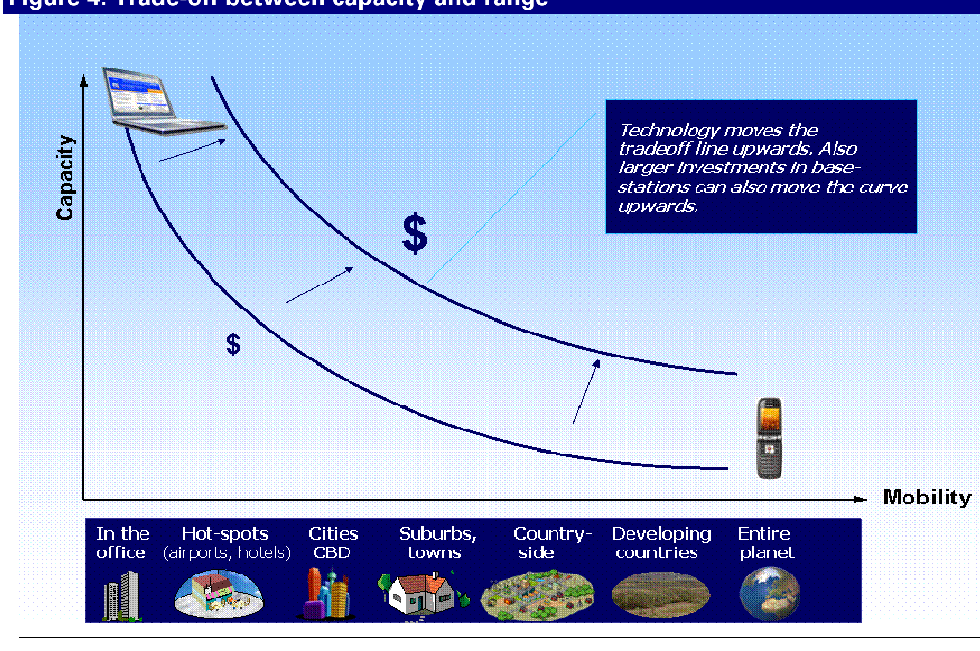
NLOS means the radio link will retain a high degree of performance and reliability even though the Fresnel zone —a series of concentric ellipsoids surrounding the visual path - is partially blocked. However, it does not mean the link can penetrate mountains or buildings. The ability to avoid link blockages is heavily dependent on the size of the first High Frequency Fresnel zone. As frequency goes up, this zone gets smaller.

As a rule of thumb, 60% of each Fresnel zone must be free of obstructions for sufficient reception - and the more obstacles that exist in your path, the more your transmission will be degraded. Some surfaces will reflect, rather than absorb, microwaves so we can create a radio link by bouncing the radio signal off a nearby object to create a reflected indirect link path around the obstacle. A portion of the reflected signal therefore will reach the receiver, along with the directly radiated signal from the transmitter. If the timing of the converging beams works out, the primary signal may just be reinforced and everything will be okay. For a link to stay working properly, the link must have enough "headroom" to operate during all of the expected variations encountered.

Shannon's law states that there is always a maximum rate, at which data can be transmitted over a limited bandwidth channel because of the presence of noise

The other thing that limits efficiency of wireless communications is Shannon's law. The law states that there is always a maximum rate, at which data can be transmitted over a limited bandwidth channel because of the presence of noise. Basically, this means that a certain amount of power is needed from the transmitter to overcome the noise in the channel to achieve a given data speed. Further that the system capacity (or throughput) is limited by interference over short distances and noise over large distances. With more sophisticated equipment, and with single antennas, one can get closer to the theoretical limit, but never surpass it.

Figure 4: Trade-off between capacity and range



Source: Stockholm School of Economics

Technical advantages of WiMAX – OFDM and MIMO

As explained above, many of the challenges that WiMAX, particularly the mobile variant (802.16e), will face are similar to those that have impeded every wide area wireless standard on the planet – capacity and range. As mobile users change location, they utilize different network access points and addresses, and the information link becomes dynamic complicating resource allocation. Broadband Wireless is difficult enough because of the interaction of the environment with the message signal. Adding mobility to wireless makes it even more formidable.

Two of the main technologies enabling NLOS operation in WiMAX include OFDM (Orthogonal Frequency Division Multiplexing) and MIMO (multi-input multi-output) receiver technology.

The use of OFDM is a technological breakthrough used by many next generation BWA systems including WiMAX. OFDM technology is regarded as the most efficient means of delivering high speed data in harsh environments with minimum bandwidth. When radio signals travel from one location to another, they are subjected to impairments, reflections, noise, and multiple paths between transmitter and receiver. This is analogous to echoes or reflections, causing multiple copies of the message to reach the receiver at different times.

OFDM decreases interference from multi-path propagation but is prone to movement of the terminal.

The main idea of using OFDM is to avoid problems caused by multi-path reflections, which are problematic at frequencies below 7GHz, by sending the message bits slow enough so that any delayed copies (reflections) are late by only a small fraction of a bit time. To maintain a high bit rate, multiple carriers (>1,000) are used to send many low speed messages at same time, which can be combined at the receiver to make up one high-speed message. In this way, we avoid the distortion caused by reflections. On the negative side, the technology requires synchronization and, because of the narrow frequency channels, it is prone to doppler shift ie, movement of the terminal.

MIMO helps improving theoretical capacity of the network

MIMO is an interesting technology to improve data rates but its advantages are often exaggerated, and deployment may be slower than expected.

MIMO (multiple-input, multiple-output) antenna systems truly hold the key to realizing much higher capacity, system performances and reliability for broadband wireless systems. MIMO systems exploit the use of multiple antennas at both the base station and the user terminal receiver to unravel the effects of the wireless signals as they traverse and scatter across the terrain. The theoretical capacity of a MIMO system is increased as the number of antennas is increased, proportional to the minimum number of transmit and receive antennas. Hence, this is in theory an efficient technology to fight against the Shannon's law. The technology is also being standardised to 3G evolution.

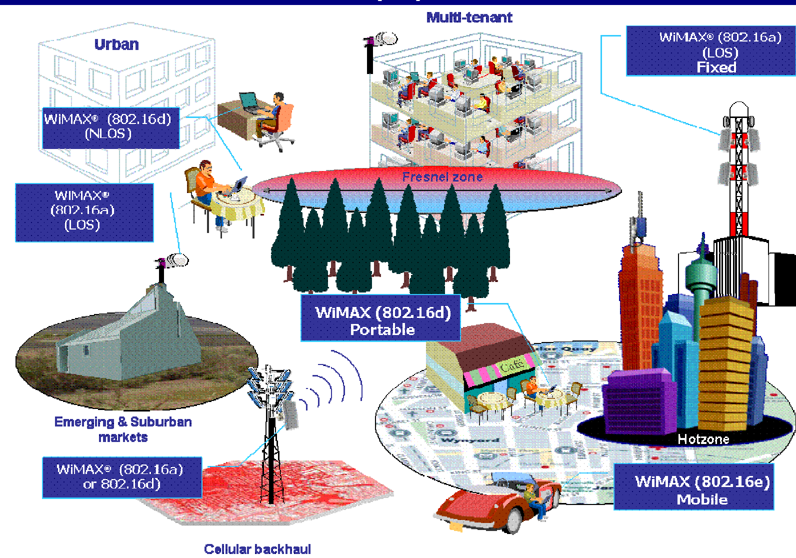
Nonetheless, in the real life, the number of antennas is likely to be limited to 4x2 and 2x2 configurations. This would imply some 40% increase in the theoretical capacity of the radio interface. In practice, the advantages are likely to be smaller. MIMO increases complexity and costs both in terminals and network equipment. The technology also increases processing requirements in the terminal, draining battery faster. One should also note that the theoretical gains in MIMO are often calculated vs. one antenna configuration and not against cross-polarised antenna configuration that is often used in mobile base stations.

It should be noted however that while MIMO is one of the sources for positive link budgets often seen in benchmark studies but, based on our discussions with industry experts, they are not that often visible in the binding roadmaps for WiMAX equipment. Nortel claims it is the first player with MIMO capability available in its base stations. While we believe that MIMO will not be even closely as overhyped as smart antennas were in the early days of 3G, we do believe that it may be dangerous to rely on this technology as of now.

Techno-economics of WiMAX deployment scenarios

The WiMAX Forum and supporting equipment vendors are promoting the deployment of WiMAX in a variety of market scenarios in both developed and emerging markets. In the following section, we review the various potential deployment scenarios, and identify some of the critical factors that are needed to evaluate a business case for WiMAX in these environments. We will also illustrate some advantages and challenges faced by WiMAX, and all broadband wireless systems for that matter, in an attempt to resolve the trade-off between capacity and mobility.

Figure 5: WiMAX standards in various deployment scenarios



Source: Deutsche Bank

Multi-tenant building scenario - urban

It has often been argued, and cogently, that only a small percentage of commercial buildings have access to fibre. Business customers and other people situated in multi-tenant apartment blocks need broadband access to the internet.

Fixed wireless systems such as WiMAX can relatively be implemented quickly and easily through the installation of antenna systems on the rooftops of buildings and reticulating services to the tenancies using existing in-building cabling. The significant deployment task, other than obtaining suitable sites, is the placement and configuration of sectors at base station sites in order to maximize coverage, and minimize overcapacity in cells, interference and infrastructural costs.

WiMAX may be economical to deploy in urban areas where there is no access to fibre

With many potential customers at a single site, the cost per customer may be significantly lower than deploying individual equipment to single-customer sites. While larger customers will certainly have high revenue potential, the benefits of clustering are especially applicable to the small- and medium-sized businesses and residential multi-dwelling unit markets. Moreover, since a large part of a wireless network's cost is not incurred until the equipment is installed on customer premises, the operator can time (pay-as-you-go) capital expenditures to coincide with the signing of new customers.

In this context, when engineered appropriately and with high enough levels of user penetrations, the investment case for this type of fixed deployment scenario may be viable, provided that existing or alternative access technologies are lacking.

Hotzone scenario 'Portable' - urban

The present WiMAX standard, 802.16-2004 (also known as 802.16d) is seen as a nomadic portable mobility extension, designed to serve nomadic notebook carrying users who need to access the internet or intranet from different locations within a central business district. This has given rise to the concept of a city-wide "mega hotspot" called a Hotzone deployment scenario.

Being able to walk around or move at slow speeds (<30kmh) and have coverage over an entire city is a service that WiMAX could potentially provide with a lower cost and better service vis-à-vis the citywide Wi-Fi movement (such as Taipei M-City see case study) alone.

For the operator, WiMAX portable has several advantages. For the same infrastructure that services users "visible" from the base station transceiver site in the access network, the number of potential (nomadic) users can be increased with portable. Portability offers the operator a service offering that is a step closer to mobility that wireline can never deliver, protecting them against competition in the future.

Brownfields scenario - suburban

Techno-economic (deployment economics) calculations show that it very difficult for new emerging broadband access technologies to capture significant market share in areas where cable modem and/or DSL are already deployed.

- **DSL has effectively no civil works costs**, since the copper is already in the ground; the significant costs being the equipping of the local exchange with DSLAM equipment, and installing the modem on the customer premises. The same is essentially true for areas covered by existing HFC (Cable) infrastructure. Moreover, due to auto configuration of the modems, the need for home installation of the DSL modems has decreased dramatically. For instance in Finland, just 10% of new DSL connections require an installation service on the customer premises.
- **The costs for DSL have been driven down by volume and work out to less than EUR50 per DSLAM port at the exchange, with customer modems costing around another EUR50.** FttN architectures (being deployed by fixed line operators), which move the fibre frontier to within a few kilometers of the subscriber, benefit from the extensive re-use of the existing copper infrastructure (and existing nodes, ducts, RoW) and require significantly less capital than any of the other broadband wireline options that require civil works or even arguable fixed broadband wireless.
- **We would concede that the DSL footprint (only a few kilometers from the exchange) will not be able to serve those seeking broadband.** Eventually through scale and volume economics, WiMAX may become a viable alternative to fixed broadband access for subscribers outside the footprint of DSL. Proponents of WiMAX estimate that, by late 2007, the total capital cost per WiMAX customer will be less than €150. In addition, the per-customer equipment costs will improve as WiMAX emerges as an embedded solution in notebooks and PDAs. In fact, the cost per customer, with scale, will likely reduce dramatically to less than €50 per client. Note that this includes just the hardware in the end-user terminal and not high-gain antennas etc. This is an important consideration as we will show that the potential coverage footprint of WiMAX may be considerably less than that often quoted and system capacity may only be met through the use of high gain antennas on the CPE.

- **European studies show that household penetrations have a significant bearing on the viability of alternate broadband technologies.** Suburban household penetrations (in Europe) of 17 HH/km^2 (or above) are required to make WiMAX-based FBWA come close to being competitive with existing DSL services. This can be justified with a simple calculation. Assume 20% penetration and a monthly subscription of EUR30 ie, equal to a low data rate DSL connection. With moderate range of 2.5km, the base station (including civil works and equipment) could be depreciated in 2.8 years, faster if co-siting can be used.

We would conclude that WiMAX networks should not be considered as a major threat to DSL networks in urban and suburban areas.

We would conclude that WiMAX networks should not be considered as a major threat to DSL networks in urban and suburban areas. This results from a sufficiently low cell range and maximum capacity per user, as well as the high prices of current generation equipment. Furthermore, constantly growing broadband penetration, together with decreasing tariffs and prices of DSL equipment, makes the entry for WiMAX systems into the market increasingly difficult.

Greenfield scenario - Emerging Markets

Much has been said regarding the potential of WiMAX in emerging (or developing) markets to bring the promise of the internet and help bridge the digital divide. These markets, where there is insufficient wired infrastructure, are the greatest opportunities for the deployment of WiMAX as an economically viable alternative to wireline. Civil works .accounts for the major costs (up to 90%) in rolling out a wireline infrastructure and remains the major impediment to the delivery of broadband services to homes. In contrast, BWA systems with their relatively low capital intensity, compared to wired telecommunications, is better suited to new entrants in greenfield markets. However for the time being, WiMAX compliant equipment and access devices (which must be mounted outdoors) may be too costly for emerging markets. With other forms of wireless link, such as mobile-cellular networks remain a cheaper way to provide a Wireless Local Loop.

The other issue is that the limited disposable income in emerging markets places major constraints on the revenue that can be spent on telecommunications and CPE. Although it is often argued that WiMAX base station equipment are significantly cheaper than say 3G/HSPA, without volume economics in silicon the price of CPE has remained high. The relatively cheap costs of mobile phones make cellular services more appealing, albeit they are often lower data-rate alternatives. In these areas, in most cases even HSPA terminals are too expensive and the cheapest WLL alternatives with, for example, shared GSM terminals are the options of choice. Our assessment is that WiMAX may offer an attractive alternative as a WLL for areas with moderate disposable income and where wireline infrastructure is either inadequate or nonexistent. However, the relatively cheap costs of mobile phones make cellular services much more appealing and a more realistic option to the low-income areas.

Backhaul scenario - 'Hotspots' – Urban

As just stated, WiMAX as a backhaul link for traffic emanating from cellular mobile base stations (BTS) does make economic sense. Backhaul is a significant cost (10-15%) to mobile network operators (MNO) and is likely to go up as new multimedia data services increase. There are over 2m BTS installed globally and approximately 70% are backhauled wirelessly using conventional microwave. The remainder is backhauled using expensive leasing of E1 or T1 lines leased from incumbent operators. The solution provides the added advantage of lessening MNO dependence on backhaul facilities leased from their competitors. Equally, public WiFi hotspots are also being installed worldwide at a rapid pace. One of the obstacles to continued hotspot growth, however, is the availability of high capacity and cost-effective backhaul solutions. WiMAX could effectively provide a viable means of backhauling traffic from WiFi hotspots. WiMAX could potentially also fill in the coverage gaps between WiFi hotspot coverage areas.

The WiMAX optimism

As with all emerging technologies that have the potential to disrupt the existing paradigm and are prone to aggressive marketing, WiMAX is no exception.

As with all emerging technologies that have the potential to disrupt the existing paradigm and are promoted and marketed aggressively, WiMAX is no exception. It potentially offers improved performance and increased capacity, some equipment interoperability, and in the future, even real volume economics. Still, we believe that the industry has created plenty of positive expectations around the technology, some, or even most of which may not live up to expectations.

Irrespective of its technical capabilities WiMAX inherits issues of its heritage, albeit with fewer of the past's limitations, and faces the normal challenges in terms of spectrum, deployment and market acceptance. The following discussion looks at the strongest of the recent marketing arguments.

WiMAX is 4G?

We would even go so far as to say OFDM is the future of wireless.

Undoubtedly, the attractiveness of WiMAX lies in OFD multiplexing. The beauty in OFDM is in its ability to resolve for the multi-paths (multiple paths that the transmitted signal can take to the receiver antenna) and provide increased capacity in harsh environments more effectively. We would even go so far as to say OFDM is the future of wireless.

The proponents of WiMAX often argue that the current 3G/WCDMA air-interface has fundamental capacity limitations for high-user loads. Accordingly, they see the future mobile communications standard, including those proposed for 4G evolving (sooner rather than later), into an entirely new modulation scheme based on OFDM. By association, since this is the technique also used by WiMAX, this enables them to pitch WiMAX as 4G and available today. A claim which misses the point of what 4G is all about (see last section – *Which road leads to the convergence of broadband and mobility – or 4G*).

An issue with switching to OFDM is that, as a completely different modulation scheme from say 3G/WCDMA, it would require new radios and hardware.

It is generally understood that rather than be a single standardized high-speed air interface and network infrastructure, 4G will be a system that will include an amalgam of several different networking and wireless access technologies. Each cooperating and combining into a seamless pool of available network resources in a manner reflecting the user's personal preferences. The paradigm is often referred to as "Always Best Connected". Think of it as using the right tool, at the right time for the right job - handed to you via a trusted tradesman's aid.

An issue with switching to OFDM is that, as a completely different modulation scheme from say 3G/WCDMA, it would require new radios and hardware. The only way to protect mobile operators' investments in 2G/3G would be to combine OFDM and W-CDMA in handsets, a difficult and presently expensive endeavour.

Significantly more capacity than DSL and cable?

If you want 70Mbps, your range will have to be reduced. If you want 70km then the data rate will be reduced. No ifs or buts.

There is a misconception that WiMAX will deliver 70Mbps from each base station over distances of up to 70km. This is a similar misconception as 2Mbps over the GSM cell in the early days of 3G. We would be willing to concede that each of these claims could well turn out to be true individually, given ideal or controlled circumstances, but they are not simultaneously true.

As we said, Range (coverage) and Capacity (data speed) are a trade-off. The number of bits of information that can be transmitted without error per second over a channel of given bandwidth is defined by Shannon's law. This is a roundabout way of saying that if you want 70Mbps, your range will have to be reduced. If you want a range of 70km, then the data rate will be reduced. No ifs or buts. Improvements in air interfaces (OFDM) will help, but Shannon's Law still holds. MIMO will help further, but the use of MIMO will be in no way limited to WiMAX.

Ultimately, the achievable data rate of any wireless systems depends on the bandwidth allocation, spectral efficiency, power levels, type of modulation technique, frequency of operation, type of antennas and whether the operation is an NLOS or LOS.

System Capacity 101

At frequencies around 7GHz and below, the wireless signal is impaired by phenomena such as scattering through foliage, reflection off buildings, interference from other wireless signals, and diffraction of the radiated energy. As a result, data rates for NLOS will always be significantly less due to multi-paths than having a clear, unobstructed line-of-sight path between the two end points of the wireless link.

Several examples may serve to clarify. Let's say the bandwidth allocated to a WISP is 10MHz and this operator uses a high modulation rate (of say 64 QAM) with a relatively high spectral efficiency of 1.91bits/Hz. It is conceivable that a data rate of 37Mbps (downlink) per sector can be achieved. If the bandwidth allocation of the license was increased to 20MHz, then the frequently cited 70Mbps may be achievable. These are ideal (almost impossible to achieve in the field) and not real world figures.

…and real world examples

Unwired (UNW), a WiMAX-ready WISP in Australia with a network of around 80 base stations, owns a 10MHz license operating at 3.5GHz. It claims to deliver a 'modest' 12Mbps of downlink capacity per sector. Bear in mind that this is the total capacity of the entire base station sector, not the throughput available to each user as is often implied. Users can expect real world rates of 1Mbps (downlink) and 345 K (uplink). Furthermore, these rates are achieved through the use of smart "beamforming" antennas provided by Navini.

Achievable real world data rates differ from theoretical published rates because of the interaction of the environment with the message signal and the impact of having more than one user.

In the UK, Pipex Wireless, a joint venture between Pipex and Intel, recently announced that it has successfully completed the latest phase of its WiMAX trial in Stratford-upon-Avon. Powered by Intel Rosedale (802.16d) chipsets, the data speeds achieved were: 2Mbps downlink/2Mbps uplink indoors at 1.2km (NLOS); with 10Mbps downlink/9Mbps uplink using external antennas over the same distance; and 6Mbps downlink/4 Mbps uplink, using external antennas at 6km (LOS).

These data rates are comparable to current generation ADSL but significantly less than the new generation ADSL 2^{+} being rolled out by fixed line operators throughout the world and a far cry from the much touted 70Mbps over 70km.

Achievable real world data rates differ from theoretical published rates because of the interaction of the environment with the message signal and the impact of having more than one user. Operators also routinely employ traffic engineering and network contention techniques (ie, overbooking) to share the available bandwidth among several users. Assuming a contention ratio of 20:1 (similar to the ratio used by many broadband operators for their residential DSL), a WiMAX operator could offer a 1Mbps per user service to 600 customers. In order to offer a 5Mbps service at the same contention, the maximum number of customers would drop to 120 with only 60 customers being supported on a 10Mbps per user service.

WiMAX mobility?

There's probably no issue that's more confusing than the ability of WiMAX to support mobility. IEEE addressed the issue of mobility support by developing specifications for a separate version of the standard, the 802.16e, which was approved on December 7, 2005, and is still being formulated.

Since the forum adopted a different physical layer (OFDMA) for its mobile version, it has caused many complications in the roadmap. Where once the 802.16 family was intended to offer a smooth transition path from fixed to mobile systems, it has changed such that there is now no backward compatibility between 16e and previous versions of the standard 16d or even 16a.

The work to certify 802.16e products has been ongoing, and it is expected that the lab will be ready to test and certify this equipment beginning January 2007. However, this is somewhat misleading as the first wave of products based on 802.16e will actually not be certified for mobility. This will happen approximately 6-8 months later. The first wave of certified products will only address nomadic and portable functionality, something that the existing 802.16-2004 standard already offers.

Mobility management may prove to be a challenge

The IEEE standards do not define the mechanisms by which mobility management is to be achieved. Unlike, the GSM standards (over 6,000 pages) which constitute a total, functional network and services and incorporate the description for a complete mobile cellular network. These include, radio resource allocation, mobility management, numbering plans, call routing and signaling transport protocols, network databases internetworking, paging messaging systems, roaming, authentication and security protection, service definitions and accounting. Most of these functions have to be replicated somehow by WiMAX to achieve mobility as we have come to know it.

When WiMAX 802.16e refers to mobility, it really means that it provides support for a fast transition of signals that will allow pedestrian users and slow moving vehicles to seamlessly switch (or roam) between different base stations.

Achieving broadband mobility handoff in WiMAX 802.16e will be a significant challenge for the nascent standard. Mobile IP, with "slow" handoff, may be fine for web-browsing but not good enough for say voice (VoIP) or video (IPTV). These types of services require seamless connections across cell boundaries without latency.

Economies of scale and integration?

Despite claims by many firms that they offer WiMAX technology, the actual number of WiMAX 802.16-2004 compliant devices in the market is relatively small and the number of 802.16e devices is nil. Operators offering services today are often going ahead with 802.16-2004 and/or pre-standard or what is referred to as WiMAX-ready equipment promising the technological advantages of 802.16e and a guaranteed upgrade should any changes be needed for certification.

Economies in a simple dimensioning example favour HSPA

Proponents of WiMAX cite that the costs for WiMAX base station equipment are as low as <EUR5,000. However, these figures are somewhat misleading, because the price is sometimes brought down with lower-gain and less linear power amplifiers. Moreover, the predominant costs (90%) in deploying any (BTS) site are civil works. Typically these costs include site survey and negotiation, permits, cost of towers, installation, housing cabinets, antenna systems and cables, power supply and backhaul. The actual wireless equipment costs can be just 10% of the overall radio network deployment costs.

Figure 6: Cost comparison between WiMAX and HSPA

	---------- Urban ----------		---------- Suburban ----------	
(EUR k)	**WiMAX**	**HSPA**	**WiMAX**	**HSPA**
Site survey and design	4,000	4,000	4,000	4,000
Permits	1,000	1,000	1,000	1,000
Civil and electricity work	8,000	10,000	5,000	5,000
Mast	1,000	1,000	22,000	22,000
Housing/Cabinet	5,000	5,000	3,000	3,000
Antenna system & cables	2,000	2,000	3,000	3,000
Base station equipment	4,000	16,000	4,000	16,000
Total/site	25,000	39,000	42,000	54,000
Estimated range	0.7	1.03	1.7	2.5
Coverage (3-cell)	1.0	2.1	5.5	11.8
Total cost 100km^2 (EURm)	2.5	1.9	0.8	0.5

Source: Deutsche Bank

In order to highlight this, we need to have a look on the attached rather simplified network dimensioning example. Without going too much into details of the link budget, we have assumed a low cost (<EUR 5k) 4W 2.5GHz WiMAX base station and HSPA base station. Although the HSPA base station is four times more expensive, and carries slightly higher civil engineering costs due to the higher output power, and accordingly better cooling, much of the items related to the network deployment remain essentially the same. Cost difference per site is some EUR12,000 in favour of WiMAX.

Civil works define the actual costs per site.

On the other hand, the cheap WiMAX base stations carry a weaker power amplifier, which in turn means less coverage per site. As up to 90% of the costs are related to other than base station hardware, the economies are rapidly reversed. Assuming a Nordic type of urban area with low buildings and medium indoor penetration loss with dense walls and small window area, the cost difference turns to 40% favour for HSPA. As for suburban area, the difference widens to 65%; thanks to better coverage with high-gain (expensive) power amplifier.

Note that this example is applicable to a coverage-limited environment. In a capacity-limited environment (ie, on area where traffic volumes are very significant), the economies would eventually turn in favour of WiMAX.

Intel ramp-ups to start soon

In terms of availability of actual end user equipment there is very little in the market presently. Intel has virtually staked the future of its telecommunications effort on WiMAX. Its objectives are, clearly, to do for WiMAX what it did for Wi-Fi with Centrino and embed every notebook PC, PDA and mobile device with the technology.

In terms of availability, Intel is scheduled to ship its Rosedale 2 (nomadic operation) chips by early 2007, which will offer both older fixed (802.16-2004) and newer fixed/portable/mobile (802.16-2005) support. On December 12, 2006, Intel announced the design completion of its first mobile WiMAX baseband chip for notebooks and mobile devices based on the IEEE 802.16e-2005 standard, and plans to sample both card and module forms beginning late 2007. We expect this to clearly help with economies of scale, but we believe the volumes will still be below the ones seen in traditional mobile terminals.

Unlicensed operation?

Although WiMAX can be used in both unlicensed and licensed spectrum, in reality it works best and is intended for licensed spectrum.

Although WiMAX can be used in both unlicensed and licensed spectrum, in reality it works best and is intended for licensed spectrum wherein the contention among other providers and interference from other devices is minimized.

The theoretical maximum data rate for all <10GHz unlicensed bands is approximately 1.5Gbps, which is a sufficient capacity to adequately provide broadband services. Provided they can avoid interference-ridden regions through the use of complicated configurations and intelligent antennas, it is possible for an unlicensed WISP to provide broadband internet services.

However, WiMAX is able to achieve its longer distances because the spectrum in which it will be deployed for licensed service allows higher signal strength and has higher parameters in every area than those that define the use in the 2.4GHz (ISM) and 5GHz (UII) bands. That is, if you have a license you can use more power. This is extremely important from a techno-economic perspective.

Extensive coverage?

To achieve the goal of not having to search for a signal, you need a massive amount of base stations, towers and rooftop sites.

The world of wireless is full of trade-offs. As stated previously, there is a trade-off between coverage and capacity. Equally, there is a trade-off between power output and coverage – remember Shannon’s law. There is also a trade-off between frequency and coverage. As we illustrate in Figure 4, technology may move the trade-off line upward. There is no escaping the fact that you need a lot of network infrastructure.

WiMAX propagates a signal that, at most, is only twice as powerful as existing WiFi 802.11a and 1/10th that of a 3G/UMTS base station. Due to this low output power and relatively high frequency band, the coverage footprint is less than 3km in normal circumstances. Moreover, due to higher frequencies, it will be difficult for WiMAX to create coverage within and between buildings. The consequence is that the CPE antenna must be placed outdoors above rooftops in order to ensure a proper operation.

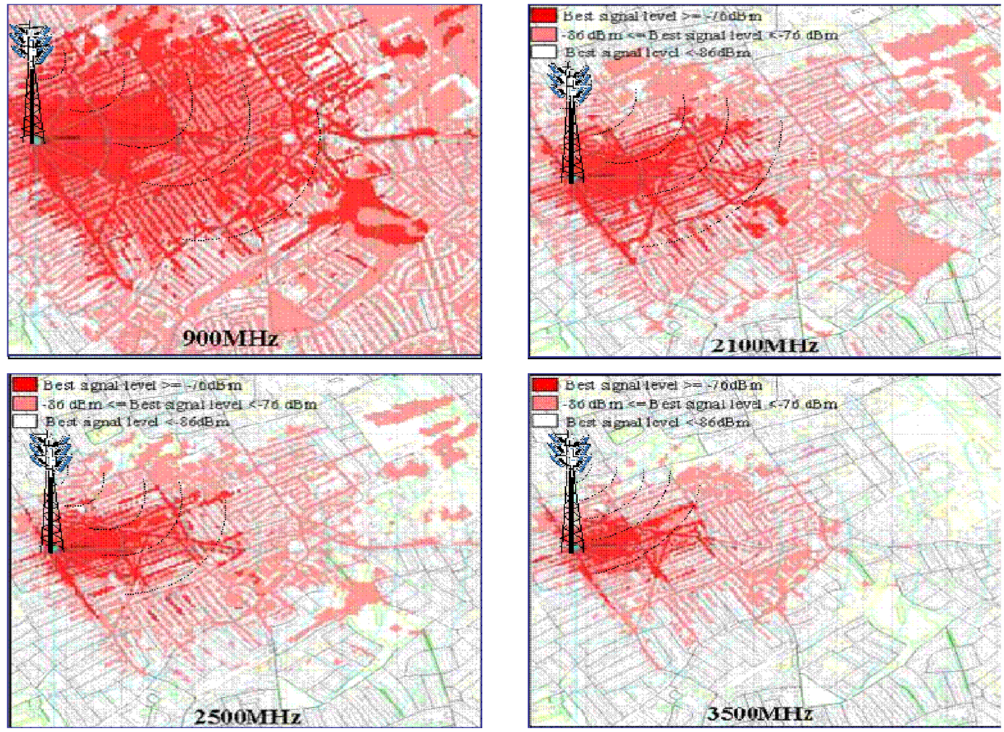
The frequency of operation has a huge impact on the deployment cost of a broadband wireless network. Typically, as the frequency increases, the network cost increases and the BTS coverage decreases.

The frequency of operation has a significant impact on the deployment cost of a broadband wireless network. Typically, as the frequency increases, the network cost increases and the BTS coverage decreases. This is why frequency bands below 3GHz are highly prized spectrum bands, but crowded, because their high-quality signals can travel many kilometres reducing deployment cost.

Conversely, the higher the frequency of operation, the lower and more fragmented the coverage which translates to increases in CapEx per km^2, OpEx as result of more complicated configuration and backhaul costs from an increased number of sites.

Figure 7 (the images from Vodafone) shows the consequences of using higher frequencies (from the same base station location and same power) which result in smaller fragmented coverage. Up to 8 times the number of base station sites would be required at 3.5GHz to provide the same coverage footprint as 900MHz and up to 4 times that at 2100MHz- simply as a by-product of operating at higher frequencies.

Figure 7: Effects of higher frequencies on coverage



Source: Vodafonek

WiMAX to replace WiFi?

WiFi often satisfies user demands for limited short-range connectivity at strategic locations.

WiFi has been revolutionizing the market for unlicensed client wireless access, both indoors and outdoors, in a wide variety of applications from the Enterprise, the SOHO/home market and in providing public access. WiFi adequately satisfies user demands for limited short-range connectivity at these strategic locations.

The large installed base of WiFi of over 100m units and chipsets that are shipping in the high 10s of millions per year suggest that it is several generations ahead of WiMAX on the learning curve. Enhancements to the WiFi 802.11 standards have pumped up the data rate to 200+Mbps and are the replacement for 802.11a/b/g while 802.11s is being developed to expand the coverage boundaries of WiFi allowing reliable mesh networks to be built.

Quizzically, there was a time when WiFi itself was considered to be the frontrunner to rule the "wireless internet" airwaves but it too did not turn out to be the wireless panacea. The business case for 'free' stand-alone WiFi hotspots (a la Starbucks) didn't stack up. It was only when mobile network operators integrated WiFi into their service portfolio to offer greater bandwidth at strategic locations, did the business case become viable. Operators such as T-Mobile, Orange, Cingular and Vodafone, have all invested heavily in WiFi hotspots across the continent to supplement their infrastructure and services portfolio.

The market opportunity for the illuminated city-wide Hotzones and municipal 'muni" networks may not be as large as many expect. Moreover it needs an operator driven business model.

We believe that the market opportunity for the illuminated city-wide "Hotzones" and municipal "muni" networks may not be as large as many believe. WiFi hotspots adequately satisfy user demands for high-speed internet applications at strategic locations while cellular networks adequately serve users demand for high speed internet access in the wide area wireless (WWAN) network. All that is required is a mechanism to manage the hand-off from the WLAN to Cellular WWAN when seamless coverage across these domains is required.

Emerging Markets opportunity?

The technology is often too expensive for emerging markets (with their limited disposable income). Since 60% of the world's mobile phone users are in emerging markets, 2G/2.5G-based services are, in many cases, more appealing.

As we have discussed, the suitability and business case for WiMAX deployment in emerging markets to bridge the so called 'digital divide' has been overstated. The technology is presently often too expensive for emerging markets (with their limited disposable income). Since 60% of the world's mobile phone users are in emerging markets, 2G/2.5G-based services is, in many cases, more appealing.

WiMAX, the DSL replacement?

This is another often touted claim that WiMAX makes sense as a suitable replacement for DSL since there is no capital to invest in putting fibre or copper wires in the ground. This is again misleading as the copper is already in the ground (no civil works). Further, the economy of extending further wireline infrastructure (say fibre) to a large extent depends on the ability to minimize further civil works costs through leveraging existing trenches, ducts, cabinets and RoW (Rights of Way). WiMAX requires the securing of sites and the deployment of new infrastructure with the ensuing civil works to install the towers, antennas and cabinets, power, etc.

When the full broadband service set is considered, the cost analyses show that the incumbent telecom operators achieve the highest average project values for all areas in terms of net present value, internal rate of return and payback period because of their ability to leverage existing assets to minimize civil works costs.

Let's face it, if you can get DSL then Fixed WiMAX access does not offer you any additional benefit.

We reiterate that the business case for deployment of WiMAX in "brownfield" scenarios where existing technologies (DSL, cable) are already in place is not viable and based on optimistic assumptions. Let's face it, if you can get DSL then Fixed WiMAX access does not offer you any additional benefit.

Global connectivity?

Rather than a harmonized frequency band across the world, WiMAX operation will be fragmented by region. This makes global or even pan-regional roaming rather difficult.

Among the strongest arguments for WiMAX is purporting global access to the Internet wherever you are in the world, because it is a global standard and will operate in unlicensed spectrum throughout the world. Still, the frequency bands are rather fragmented, in line with what we have seen in GSM, and in some cases even more. In Europe, for instance, the spectrum earmarked for WiMAX is 3.5GHz and 5.8GHz as there is a bias towards using lower bands for UMTS extension. There are, however, no spectrum allocations for WiMAX in Sweden. In the United States also, it is 3.5 and 5.8 GHz; but in Asia Pacific 2.3, 2.5, 3.33 and 5.8GHz are earmarked.

This makes global or even pan-regional roaming rather difficult. Users visiting different countries will either have to hope that the country uses the same band as their domicile or have their devices equipped with multiple modes to enable connectivity to other WiMAX-based BWA networks.

Roaming is more complex than what many think.

Moreover, seamless roaming is more complex than what many think. International roaming is facilitated by an extensive palette of Authentication, Authorization, and Accounting (AAA) principles. These principles are used as templates to facilitate interoperability, cross authentication and commercial arrangements between network operators. For instance, authentication algorithms and the subscriber's credentials in mobile phones are actually stored in a purpose-built SIM to enable roaming. These AAA mechanisms and the associated commercial arrangements would all have to be developed or borrowed and then implemented by any new or coverage-limited mobile wireless technology.

HSPA and the 3GPP contenders

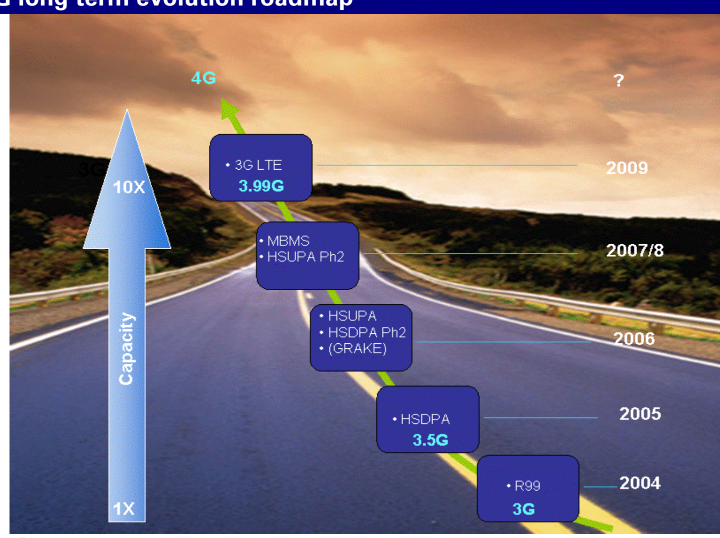
Probably, no single telecommunications system in recent history has had as profound an impact on global society than the mobile phone. In our view, 3G evolution path with its improved capacity, backward compatibility and global adoption has an opportunity to add a further dimension to this in the form of seamless connectivity to the data services when being mobile.

The roadmap from 3.5G to 3.99G

3G constantly evolving

The 3G standards, through the initiatives of the Third Generation Partnership Project (3GPP™), have been enhanced through the introduction of High Speed Packet Access (HSPA) that works to address the need for improvements in both spectral efficiency and data-carrying capacity. That is, it reduces the cost of transporting packet-based multimedia on the existing 3GPP mobile cellular infrastructure.

Figure 8: 3G long term evolution roadmap



Source: Deutsche Bank, Ericsson

Release 5 of WCDMA (finalized in 2002) introduced improved spectral efficiency and support for downlink packet data, dubbed 3.5G. It was followed by release 6 (finalized in 2005), in which the packet data capabilities in the uplink were improved. Release 6 also brought support for broadcast services through multimedia broadcast services (MBMS), enabling applications such as Mobile TV/video.

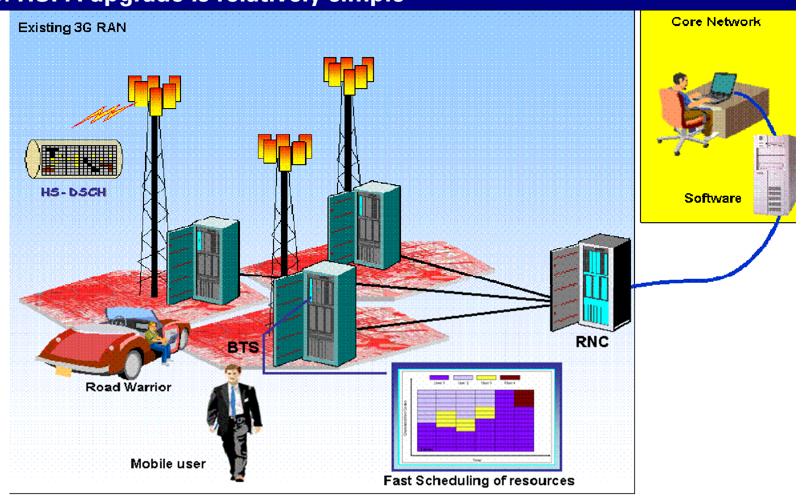
HSPA (High Speed Packet Access) - Pumping up the data rate

High Speed Packet Access (HSPA) addresses the need for improvements in both spectral efficiency and data-carrying capacity. Essentially, HSPA is a software upgrade (with minimum impact) of the network, which provides essentially three significant improvements. The first is a reduction in the latency of the data connection. This means that the time between clicking on a link and the data being downloaded is reduced by half. The second improvement is the data capacity increase, which is being pumped up to a theoretical maximum of 14.4Mbps from 2Mbps previously. In practice, data rates are likely to improve from the current 384kbps to around 1.8-3.6Mbps. The third is a reduction in the cost of transporting packet-based multimedia on the existing 3G mobile cellular infrastructure.

How it works?

Operating in the W-CDMA downlink (ie, from BTS to mobiles), HSDPA (High Speed Downlink Packet Access) mainly furnishes a high-speed shared channel called the High Speed - Downlink Shared Channels (HS-DSCH). Up to 15 of these can operate in the 5MHz WCDMA radio channel so that it can provide a higher peak rate and higher spectral efficiency. It also enables the shared channel to deal with the "bursty" nature of IP traffic (traffic generated by web browsing for example) which poses rapidly varying requirements of the amount of radio resources required, through a demand-based statistical multiplexing technique.

Figure 9: HSPA upgrade is relatively simple



Source: Deutsche Bank

For instance, in a "traditional" W-CDMA network, when a user at the edge of a cell is accessing the network at a high data rate, that affects the capacity of the rest of the cell because that one user takes up a lot of the base station bandwidth. A channel that is established at a certain data rate will remain at that data rate continually—so that one user not only takes up a lot of capacity, but could potentially occupy it for some time. Such was the static nature of W-CDMA.

HSDPA uses fast scheduling in order to better manage expensive radio resources

The improved performance gains and cost reduction is the main driver for upgrading to HSDPA enabling operators to support considerably higher numbers of high data rate users offer enhanced data services at significantly lower costs and with increased profitability.

With HSDPA, the base station can dynamically change the bandwidth allocation that's given to one user, based on the cell conditions at any one point. Users with better channel conditions are assigned higher data rates so that they require base station resources for a shorter duration, while users with poor channel conditions at the outer edges of a cell are serviced frequently. This fast scheduling greatly improves network throughput efficiency.

In order to meet the requirements of low latency and rapid resource allocation, the corresponding functionality must be located close to the air interface. That is at the MAC (Medium Access control) layer of the Base Station Transceiver site (BTS) or Node B.

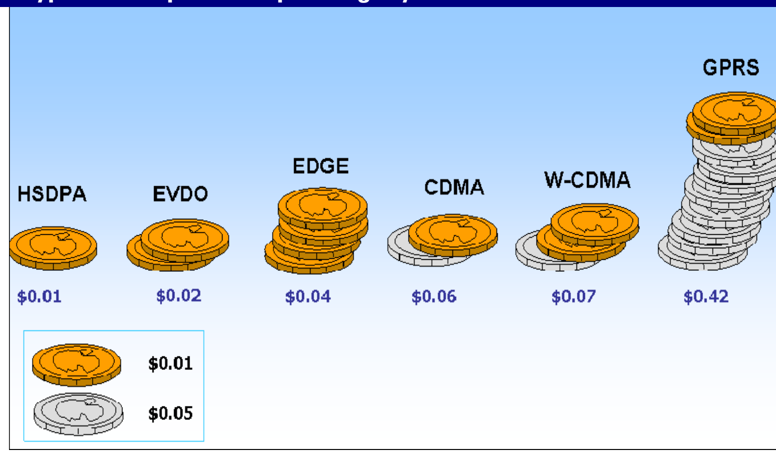
HSDPA can bring significant savings for capacity limited operators

The improved performance gains and cost reduction is the main driver for upgrading to HSDPA, enabling operators to support considerably higher number of high data rate users offering enhanced data services at significantly lower costs and with increased profitability. For operators, this translates to increases in both the number of users on the network and the amount of revenue per user.

More importantly, the transport cost per megabyte of data is lower than any other previous mobile data transport method. It is estimated that delivering a 10MB file with HSDPA will be only 14 percent of the cost of delivery with W-CDMA.

More importantly, the transport cost per megabyte of data is lower than any other previous mobile data transport method. It is estimated that delivering a 10MB file with HSDPA will be only 14 percent of the cost of delivery with W-CDMA. For end-users this means an enhanced user experience with faster connections and less delay for web browsing and downloading emails with large attachments. This also means DSL grade of access to the corporate intranet and Internet.

Figure 10: Typical transport cost per megabyte of data



Source: Qualcomm

The goal of 14.4 Mbps – reachable in theory

Independent user tests conducted on Telstra's new NEXT G™ HSDPA network found that they regularly achieved rates of 600-800kbps in the field. While in stationary office environments, the average speed reached up to 1.5Mbps.

Although HSDPA should theoretically deliver data rates of up to 14.4Mbps and the industry often cites data transmission speeds of up to 8-10Mbps over a 5MHz bandwidth, in reality, the average sector throughput is 1.8 to 3.6Mbps in a 5MHz spectrum. As spectrum is a shared resource, end users in wide-area networks can expect "real world" throughput rates of between several hundreds of kbps to perhaps a couple of megabits. Independent user tests conducted on Telstra's new NEXT G™ HSDPA network (see case study 2 – *NEXTG -3G on Steroids*) found that they regularly achieved rates of 600-800kbps in the field. While in stationary office environments, the average speed reached up to 1.5Mbps. This makes it faster than many DSL connections with the added convenience of mobility. Of course, the different throughput rates that users can expect will depend on the modulation, the coding rate, and the number of HS-DSCH codes in use. For instance, the first HSDPA mobile devices support five codes with a peak rate of 3.6Mbps (actually, the first ones supported just QSPK with 1.8Mbps data rates). Subsequent devices will support 10-15 codes with a peak rate of 10.7Mbps.

Figure 11: HSDPA throughput with different code rates

Modulation	Coding rate	Throughput		
		With 5 codes	10 codes	15 codes
QPSK	1/4	600 kbps	1.2 Mbps	1.8 Mbps
	2/4	1.2 Mbps	2.4 Mbps	4.8 Mbps
	3/4	1.8 Mbps	3.6 Mbps	5.4 Mbps
16 QAM	2/4	2.4 Mbps	4.8 Mbps	7.2 Mbps
	3/4	3.6 Mbps	7.2 Mbps	10.7 Mbps
	4/4	4.8 Mbps	9.6 Mbps	14.4 Mbps

Source: Deutsche Bank, Ericsson

A coding rate of 1/4 means that error correction takes 75 percent of the bandwidth and the user data rate is only 25 percent of the maximum. Likewise, a coding rate of 4/4 means that the user achieves the maximum data rate, but there is no error correction, and therefore many errors may result in the channel.

Also note that the peak rate of 14.4 Mbps (almost impossible to achieve in the field) occurs with a coding rate of 4/4 which, as we said, means that the user achieves the maximum data rate but there is no error correction, with 16 QAM and all 15 codes. Some equipment vendors have achieved the 14.4 Mbps in test environments using MIMO antennas.

Improvements to the uplink

Work is already well advanced on High Speed Uplink Packet Access (HSUPA) to enable the uplink data rates on the 3G /W-CDMA to be able to handle data at similar speeds to that of HSDPA.

For most applications including web surfing, emails, video downloads and the like, data flowing in the downlink (from BTS to user) is far greater than the uplink (from mobile to BTS). However, for applications such as videoconferencing, data flows are more or less symmetrical in both directions.

Work is already well advanced on High Speed Uplink Packet Access (HSUPA) to enable the uplink data rates on the 3G /W-CDMA to be able to handle data at speeds similar to that of HSDPA. HSUPA extends the uplink capability, providing peak uplink data rates of 5.76Mbps (up from typically a maximum of 384kbps in today's networks) and reduced data latency.

HSUPA enables the introduction of new services such as two-way videoconferencing and sharing other user created multimedia (eg, video podcasting) content which may prove to be solid revenue generators for operators.

Samsung demonstrated High-Speed Uplink Packet Access (HSUPA) systems and mobile phones at ITU Telecom World 2006 held last month in Hong Kong. At the demonstration, Samsung showed the capabilities of the system to handle large data files. It took one minute to upload 5 MP3 songs (assuming 3 mega bytes per song) under HSUPA, while it took five minutes to upload the five MP3 songs under WCDMA. Samsung plans to introduce the first commercial HSUPA phone in Europe by 2007.

Despite the impressive capabilities of HSPA, researchers and developers are working on additional enhancements. Release 7 of the standard will probably also include multiple-input multiple-output (MIMO) antennas for further increases in system capacity.

Backward compatibility is HSPA´s main virtue

The greatest strength of HSPA isn't the speed of its data rate, but how well it interoperates with that which has gone before.

The greatest strength of HSPA isn't the speed of its data rate, but how well it interoperates with that which has gone before. HSPA has been developed to be backward compatible with existing 3G/UMTS networks, and is already consistent with 3GPP standards. As such, operators aren't required to scrap their existing networks, but are instead offered the chance to develop on what they already have.

After circa EUR150bn invested in 3G licences in Europe alone, and some EUR53bn on 3G networks, operators have little interest in throwing away that investment and deploying a new technology simply because it provides moderate increases in data-carrying capacity. It is natural that operators are more likely to opt for broadband mobility solutions that complement and leverage their existing networks.

The main reason for HSDPA´ rapid deployment around the world is because a software upgrade to existing UMTS networks is all that is needed to support it and provide personal broadband services.

This has been supported by the fact that operators have shown a surprisingly rapid adoption of HSDPA. The main reason behind HSDPA´ rapid deployment around the world is because all that is needed to upgrade the existing networks is a software upgrade. Consequently, Mobile Network Operators are already investing heavily in HSPA, with 117 HSDPA network deployments in 54 countries. Of these, 74 networks have commercially launched services in 43 countries.

HSPA end-user device availability

According to the GSMA there are already 94 HSDPA devices launched in the market, including (27) mobile phones, (30) PCMCIA cards and (4) USB modems and (7) Wireless routers, and the number is constantly increasing. HSDPA requires just a few modifications on the terminal with no compromises on the form factor. It only adds to the existing set of features of 3G products with multi-megapixel cameras, MP3 players, microSD slots plus multi-band operation to operate on existing 2.5G and 3G networks. The availability of mobile end user devices is an important driver to the introduction of any new technology and holds the key to attracting new users. Given its importance, HSDPA is discussed further in the context of the mobile variant of WiMAX a little later.

Techno-economics and network coverage

The business case and network deployment economics modeling for implementing HSDPA have been carried out by various specialist European techno-economics research organizations. These techno-economic calculations evaluate the "economic value" of the rollout of different technologies. The key metrics being the net present value (NPV) which describes today's value of the sum of resultant discounted cash flows (annual investments, running costs, revenues, etc.), or equivalently the volume of money expected over a given period of time. The cash balance (accumulated discounted cash flow) and the point in time when the cash balance turns positive represents the payback period for the project. The results show that upgrading to HSDPA results in a reduction in the costs (CapEx) related to investments in equipment, design and implementation of the network infrastructure: site acquisition, civil works, power, antenna system and transmission compared to other technology options. Site construction & deployment costs and rents are the dominant part of the network costs with equipment costs only accounting for a 10-30%.

Furthermore, 3G/UMTS+HSDPA operator's benefits from a greater NPV than not implementing HSDPA with increasing revenues, increasing discounted cash flows, and declining running costs (OpEX). As discussed earlier, improvements in technology and better performance make it possible to not only move upwards on the Capacity-Coverage trade-off curve but lower even further the cost of network infrastructure deployments. These include site-sharing, multi-hop systems and intelligent relaying systems.

Operating frequency vs. network coverage

We highlighted previously the impact of the frequency of operation on network deployment costs. As the frequency increases, the network cost increases and the coverage decreases. And why frequency bands below 3GHz are so highly prized is because their high-quality signals can travel many kilometres reducing deployment cost. (See Figure 18)

The following example (provided by the UMTS forum) serves to highlight the impact of frequency on deployment cost. Consider a requirement to cover an area of 10,000 km^2 (~half the size of Wales, UK) and provide a modest 64kbps/384 kbps using the 2GHz band. To support this data rate would require approximately 1,980 base stations transreceiver sites. To provide the same service operating at half the frequency say 1GHz would require only 665 sites. A 66.4% reduction in the number of base stations and a resultant reduction in deployment cost of up to 40%.

Case study – lower bandwidth has given a clear coverage edge for Telstra

A concrete example is given by Telstra (in Australia) which recently launched a HSDPA-enabled 3G network dubbed NEXT G™ operating in the 850MHz, geographically the biggest 3G network in the world. NEXT G™ is more than 100 times larger than any other 3G network in Australia and covers an area of 1.6m km^2 (40% geographic coverage) which is roughly the geographical size of Germany, France ,Spain and Italy combined and 96% of the population using less than 2000 BTS. By comparison, Singtel/Optus & Vodafone 3G have deployed a (UMTS2100) shared network in Australia that covers around 37% of the population and also uses around 2000 BTS. Telstra's deployment highlights an important point regarding the leveraging of existing network assets and sites. Almost 95% of Telstra's NEXT G™ node B equipment (base station transceivers) reused existing towers, antenna systems, feeders and housing facilities presently utilized for its CDMA (IS-95A) network.

It may be argued that 3G deployments worldwide have been slower than anticipated which has fuelled criticism. But the successful implementation of HSPA, with its superior efficiency and data capabilities, in other frequency bands as evidenced by Cingular and Telstra (see Appendix A and B - case studies respectively) highlights the coverage benefits of using lower frequency bands. An optimum way to deploy 3G is to use 2.1GHz for high demand areas (city centres *et al*) and use 850/900MHz for rural and low demand areas and in-building penetration either in the form of existing GSM/EDGE network with seamless connectivity, or with lower-band versions of HSPA. This makes 3G a much more attractive commercial proposition and translates into cheaper service and more investment serving both consumers and economic efficiency the best. Frequencies bands 900MHz and below are particularly attractive as they have exceptional coverage and provide up to 25% improvement in penetration into buildings versus 2GHz+ bands.

Super 3G (aka 3.99G)

Although 3G/HSPA enhancements have tweaked and tuned the WCDMA to deliver impressive speeds up to a theoretical 14.4Mbps. W-CDMA essentially comes to a standards pause after HSDPA/HSUPA, leaving mobile operators' anxiously wondering what will get their networks up to, say, 100Mbps. Enter what is now dubbed "Super 3G", which had earlier been given the rather long-winded name of UMTS Terrestrial Radio Access Node Long Term Evolution (UTRAN LTE), and sometimes called 3.99G, or Evolved UMTS. The LTE (Long Term Evolution) is a new global standard for an even faster mobile transmission technology, which has already gained wide support from, including some of the world's largest mobile operators and telecommunications equipment manufacturers. The Third Generation Partnership Project (3GPP) has started to look at the required specifications for Super 3G /LTE that is ambitiously intended to come up with new standards by mid-2007.

Super 3G plans to reduce the cost-per-bit even further while undergoing a vast spectral-efficiency improvement to the air-interface. First, by increasing the bandwidth from 5MHz up to 10MHz, Super 3G plans to offer throughput of 30Mbps (downlink) in the wide area and more than 100Mbps (downlink) in the local area (10 times the current speed of 3G). Super 3G does not specify any particular technologies (although a robust form of OFDM has been nominated) but instead indicates a need for identifying methods for greater bandwidth that maximize the use of the radio spectrum, and that offer increased flexibility for the delivery of future services. One goal of Super3G is to enable an easy migration into all spectrums (including 900 MHz) and offer seamless mobility and hand-off between existing WCDMA/HSDPA networks.

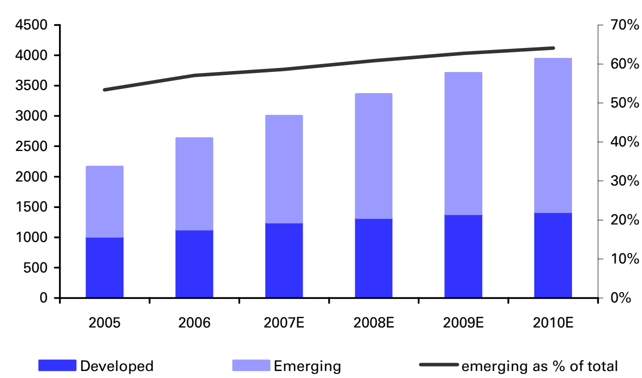
Sizing the markets

Cellular penetration continues to increase

One of the biggest challenges for WiMAX is to challenge the legacy investments on digital cellular technologies, which have cumulatively added up to over USD500bn in the course of the last 15 years. This, combined with slightly over 2.5bn users in cellular networks globally, generates substantial economies of scale for the equipment vendors, phone manufacturers as well as operators to economically maintain the complex service infrastructure that is required for offering telephony services to c.40% of the world population.

We expect cellular penetration to continue growing at a brisk rate in the coming few years, mainly being driven by the emerging markets. We expect the global number of subscribers to rise above 3bn in 2007, and the global penetration to hit the 50% mark by 2009. By 2010, almost everyone of the world's 4.5bn population with electricity should have a mobile phone. Hence, every year increases the legacy base of the existing cellular equipment in the market, and makes it more difficult for a new technology platform to penetrate into the market. Moreover, the growth is currently stemming from segments with total cost of ownership at below USD5 per month. Therefore, in order to benefit from this growth, a technology should have reached a sufficient maturity level with sufficiently low fixed-cost per subscriber in order to benefit from this side of the market volume growth.

Figure 12: Mobile phone subscribers



Source: Deutsche Bank, company data

Network markets

There are more than 130 3G networks worldwide, and the list is getting longer

After a seemingly slow start, there are now more than 130 commercial 3G/WCDMA networks in 53 countries. The first HSPA networks were launched in late 2005 and already there are 114 HSDPA network deployments in 60 countries. Due to its relative simplicity and ease of integration, we believe that HSPA will soon become an integral feature to 3G devices. We believe that it will be available in over 70% of 3G terminals in 2010. Currently, the number of HSDPA connections is some 700,000 in Western Europe.

3G market reached USD20bn in 2006

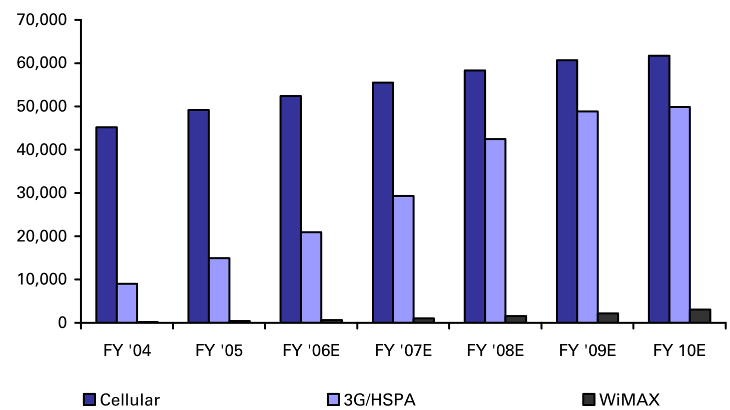
WCDMA and CDMA EV-DO variants continued at the brisk growth rate in 2006 driven by WCDMA operators' coverage expansions in Europe, WCDMA commoditization in Japan, and US drive for faster data rates. We estimate that 3G cellular market reached USD20bn. In '07-'08, the growth will continue, but drivers will change. Coverage expansions continue, and some of the operators, such as T Mobile US are just entering the aggressive growth spurt.

Still eyes are turning to Asian 3G ramps, and particularly to China. We expect the first 3G licenses in China to be announced in Q1, with investments to start in earnest in H2. This schedule may push back a share of our USD9bn growth to '08.

WiMAX markets is currently waking up

Presently, there are very few WiMAX compliant networks deployed focused on providing fixed broadband services as an alternative to wireline technologies. The difficulty arises that FBWA networks claiming WiMAX compliance are in reality either pre- WiMAX or WiMAX-ready networks promising the technological advantages of 802.16e and a guaranteed upgrade should any changes be needed for certification. Commercial WiMAX deployments are currently based on products conforming to the 802.16-2004 standard and supporting only fixed end-user terminals in both line-of-sight and non-line-of-sight environments. By comparison, the network equipment vendors for fixed WiMAX products are relatively smaller companies to the 2G/3G mobile network equipment vendors including entities such as Alvarion, Airspan, Navini, Proxim, Redline Communications and SR Telecom although Alcatel-Lucent, Nokia- Siemens, and Motorola have announced to support WiMAX in their future network products portfolio.

Figure 13: Cellular vs. WiMAX network equipment market (USDm)



Source: Deutsche Bank

We forecast WiMAX infrastructure market to post '05-'10 CAGR of 48%, which is ten times faster than that of the mammoth cellular market with CAGR of 4.6% and almost two times faster than the estimated 3G segment CAGR of 27%. Still, the low starting base will mean that the market will remain small compared to the cellular markets.

End-user terminals

End-user devices are crucial to user experience; it is the medium through which the services are accessed and information is presented. End-users already have access to a range of networking devices and contexts for performing a set of similar and different tasks. Hence it is difficult to compare apples and apples here, as in some cases, such as a PC's radio interface can be just a dummy PCMCIA card, and in mobile phones an integrated part of the user experience.

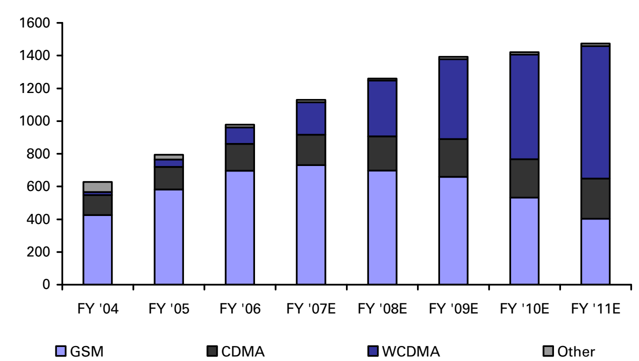
Moreover, given that both wireless technologies (WiMAX and HSPA) can be used to provide network connectivity, they are substitutive rather than complimentary from this point of view. For instance, emails can be read on desktop/notebook PCs connected to a corporate LAN or at home connected to a broadband connection. Similarly, handheld devices (smartphones, PDAs, etc) can now be used to retrieve/send email while on the move.

3G volumes to grow by 67% per annum until 2010

By 2010, we estimate that the cellular handset shipments will surpass 1.4bn. This would imply a '05-'10CAGR of over 10% in volumes. At the same time, WCDMA continues to replace 2G technologies in the mid range and high tier, leading to 640m annual 3G volumes by 2010; this implies '05-'10 CAGR of 70%. These volumes should drive economies of scale for 3GPP standards both for the benefit of operator and consumers.

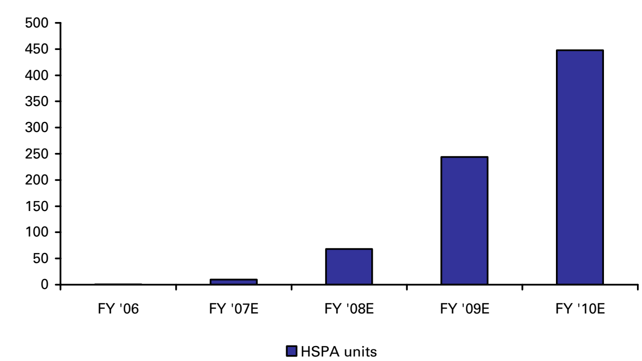
We also expect the life-cycle of mobile handsets (two years) to remain at the current level, as increasing demand for robust data communications applications, especially mobile email and instant messaging, combined with lower prices for operating systems and hardware, will drive a growth spurt in the smart-phone market. We believe that it will be available in over 70% of 3G terminals in 2010. We estimate that the global market for smart-phones will grow from 53m in 2005 and 82m in 2006 to almost 250m by the end of 2010. We also estimate that some 90% of the smart-phones sold in 2010 will include the ones with HSPA functionality.

Figure 14: Cellular handset market (m units)



Source: Deutsche Bank

Figure 15: HSPA market



Source: Deutsche Bank

The first HSDPA devices were launched in 2005, and according to the GSMA there are already 94 HSDPA devices launched in the market, including (27) mobile phones, (30) PCMCIA cards and (4) USB modems and (7) Wireless routers.

Mobile WiMAX will face an uphill battle

Mobile WiMAX (802.16e) end-user devices are yet to be introduced to the market. It is expected that 802.16e-compliant devices will not be available in quantities until 2009. The first WiMAX 802.16d-compliant devices for fixed operation were 'rabbit ear' modems followed by PC cards. Intel, the main driving force behind WiMAX, has staked the future of its telecommunications effort on the standard. Its stated vision is to do for WiMAX what it did for WiFi ie, embed the technology into silicon for laptop/notebook designs initially and then in PDA and mobile handsets. Both Motorola and Nokia have also announced support for WiMAX, and are expected to support it in some form in their handsets in future.

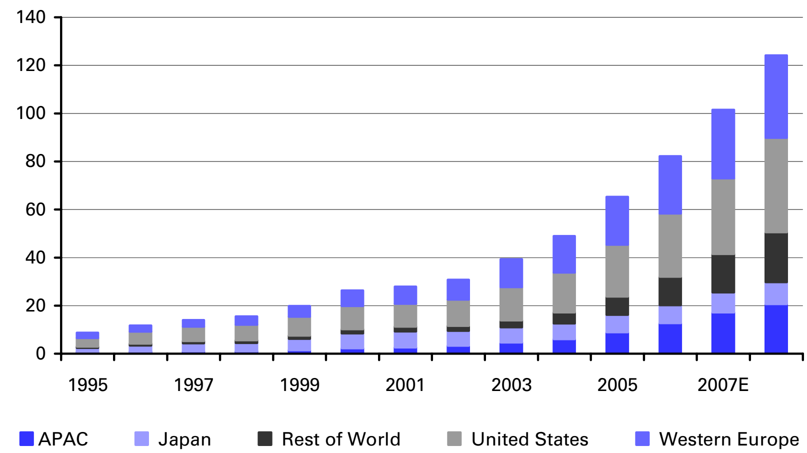
Laptop volumes to reach almost 170m by 2010E, we expect 16% WiMAX penetration

In comparison to the aforementioned mobile phone market, annual volumes of desktop PCs, (about 140m and laptop/notebook computers (80m) are significant, but relatively small when compared with those of mobile terminals. We see this as a main market for WiMAX radios, but with 16% penetration. Our reasoning is as follows:

- We see no reason to assume that desktop PCs would carry any integrated wireless wide area network solutions on an integrated basis.

- We assume that even for an average laptop user, short-range wireless broadband remains the most important application. This would imply that the WiFi evolution path would be the most applicable technology for this segment.
- By assuming WiMAX penetration of some 15% for the laptop market in Europe and the US, and 25% for Japan, and 10% for the others, the overall WiMAX-equipped laptop market would be 23m units.

Figure 16: Market for WiMAX equipped laptop PCs



Source: Deutsche Bank

Total WiMAX terminal market to be around 30m units in 2010

In addition, we believe that we will see WiMAX-enabled handhelds emerging to the market from 2008, and fully 802.16e-compliant devices from 2009. WiMAX handhelds are likely to gain some traction amidst tech enthusiasts, but we expect this demand to be limited to just a few markets. We forecast this additional demand will correspond to some 3% of the North American mobile phone market and some 10% of the South Korean market. This would boost the overall WiMAX terminal market to 29m units.

WiMAX (*802.16e*) *vs.* HSPA (*3GPP*)

It may be unfortunate but it is true when two or more technologies are close substitutes and target the same markets, a technology battle often ensues.

It is our view that WiMAX (in which we refer here to 802.16e) and HSPA are essentially substitutes. That means that either technology, in and of itself, can be substituted for the other.

From an idealist´s position, WiMAX and 3G/HSPA could be viewed as complimentary (and therefore, can co-exist) and with their own pros and cons fulfilling largely separate roles in the converged wireless technologies landscape in future.

It is our view that WiMAX (which we refer here to 802.16e) and HSPA are essentially substitutes. That means that either technology, in and of itself, can be substituted for the other. Accordingly mobile WiMAX, compelled to compete in the mobility arena where the 3GPP technologies reign, is locked in a high-stakes battle. With both technologies seeking to gain user acceptance and become the front-runner in the transition from today's cellular mobile services to next decade's 4G (mobile broadband) technologies.

Although, we recognize that each technology offers advantages and has disadvantages, in various deployment scenarios and end user markets the outcome of any dispute will undoubtedly have repercussions for each and possibly the industry at large.

External forces

In our view, any analysis of emerging wireless technologies needs to be considered in the context of all market players and the influences of external forces such as technology standards, governments, public policy and regulation, spectrum, and operator licenses.

Industry policy

Access to broadband is widely considered by government and industry groups as key to enhancing the competitiveness of an economy and sustaining economic growth. Many governments around the world are becoming more committed than ever to extend broadband networks to their citizens.

Emerging wireless technologies will play an ever increasing and important role for providing broadband access in both fixed and mobile environments.

It is clear that the insatiable appetite for broadband will be not be quenched solely by wireline technologies. Emerging wireless technologies will play an ever increasing and important role in providing broadband access in both fixed and mobile environments. Accordingly, governments are articulating vision and national technology initiatives for modernizing their country's infrastructure and enabling their citizenship to gain access to broadband. These policies and initiatives can influence the outcome in the selection between wireless technology alternatives.

Much of the global success of GSM mobile communications today can be attributed to European telecommunications policy, liberalization, harmonization of conditions of the regulatory framework which forced (and forged) partnerships between academia, governments and the telecommunications industry.

Operator licenses

The investments in the 3G/WCDMA (licenses and systems) were enormous – one of the biggest investments in telecoms history. Consequently, mobile operators try to use this resource as efficiently as possible.

The investments in the 3G/WCDMA (licenses and systems) were enormous – one of the biggest investments in telecom history. Consequently, mobile operators globally are eager to improve returns on their investment as quickly as possible.

Accordingly, this also influences both strategies and selection of wireless technologies. Operators are more than likely to opt for broadband wireless solutions that utilize these licenses while complimenting and leveraging their existing network assets.

An important point often overlooked is that the government regulators in many European and other countries require certain coverage milestones (Germany 50%, UK 80%, Sweden 99.98%, etc] in terms of the population coverage to be completed by certain dates (2007) to fulfil the conditions of their 3G licenses.

Spectrum allocation

The concept of free, unregulated access to a limited resource such as spectrum does not work if the number of its users exceeds a certain limit. A concept referred to as the "tragedy of the commons" published by G. Hardin. Regulation, coordination, rational management of uses of the spectrum is an unavoidable necessity as wireless signals do not recognize political borders and so the same frequency of operation may not be assigned worldwide. Harmonization attempts of spectrum across regions try and help wireless standards to get broadly adopted and are critical to the ability of manufacturers to achieve volume economics.

Every government around the world has a regulatory body that coordinates and decides what types of uses are permitted for its radio spectrum. Spectrum management through market forces has been put forward by some countries and has found supporters and opponents. The idea is to replace the centralized "government-controlled" system by a decentralized competitive market economy mechanism which matches the demand to the available resource capacity. Critics of the centralized approach (as it is currently in Europe) argue that relying on administrative decisions is inferior to relying on market forces. However, market forces could make wireless spectrum more expensive.

It is anticipated that new wireless spectrum will favour the extension of 3G-based systems.

In Europe, the spectrum allocations for mobile broadband wireless access services have not as yet been finalized. However, it is anticipated that new wireless spectrum will favour the extension of 3G-based systems. In any event, it is a key influencing factor.

Building the footprint (radio access network)

While both technologies attempt to address similar market segments, namely mobile users whose appetites are for much higher data rates. The key difference between HSPA and WiMAX is that HSPA doesn't require the building of a new radio access network.

The key difference between HSPA and WiMAX is that HSPA doesn't require the building of a new radio access network.

There are only a handful of WiMAX networks deployed and none are compliant with 802.16e. They are mainly deployed in urban/suburban "brownfields" scenarios serving as a fixed broadband wireless broadband alternative to DSL for users who are unable to get such services.

3GPP systems, on the contrary, are years ahead in terms of rollout. There are estimated 2m cellular (2.5/3G) base stations sites globally covering 80% of the world's population–too big a rollout of physical infrastructure for any new wireless technology to attempt to replicate.

3GPP systems are years ahead in terms of rollout. There are an estimated 2m cellular (2.5/3G) base station sites globally covering 80% of the world's population– too big a rollout of physical infrastructure for any new wireless technology to attempt to replicate.

Mobile Network Operators can leverage their existing network assets and sites resulting in huge reductions in deployment costs and increased coverage footprint. The existing installed base of 2.5/3G technologies worldwide provides a tremendous deployment advantage and gives HSPA a first-mover advantage over WiMAX in the race for personal broadband.

At this point, we again cite Telstra´s (see case study 2) leveraging of its 2,000 existing 2G sites to deploy a 3G/HSPA network covering 96% of the population of Australia in only 10 months - the fastest network deployment in the world. Cingular too (see case study 1) was able to leverage its existing nationwide cellular footprint covering almost 300m people to build the first large scale dual mode (850/1900 MHz) HSPA network.

Capacity vs. Reach trade-off

Both camps will argue their technological superiority in terms of capacity and reach. We believe (and have shown) that real world capacity claims of both the technologies have been overstated.

We have pointed out that range (coverage) and capacity (data speed) are a trade-off. If you seek capacity, your range will be reduced; if you seek range, the data rate will be reduced. In this respect, no singular technology can resolve the trade-off completely.

Improvements in technology (OFDM, MIMO et al) and better performance make it possible to move upwards on the Capacity-Coverage trade-off curve as previously stated. But there is really no escaping the fact that to resolve the capacity vs. coverage trade-off to deliver higher rates to users, mobile network operators will require building (or having access to) a vast array of sites and towers. An advantage HSPA, as part of the 3GSM ecosystem, has over WiMAX.

We believe that the lower power and frequency of operation of WiMAX (802.16e) will necessitate the installation of far more towers, antennas and rooftop sites than is being presently predicted. To reinforce the importance of the frequency of operation, we discuss it again in the comparative analysis section *Availability, Spectrum and Regulation - A little further on*.

Suffice to say that we believe that HSPA has the advantage of leveraging the extraordinarily large network assets of 3GPP-based networks globally and will adequately provide many hundreds of kilobits per second of mobile broadband services to end-users.

Mobility Management and Network Architecture

We believe that full mobility is something that WiMAX cannot yet (and may never) match even with WiMAX (802.16e).

From the outset, we have highlighted that the value of wireless is mobility. We believe that full mobility is something that WiMAX cannot yet (and may never) match even with WiMAX (802.16e). We maintain that achieving mobility is more than simply tweaking the air-interface with a new form of modulation (OFDMA).

Both WiMAX (802.16e) and HSPA only define the air-interface (physical) and MAC (Medium Access Control) layer in their specifications. Higher layer protocols are required for mobility management. HSPA has evolved from the GSM mobile communications world drawing from 20 years of experience and extensive 3GSM/UMTS specifications and network architecture in providing mobility management.

The IEEE WiMAX (802.16e) specification only nominates and provides support for fast signaling mechanisms to enable hand-off between cells but the mobility and resource management functions have been left for the WiMAX forum to sort out.

Techno-superiority versus Techno-economics

Technological superiority has been the basis of much FUD (fear, uncertainty and doubt), hype and vitriol between the two technologies.

Our view is that while WiMAX radio technology, arguably, is ahead of HSPA; this advantage in terms of capacity and spectral efficiency has been overstated or at least is misleading. As equipment for the mobile variant WiMAX (802.16e) is not yet available, no real-life measurements have been made to compare the technologies side-by-side, leaving room for only speculations, biased opinions, and hype. To which, we do not wish to add.

Based on our initial analysis, the technical differences between HSPA and mobile WiMAX (802.16e) are not seen as being very significant

Given the newness of both the technologies, there is considerable uncertainty about the efficiency of both WiMAX and HSPA in different environments, for different usage patterns, and for different numbers of users. Proponents of both camps have published results from simulation studies about the performance of their standards resulting in, not surprisingly, different and contradictory outcomes.

Based on our initial analysis, the technical differences between HSPA and mobile WiMAX (802.16e) are not seen as being very significant. We therefore have limited our analysis to the "big ticket" items affecting the key technical parameters of the systems, including coverage, capacity, cost, service and availability of networks and end-user devices. Further we maintain that technical superiority alone does not automatically guarantee success. Consider VHS versus or Microsoft Windows vs. IBM OS2 or GSM vs. IS-95. Nor does it warrant the huge expense to operators of rolling out another network.

It all comes down to Techno-economics

From the outset, WiMAX's ability to deliver new, cheaper, faster, and better services to the market hinges on Standards, Unlicensed (*operation*, *spectrum*), Volume (*economics*), and Availability (*networks and end-user devices)*. We will analyze and compare the two competitive emerging technologies in the context of each of these criteria.

Standards

When a standard is adapted, extended, or selectively implemented, (even for good reasons) its purpose is likely to be undermined. Its value declines sharply because interoperability between standard compliant implementation becomes uncertain.

Since the WiMAX forum adopted a different physical layer (OFDMA) for its mobile variant; it has caused many complications in the roadmap, and may fragment rather than coagulate the market as its interoperability (between 16e, 16d, and 16a) is not self-evident anymore.

We believe that WiMAX 802.16e mobile end-user devices will not be available until at least 2009. By which time, it may be too late!

We have pointed out that manufacturer and operator claims of WiMAX 802.16e certified equipment today is overstated and misleading. We have further pointed out that the first wave of products based on 802.16e will not be certified for mobility but will address nomadic and portable functionality only.

Given the current track record of modifications, certification delays, and availability we believe that WiMAX 802.16e mobile end user devices will not be available until at least 2009. By which time it may be too late!

On the other hand, HSDPA is defined in release 5 of the 3G standards completed in 2002 and being widely deployed throughout the world. HSUPA is defined in release 6 which was finalized in April 2005 and is undergoing trials and expected to be implemented into networks and end-user devices by the first half of 2007.

Unlicensed bands

We have already stated our belief that unlicensed operation for WiMAX is idealistic and has been overstated. The use of unlicensed spectrum while offering intrinsic benefits suffers from problems of the "tragedy of the commons" mentioned earlier where unrestricted demand for a finite resource ultimately dooms the resource through over-exploitation.

The use of unlicensed spectrum while offering intrinsic benefits suffers from problems of the "tragedy of the commons" wherein unrestricted demand for a finite resource ultimately dooms the resource through over-exploitation.

The unlicensed bands are already utilized by a plethora of wireless technologies for personal and commercial use. Premier amongst them is WLAN (Wireless Local Area Network - that is WiFi) which has been garnering increasing market acceptance for short range wireless connectivity. Other wireless technologies operating in unlicensed spectrum include Bluetooth, cordless phones, microwave ovens, wireless video cameras and motion detectors to name but a few.

The license-exempt National Information Infrastructure (UNII) band covering the higher 5GHz band is, not as populated (although we believe no WiMAX profiles exist yet), requires line of sight and works only at shorter distances negating the potential coverage value of WiMAX.

We therefore do not accept the claims of its use in license-exempt frequency bands and strongly believe that WiMAX is essentially a service level agreement (SLA) technology intended for licensed spectrum.

Availability - spectrum and regulation

We have discussed how any broadband wireless access network's performance and viability is determined by the evaluation of four key system parameters.

- Coverage – which determines Base station density
- Capacity – the total capacity able to be served by each base station
- Spectrum – Bandwidth efficiency Bits/Hz is critical to network cost
- System Cost – Infrastructure costs, spectrum costs, end-user device costs

As stated previously, HSPA operates globally in the harmonized spectrum in the 2GHz bands and at 850MHz in Australia and at 850MHz/1900MHz in the US (Cingular - see case study 1). We believe that sub 3GHz spectrum for WiMAX (802.16e) systems will be difficult to find, if not expensive, and its frequency of operation will be fragmented by region.

If, spectrum permitting, WiMAX is deployed in the 3.5GHz (licensed) frequency band then we submit that the coverage footprint (at this frequency) will be limited to cell sizes of a few kilometres.

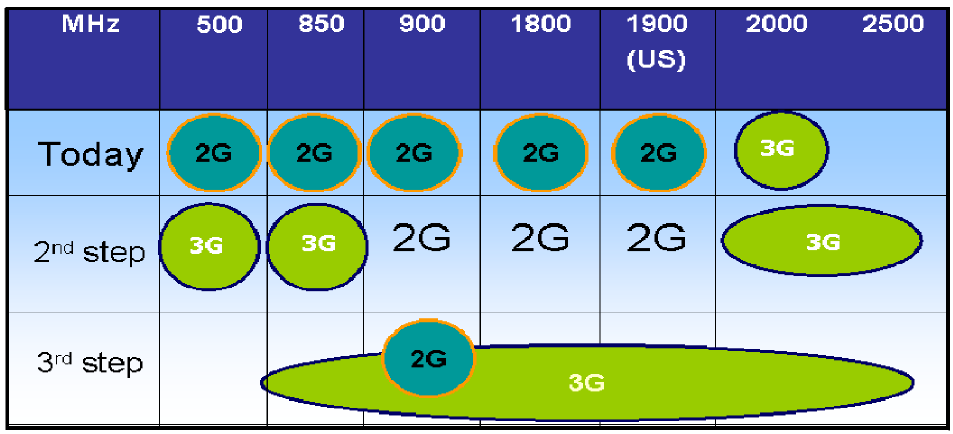
Dependant on spectrum, if WiMAX is deployed in the 3.5 GHz (licensed) frequency band then we submit that the coverage footprint (at this frequency) will be limited to cell sizes of a few kilometres. This will necessitate a large investment in physical infrastructure to provide contiguous coverage for mobility.

Although spectrum allocations for mobile broadband wireless access have not been finalized, we strongly believe that policy decisions particularly in Europe, will favour the IMT2000/3GPP-based technologies and their extension into other bands namely 2500MHz and 2690MHz.

We strongly believe that policy decisions, particularly in Europe, will favour the IMT2000/3GPP-based technologies and their extension into other bands namely 2500MHz and 2690 MHz.

We also believe there is a strong likelihood that lower spectrum bands (850/900MHz *et al*) with their far superior coverage/penetration capabilities and deployment economics are being considered for W-CDMA enabled with HSPA in the future.

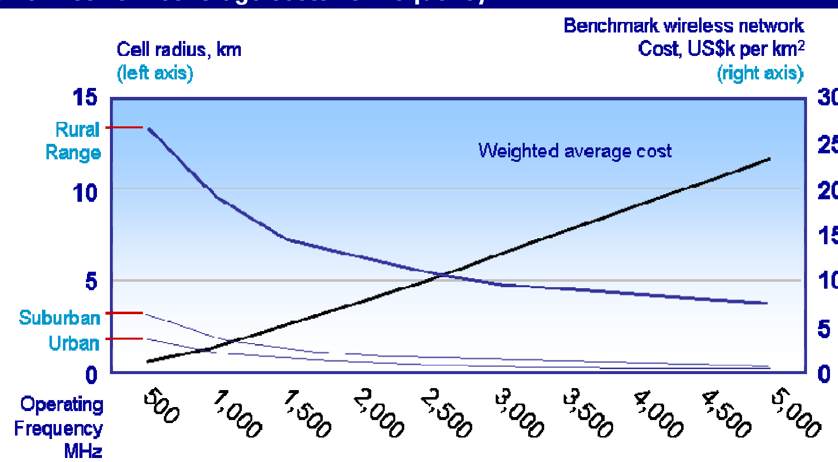
Figure 17: Possible 3G future frequencies scenario development



Source: Deutsche Bank

We have cited that commercial HSDPA networks have already been deployed on 850MHz; 1900MHz and 2100MHz bands (see case studies). By decreasing the frequency of operation to say 900MHz or less, the coverage footprint increases significantly resulting in reduced deployment costs (up to 40%) and fewer sites (up to 60% reduction) with less environmental impact compared to the existing 3G/UMTS (2.1GHz) band.

Figure 18: Network coverage costs vs. frequency



Source: Deutsche Bank, Investech

We believe that operators will seek out these optimum deployment scenarios for the extension of 3G services. Using 2.1GHz spectrum for high demand areas (city centres, urban, *et al*) and use 850/900MHz for rural and low demand areas and in-building penetration.

In anticipation, mobile handset vendors have been already shipping multi-mode smartphones that operate W-CDMA at 850MHz, 1900MHz and 2100MHz frequencies.

In November 2006, Nokia and Finnish telecom operator Elisa carried out the world's first WCDMA/HSDPA data call on the 900MHz band in a commercial network. While O2, Manx Telecom, Lucent Technologies, and QUALCOMM recently conducted a 3G UMTS/HSDPA field trial using 900MHz spectrum on the Isle of Man.

Volume economics

Wireless telecommunications is an R&D-intensive endeavour where the stakes are high and returns are uncertain. The theory goes that prices fall by increased production volume, giving *de facto* winning technologies an additional advantage. As electronic equipment becomes very cheap, maintenance, service and physical infrastructures as masts, buildings and cables will become the dominant part of costs.

We do not believe that volume economics in silicon for WiMAX has yet manifested due to the small market penetration of the technology.

For instance, initial price points for 1st generation WiMAX-based equipment exceeded 2nd and 3rd generation proprietary equipment (see Figure 19). Therefore, volume economics will have a much greater impact on end-user devices when, and if, the technology is embedded into silicon, than on BTS.

Large production volumes crucial to amortizing the R&D expenditure

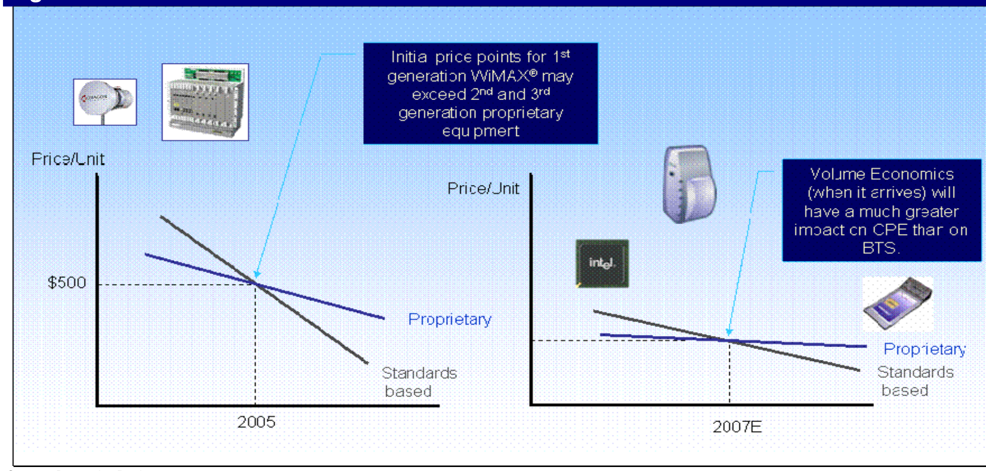
As described above, the cost structure is also driven by adoption levels of the technology. Wireless technology is an R&D-intensive industry. For instance, Ericsson alone spends EUR8.9bn per annum on research and development of telecommunications equipment and related applications. In order to amortize such an investment, equipment vendors need substantial volume economics. This can be reached either with high market share in a niche, or smaller share in larger, albeit more competitive market.

We do not believe that volume economics in silicon for WiMAX has yet manifested due to delays in compliance and the relatively small market penetration of the technology.

Claimed declines in WiMAX-based equipment prices relative to proprietary BWA systems are largely due to the lower frequency of operation (<5GHZ) and use of inexpensive off-the-shelf components (achieved from other technologies operating in unlicensed bands) in which WiMAX hopes to operate.

We submit that the fertile ground of over 2.5bn users operating in harmonized spectrum is an incentive enough for WNEV and component vendors to pursue the 3GPP-based cellular market and drive down the cost curve, while simultaneously driving up their capabilities curve. Just as the significant market penetration of mobile networks and phones has helped both vendors and operators reap unparalleled economies of scale.

Figure 19: Volume economics



Source: Deutsche Bank

Moreover, we maintain that focusing solely on equipment cost reductions to draw attention to network deployment advantages is misleading. We have illustrated that equipment costs represent only 10-30% of the deployment cost of a BTS. The predominant costs are made up of civil works, namely site preparation, towers and antenna systems, cabinets, and power. Unfortunately, volume economics in silicon doesn't apply to real estate, civil works and labour.

Availability of networks

The proponents of WiMAX have somewhat of a chicken-and-egg problem in terms of supporting WiMAX, particularly the mobile and portable/nomadic form, in that they need networks to drive interest in the chipsets they plan to embed in their notebooks, PDAs and potentially mobile phones. However, without these end-user devices being available and competitively priced, operators are reluctant to deploy network infrastructure. Which in turn means PC manufacturers will not embed technology in their notebooks. Intel, the main driving force behind WiMAX, has staked the future of its telecommunications effort on the standard. To that end, they have headed standards bodies, built chipsets, and subsidized a lot of early network development. Intel has invested into dozens of start-up vendors and operators including Navini (equipment - $17.5m), Clearwire (WISP -$600m), Unwired (WISP-$37m), to name a few. By investing heavily in start-ups, Intel hopes to ensure that WiMAX networks will be deployed. Intel's World Ahead Program is an initiative which invests in emerging market communities worldwide to accelerate access to technology.

In the process, it is putting mobile network operators - who have not been great supporters of the technology - on notice that Intel (and WiMAX for that matter) is not their partner. Despite almost $1bn of investments, there are still very few fully compliant commercial WiMAX networks in the world today. Almost all of these networks are based on WiMAX *(802.16-2004) supporting mostly fixed applications and/or portability at best. We believe that no wide-scale deployments of WiMAX (only trials such as Pipex) have been announced in Europe. In contrast to the vast installed base of over 800 3GPP/GPP2-based cellular networks spanning the globe, the number of WiMAX networks pales into insignificance.

The lack of fully compliant WiMAX 802.16e equipment and end-user devices (not due to be available till 2009) will give HSPA a first-mover advantage resulting in vast areas of the globe being covered by cellular networks that can efficiently provide "real world" data speeds of many hundreds of kilobits per second of reliable mobile wireless access.

Equally, public WiFi hotspots are also being installed worldwide at a rapid pace adequately satisfying user demands for limited short-range connectivity at these strategic locations. Their successful deployment has fuelled the need for inter-working mechanisms between Public WLANs and WWAN technologies such as cellular mobile data networks. In response to this need, several standardization bodies worldwide and mobile network operators have started to consolidate WLAN (WiFi) and WWAN (cellular), which could satisfy their users´ demand for high speed internet access without sacrificing the huge investments made in the cellular network infrastructure.

Enabling end-users to seamlessly access multiple networks is crucial to the end-user experience and the appearance of seamless connections across network boundaries. Although it is relatively easy to deploy a hotspot, it is often not easy to sustain enough traffic to provide enough revenue from a single location. The ability to offer roaming between WiFi hotspots and cellular networks provides a welcome additional revenue stream for operators. Two key issues, however, which need to be resolved are security and end-user authentication. By placing the SIM smartcard at the heart of the security mechanisms handling access to WiFi networks, allows 3GPP-based operators to extend their services without substantial investments in infrastructure or development.

The extensive palette of Authentication, Authorization, and Accounting (AAA) principles, coupled with the numerous regional and global alliances of 3GPP operators, places it with a distinct advantage over any emerging and potentially disruptive wireless technology.

Finally, no matter how useful the cellular-WLAN integrated network may be, its respective research should be seen as an important step towards a much greater goal, which is a heterogeneous network architecture that, with the support of several different access technologies and a common IP core network, would take us closer to realizing the promise of 4G.

Availability of end-user devices – the tipping point

The availability, form, function and price of end-user devices will be a key driver and influencing factor to the success or failure of competing technologies and future telecom services.

The availability, form, function and price of end-user devices will be a key driver and influencing factor to the success or failure of competing technologies and future telecom services. New visually appealing multimedia services require additional functionalities to be included into end-user devices and service usage will depend on their capabilities. It is here we believe the tipping point for the adoption of personal broadband wireless technologies and services lies.

From the end-user point-of-view, comparison between WiMAX and HSPA does not reveal any significant differences between the two technologies: both are aimed at similar uses. Both camps believe that the initial target for the technologies is to provide broadband connectivity via device equipped air-interface to the business road warrior (who needs to gain itinerant access to the corporate intranet and internet while on the go). At a later stage, through scale to extend the market towards multimedia-savvy consumers.

Although we might concur that the market consists of both business users and consumers willing to have broadband connectivity for their notebooks and mobile phones, we argue that it is not sufficient to match only the end-user needs with specific technical characteristics of the standards; the technology has to find acceptance on all levels of the (CEWEN) network.

End-users, both consumers and business, have a need to use certain applications in certain contexts. In different contexts, different groups of devices are available, with different characteristics such as aesthetics, size and usability. (See Figure 20)

The battle for the road warrior

While ostensibly a philosophical argument, we believe the world is becoming increasingly mobile-centric. End-users (both business and consumer) will soon have a myriad of choices to access information and entertainment on the go. While we agree that initially the CEWEN market consists of both business users and consumers wishing to have broadband connectivity to their notebooks and mobile phones, we differ on the nature of their use.

We believe the market solely for the notebook carrying road warrior requiring multi-megabits per second while on the move may not be as big as the industry believes. We cite commercial networks such as IP Wireless, iBurst and EVDO which adequately support mobile broadband connectivity to notebook carrying users today and yet traction and user acceptance for these services have been somewhat lacklustre. An important ingredient is missing.

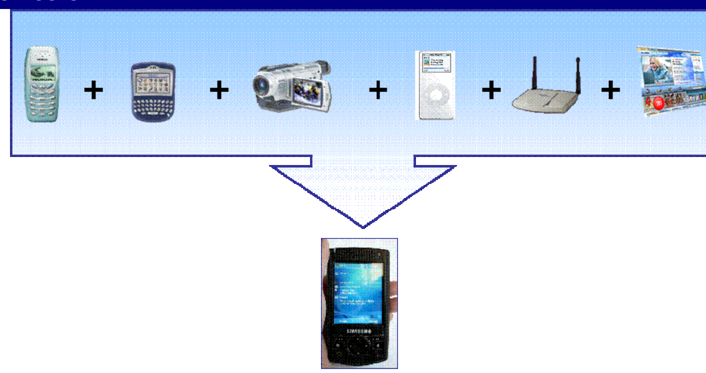
This leads us to deduce that the larger market need for mobile broadband access is not just simply replicating the PC-centric use of broadband access today extended to the wireless domain. It is providing access to information and entertainment to users while on the go in a highly personalized and controlled way - in a manner which combines the best of both (Fixed and Mobile) worlds. Some define it as FMC (discussed previously). We like to define this as the concept of personal*ized* broadband mobility. The vision of a mobile WiMAX-enabled notebook carrying road warrior (or nomadic user), while needed, is symptomatic of a PC-centric view of the future. One of the main problems with the PC-centric view is that it presupposes that the manner and means by which we currently access the internet (that is via a PC) will be the manner in the future. In our introduction we stated that the world is evolving from one in which almost all access to the internet comes via the PC, to one in which small 'smart' mobile computing/communications devices are expected to make up for a growing share of the end-user equipment. That is, information will no longer be bound to the desktop or laptop PC.

Smartphones subsuming a lot of the notebook function

We are not advocating the ditching of notebook PCs in favour of smartphones. Both are needed and are complementary in the sense that each is preferred by users in different contexts and for different applications. From the end-users´ perspective, whether a technology is complementary or substitutive depends on how well it provides function, additional value and enhances the user experience. If we are to assume the initial market opportunity is mobile broadband wireless connectivity to notebooks, then this raises the question of what air-interfaces should be accommodated on the device. Many of today's notebooks already have Infrared, USB, Ethernet, Bluetooth and now WLAN (WiFi). The advent of ultra-portable notebooks means there is limited space for all interface types to be accommodated. Add to that the complicated requirement of adding WWAN air-interfaces and high gain antennas.

Since both mobile WiMAX and HSPA are substitutes, then we believe that the vendors of these devices will take into account the end-user demand, market size, network availability and future mode of operation. Since WiMAX 802.16e devices are not available today and chipsets are not due for sometime as well, this will lead notebook and PDA vendors to favour 3GPP-based WWAN air-interfaces. There is no point in denying that many end-users will probably prefer conventional notebook PC devices over handhelds for accessing internet content and services. But many of the features that were exclusively in the computer domain have leaked into mobile handheld devices. Already, smartphones (equipped with email/messaging, etc) of the BlackBerry type and their ilk have addressed the need of the road warrior and other mobile users for retrieving and sending email while out of the office environment. Because of their expanded storage capacities, you can usually store documents, contact information and other applications on them. You can also synchronize such mobile handheld devices with your office intranet or desktop PC environment. Many scaled-down versions of popular browsers exist now for smartphones equipped with good quality colour displays, providing both narrow and original modes for viewing web pages in the same layout as on a PC. Many of the latest smartphones are also equipped with music and video capabilities replacing multiple and separate devices into one hybrid personalized package that uses can carry almost everywhere.

Figure 20: Smart-phones embedded with cameras, messaging, music players, WiFi and web browsers



Source: Deutsche Bank

Interestingly Martin Cooper mentioned earlier that he didn't carry a mobile phone until they weighed less than 4 ounces (~113 grams). Before that it was too heavy. Many of today's popular 3G smartphones weigh less than 110grams and are less than 16mm thick.

Although many end-users may choose to have multiple devices (notebook, PDA, music player, camera and mobile phone), each capable of unique functions and serving a unique purpose, there is only one device that they carry almost everywhere – the mobile phone. When it is embedded with even more features including multi-megapixel image/video cameras/recorders, music players, email/messaging, document handling, gaming, then it will truly warrant the title of a personal broadband communicator.

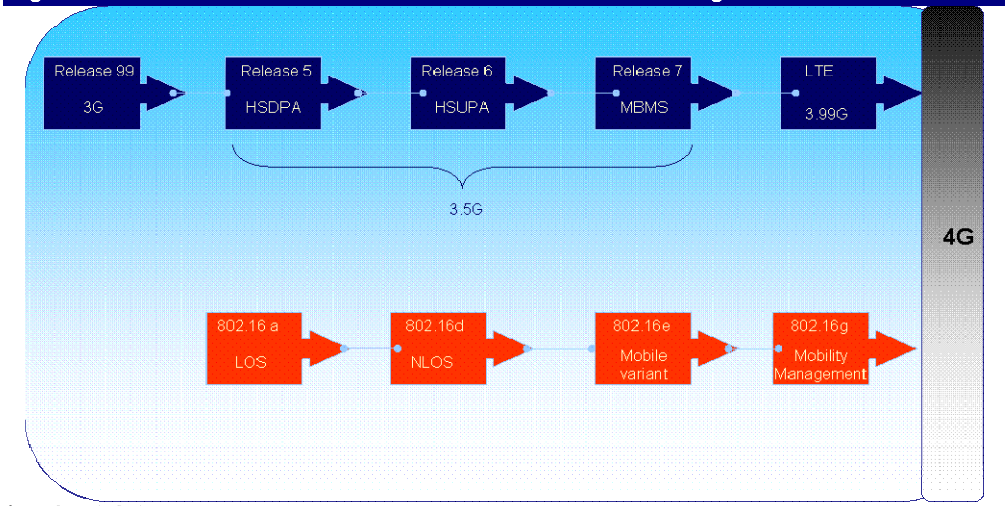
The advent of HSPA finally signals the coming of age of mobile communications, providing the capacity and throughput to marry mobility and the Internet and bring about the converged future that has been promised.

Which road leads to the convergence of broadband and mobility – or 4G

The two competing emerging wireless technologies will continue to position themselves for the fourth generation (4G) systems. Which one will prevail? To answer this, we take a look at the key objectives and goals of 4G systems to see which of the technologies is more aligned to those objectives and goals.

Since 4G systems are not uniquely defined and the term 4G means different things to different people, there is a need for a high speed air-interface capable of 100Mbps or more to enable access to the internet with Quality of Service certainly being one but not the only requirement. Presently, there is no single wireless technology good enough to replace all existing technologies, along with the huge investments required in wireline and wireless network access infrastructure.

Figure 21: Evolution trend of 3G and Mobile WiMAX technologies



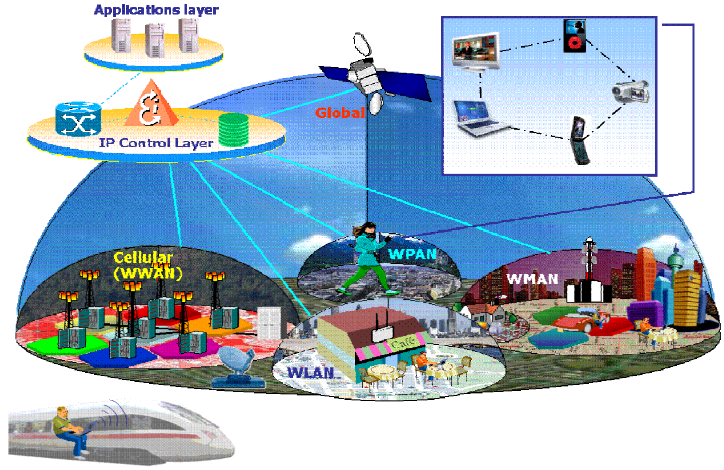
Source: Deutsche Bank

Both of the technologies discussed have embarked on an evolutionary path which will see them both get their respective air-interfaces up to the 100Mbps mark in a stationary environment and 20Mbps on the move]. But this is only one of the goals of 4G.

4G systems are expected to fulfil the requirements of "always best connected" or if you prefer "anytime, anywhere, any technology". In order to meet this difficult challenge, 4G networks are expected to encompass heterogeneous technologies forming an integrated network environment that comprises various wireless technologies (both existing and new) and other access systems in a complementary and unifying manner. This brings us to a key point, namely 4G will be an evolutionary migration interoperating technology complementing the vast existing infrastructure rather than a revolutionary disruption that dispenses with it.

By evolution, we mean it will take into account current 3G mobile technologies and integrate them with other wireless access technologies in a higher bandwidth and capacity environment. The evolutionary approach will extend to service and applications creation as well which will need to be designed to cope with heterogeneous wireless technologies. An example is the 3G/WLAN integration effort discussed previously. Although 3G/WLAN integration is sometimes referred to as beyond 3G, the concept will be extended in 4G to include many different access technologies. From a user's point of view, a common network fabric is beneficial, since this basically enables communication between various devices, over short as well as long distances, through whatever communication means that is available. This is where a common platform such as IP comes into play, making software development much easier, not only for new network and application components but also for services.

Figure 22: 4G –convergence of networks, devices centered on end-users



Source: Deutsche Bank

4G will also incorporate the user to a much higher degree (almost as the centre point) than previous generations of communication networks. In this sense, user centricity means applications and services will be developed with the end-user as a person and not as some anonymous entity that will have to use whatever the technology is capable of offering.

4G end-user devices are foreseen as highly integrated multi-technology, multi-homed (multi-interfaced) systems able to utilize a range of applications provided over multiple wireless networks. Above all, to do it at a lower cost than today in turn means volume economics. It also means minimal deployment costs, lower spectrum costs to achieve universal coverage.

In the end, if you believe (as we do) in the paradigm that adaptively supports the traffic coming from either fixed or mobile terminals and the services are provided independently of the underlying network infrastructure, but depending on the context (location, terminal capabilities, personal preferences, etc.) interacting with services and applications at home, in the office and around us, then you concur with this view of 4G.

Looking carefully at these objectives, it seems much more likely that the 3GPP/HSPA evolutionary path with its vast physical network infrastructure, evolutionary nature and services integration capabilities will move us closer to realizing the goal of 4G than any of the other emerging MBWA wireless systems discussed.

Conclusion

The two most important phenomena impacting telecommunications over the past decade have been the explosive parallel growth of mobile communications and the Internet. Consequently, the world is now evolving from one in which almost all access to the Internet comes via the PC, to one in which mobile handheld computing/communications devices are expected to make up a growing share of the end-user equipment.

The rapid evolution and increasing capacity of wireless networking technologies have opened up new possibilities for wireless delivery of broadband multimedia services and content. But arguably the real value of wireless lies in mobility. Mobility is the killer application that has freed users from the constraints of physical proximity and geographical location and empowered people to communicate and conduct their affairs from anywhere at any time.

Lines have been drawn between HSPA and WiMAX

In recognition of the value of mobility, a technology battle is looming between two technically substitutive technologies for dominance in providing Personal Broadband Mobility. The battle lines are being drawn between those in the IEEE fraternity representing a suite of next-generation microwave broadband wireless air-interfaces known as IEEE 802.16 (*aka* WiMAX). In the other corner, there is the mobile cellular industry or 3GPP fraternity representing 3G/WCDMA/HSPA.

Originally conceived as a fixed broadband wireless access system, a separate mobile variant (still being formulated) of the WiMAX standards has emerged as the frontrunner of the air-interfaces to meet the needs for personal broadband mobility. Although we consider the evolution of the WiMAX standard from its fixed roots to portable and to mobile, the focus of our analysis is a comparison of the mobile variant known as 802.16e.

Despite claims by the nascent technology, more careful examination and techno-economics modelling suggests that a secure, long-term business case can be difficult for WiMAX in mobile, and even many fixed deployment situations without resorting to rather optimistic assumptions. Accordingly, WiMAX is compelled to compete in the enticing mobility market with cellular mobile services such as 3G to avoid being marginalized as a niche fixed access solution.

Although backed by some of the ICT industry's heavy hitters, it is not foregone conclusion that mobile WiMAX will be preferred for personal broadband mobility. It will have to prove itself as a more cost-effective, more robust, seamlessly interoperable, and a generally better alternative to other technologies designed specifically for mobility on offer today. Premier amongst them is the turbo charged 3G technologies called HSPA (High Speed Packet Access).

Backward compatibility the main virtue for HSPA

The greatest strength of HSPA isn't the speed of its data rate, but how well it interoperates with that which has gone before it. HSPA has been developed to be backwardly compatible with the vast array of existing evolved 3G/UMTS networks, and is already consistent with 3GPP standards. Mobile operators have invested billions of dollars in 3G licenses and networks and as such have little interest in throwing away that investment and deploying a new disruptive technology simply because it potentially provides marginal increases in data carrying capacity.

Both camps, therefore, believe that through improvements to their respective air-interfaces, use of lower spectrum, volume economics and various enabling technologies, they can resolve the Capacity/Mobility trade-off problem. Both also promise to bring about the convergence of mobility and the Internet. Accordingly, the two technologies are locked in a high-stakes race for user acceptance with both seeking to become the front-runner in the transition from today's cellular mobile services to the next decade's 4G (personal mobile broadband) technologies.

Technical differences will not decide the outcome, economics dominates

Based on our initial analysis, the technical differences between HSPA and mobile WiMAX (802.16e) exist, but they are not seen as being very significant. OFDM has arguably a more efficient radio interface, but it lacks in terms of standardization and ruggedness. We, therefore, have limited our analysis to the "big ticket" items affecting the key technical parameters of the systems, including spectrum, coverage, capacity, cost, service and availability of end-user devices and networks.

From the outset, WiMAX's ability to deliver new, cheaper, faster, and better services and disrupt the market hinges on Standards, Unlicensed (operation, spectrum), Volume (economics) and Availability (networks and end-user devices. Accordingly, we have analyzed and compared the two different technologies on the basis of these criteria.

Standards

When a standard is adapted, extended, or selectively implemented, (even for good reasons) its purpose is likely to be undermined. Its value declines sharply because interoperability between standard compliant implementation becomes uncertain. Compelled to address the requirements for mobility, the WiMAX forum adopted a different physical layer (OFDMA) for its mobile version. As a result, it has caused some delays and complications in the roadmap. Where once the 802.16 family was intended to offer a standardized smooth transition path from fixed to portable to mobile systems, it has changed such that there is now no backward compatibility between 16e and previous versions 16d, 16a et al.

Unlicensed Spectrum

While the use of unlicensed spectrum, often cited as a great advantage by the WiMAX community, offers intrinsic benefits (namely not having to pay for it), it suffers from problems of the "tragedy of the commons" where unrestricted demand for a finite resource ultimately dooms the resource through over-exploitation. We, therefore, dismiss the claims and advantages of its use in license-exempt frequency bands and strongly believe that WiMAX is essentially a service level agreement (SLA) technology intended for licensed spectrum.

The dispute between the technologies is then as much about grabbing precious spectrum and user acceptance as it is about technical superiority. Every government around the world has a regulatory body that coordinates and decides what types of uses are permitted for its radio spectrum. These decisions influence both strategies and selection of wireless technologies and may ultimately determine their fate.

Although spectrum allocations for mobile broadband wireless access have not been finalized, we strongly believe that policy decisions, particularly in Europe, will favour the IMT2000/3GPP based technologies and their extension into other bands, namely, 2500 and 2690MHz. Further, we also believe there is a strong likelihood that lower spectrum bands (850/900MHz et al) with their far superior coverage/penetration capabilities and deployment economics are being considered for W-CDMA enabled with HSPA in the future.

Volume Economics

Wireless telecommunications is an R&D intensive endeavour where the stakes are high and returns are uncertain. In order to offset pricing pressures and achieve volume economics, Wireless Network Equipment vendors need a sufficient market space, and therefore, prefer to sell into a large installed base with broadly adopted standards. This is usually more profitable than competing for initial business and critical to the ability of manufacturers to achieve volume economics.

We submit that the fertile ground of over 2.5bn mobile users, operating in a harmonized spectrum, is incentive enough for Wireless Network Equipment and component vendors to pursue the 3GPP-based cellular market and drive down the cost curve, while simultaneously driving up their capabilities curve.

Availability of network elements and end-user devices

The availability, form, function and price of end-user devices will be a key driver and an influencing factor to the success or failure of competing technologies and future telecom services. Moreover, without these end-user devices available and competitively priced, operators are reluctant to deploy network infrastructure to support them. Without networks, mobile handset and PC manufacturers' vendors are reluctant to include the air-interface in their products. This is a classic chicken and egg problem.

The key difference between HSPA and WiMAX is that HSPA doesn't require the building of new radio access network. We believe the huge existing install base of 2.5/3G technologies worldwide provides tremendous advantages of HSPA over WiMAX in full mobile use. Mobile Network Operators can not only leverage their existing network assets and sites resulting in huge reductions in deployment costs, but this first-mover advantage can also influence the decision of technology vendors as to which interfaces they can put into their mobile handheld devices and notebooks. The lack of availability of both fully compliant WiMAX 802.16e network equipment and end-user devices puts it at a distinct disadvantage which it may find difficulty to recover from.

Which road leads to the convergence of broadband and mobility – or 4G

The two emerging wireless technologies will continue to position themselves for the fourth generation (4G) systems. Although 4G systems are not uniquely defined and much confusion exists in the market as to what it is, we reject the notion that any technology can lay claim to being 4G compliant simply by tweaking its air-interface to be capable of delivering 20-100Mbps or more.

Both of the technologies discussed have embarked on an evolutionary path which will see them both get their respective air-interfaces up to the 100Mbps mark in a stationary environment and 20Mbps when moving. WiMAX is likely to get to that kind of ballpark faster, but this is only one of the stated goals of 4G.

In order to meet this difficult challenge, 4G networks are expected to encompass heterogeneous technologies forming an integrated network environment that comprises various wireless technologies and access systems in a complementary and unifying manner.

4G will also incorporate the user to a much higher degree (almost as the centre point) than previous generations of communication networks. In this sense, user centricity means applications and services will be developed with the end-user as a person and not as some anonymous entity that will have to use whatever the technology is capable of offering.

When you look carefully at these objectives, it seems much more likely that the 3GPP/HSPA evolutionary path with its vast physical network infrastructure, its evolutionary nature, its inter-working mechanisms and services integration capabilities will move us closer to realizing the goal of 4G than any other emerging MBWA wireless systems discussed.

Conclusion

In this paper, we have looked at the evolution of WiMAX from its roots as a fixed standard to portable and now on to the challenge of addressing mobility. We have briefly looked at the techno-economics of various proposed deployment scenarios and identified some of the critical issues which will make or break the business case. We have illustrated the difficulty of wireless technologies in resolving the trade-off between capacity and mobility. In the process, we have dispelled some of the speculations, biased opinions, and hype surrounding the technology.

Our attention then turned to the performance roadmap and series of enhancements of the 3GPP community for 3G/WCDMA-based networks chief amongst them being HSPA (High speed Packet Access). HSPA introduced improved spectral efficiency and support for both downlink and uplink packet data capabilities along with support for new enhanced multimedia services enabling users to realize the 3G experience that we have been promised.

Our analysis suggests that WiMAX has radio technical advantage, but the value proposition of HSPA is more compelling and more capable of providing a full personal broadband mobile service to the market, consisting of networks, end-user devices, applications and content and will find broad user acceptance. We believe that the cellular market will concentrate around 3GPP technologies, while WiMAX will find its role in several BFWA (Broadband Fixed Wireless Access) and nomadic, even in some limited mobility, applications.

Appendix A: Case study 1

Cingular, the first large scale dual mode HSPA deployment

About Cingular

Cingular Wireless is the largest mobile operator in the USA, with 58.7m active customers and cellular footprint that reaches close to 300m people. It has a strong brand and a reputation for innovation; with a motto of "more signal bars in more places", it is clearly focused on providing superior coverage and higher speeds which will be appealing to both businesses and consumers. Cingular is the product of a joint venture between the domestic wireless divisions of SBC and BellSouth. SBS subsequently acquired AT&T, renamed the group AT&T and then, in 2006, proposed a merger with BellSouth. When this is finalized, Cingular will be solely owned by the new AT&T.

Initially a TDMA operator, via its AT&T and BellSouth heritage, Cingular has been actively migrating customers (86%) to GSM over the past five years and completed in September 2006. Only handfuls remain on the legacy TDMA (IS-136) network which is being progressively turned down. In November 2005, Cingular became the first operator in the world to launch HSDPA services on a UMTS-based network. Now available in 22 cities and growing, it plans to have HSDPA available everywhere there is UMTS. Already with 20m data customers, Cingular has focused on an evolutionary migration attempting to provide the right services and tools to support different consumer behaviour.

Spectrum

The US has one of the most fragmented spectrum and licensing regimes anywhere, with no nationwide spectrum licenses. This has led to multiple mobile licenses being issued on a market-by-market basis. With little regulation over license conditions, the mobile industry became fragmented with diverse technologies, patchy coverage and incompatible billing procedures. This led to a proliferation of licensed mobile operators, many focusing on only a handful of geographical markets. In recent years, a considerable amount of market consolidation has made it easier for customers to purchase from a single provider, services that could be used nationwide without paying roaming charges.

In 2003, Cingular purchased Nextwave which in turn had purchased 10MHz of 1900MHz spectrum in several cities. In markets where the additional 1900MHz spectrum overlaps with Cingular's existing 1900MHz spectrum, the company will be able to instantaneously use the spectrum. However, in markets such as Atlanta where Cingular's existing spectrum is in another frequency, the company will probably introduce service in the 1900MHz frequency when it is cost effective to do so.

Both AT&T Wireless and its betrothed, Cingular, have a lot of 850MHz spectrum across the United States. Both currently use the spectrum for GSM, and for the newly built nationwide 3G/UMTS network. The 850MHz band offers superior propagation characteristics. So, Cingular requested equipment that would offer higher system performances when operating in this band. When a deployment in the 1900MHz was the only initial possibility, the network was designed to offer the same level of voice coverage as GSM 850, which turned out to be a major constraint on the system design when considering that a single carrier had to be used for voice and data traffic. For the same reason, the system was designed to operate with high power amplifiers able to provide the necessary resources to data users to achieve an acceptable level of performances in high traffic load.

Technology, Vendors and Network Rollout

Cingular's entire GSM 850 network supports GPRS packet data services, though in 2003, the process of upgrading to support EDGE services began. This gave customers an always-on connection and practical data rates in the 75-125kbps range. Cingular's EDGE network, the first in the US, is now the largest national wireless data network in the United States, with availability in more than 13,000 cities and towns and along about 40,000 miles of interstate highways, and accessible to 270m people.

With the acquisition of AT&T Wireless, Cingular offers even faster network speeds with AT&T Wireless' 3G/UMTS (Universal Mobile Telecommunications System) data network, which was implemented in early 2004 in selected cities.

Cingular is building on that deployment, and in November 2004, announced its plans to deploy the nation's fastest high-speed mobile wireless data network based on 3G/UMTS with HSDPA (High Speed Downlink Packet Access), offering average data speeds between 400-700kbps and bursts up to several megabits per second on capable end-user devices. Its 3G/UMTS network (rolled out in 16 markets) is the first widely available service in the world to use HSDPA (High Speed Downlink Packet Access) technology.

The Vendors providing radio access network equipment to Cingular to expand the nationwide 3G/HSPA network footprint include Lucent Technologies (its first large-scale UMTS deployment), Ericsson AB and Siemens AG. Ericsson and Lucent relate to upgrades of existing 3G systems originally deployed by AT&T Wireless prior to its acquisition by Cingular, whereas Siemens delivered the "direct-to-HSDPA" equipment from the get go, as the operator continues to build out its nationwide 3G footprint. Cingular has not released an overall figure for the cost of the network expansion but the investment for the Siemens portion of the contract is estimated at over $1bn.

By the end of 2006, Cingular had added 4000 new cell sites, increased capacity to support 14m GSM users, removed 10,000 radios from its TDMA network, and launched UMTS/HSDPA services in 16 markets.

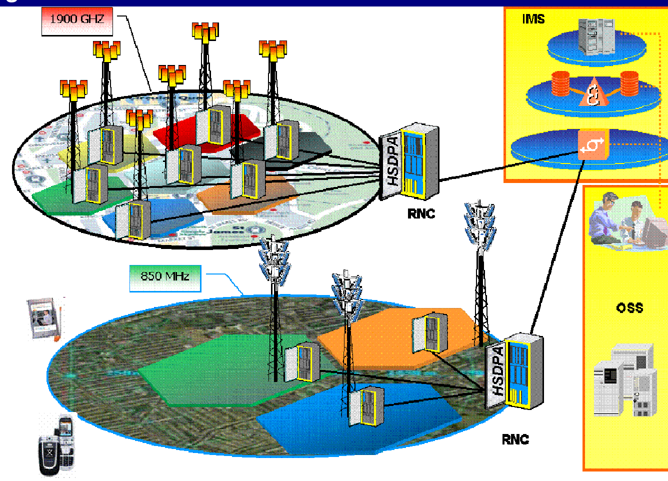
The Cingular UMTS/HSDPA network will initially support data speeds of up to 3.6Mbps (the peak speed of the first generation of HSDPA (Class 6) end-user devices. Speeds will increase later this year to 7.2Mbps as more advanced devices become available. At the same time, Cingular has awarded a contract to Nokia to enhance its existing GSM/GPRS/EDGE networks and possibly provide support for additional 3G expansions in the future.

By deploying HSDPA at the same time as UMTS, obviates the need to upgrade to HSDPA at a later date and means that Cingular's network is turbo charged with the spectrally efficient and capacity rich technology at launch. Rollout priority focused on metropolitan areas of target markets with EDGE providing the service continuity outside of the UMTS/HSDPA coverage area.

UMTS/HSDPA was deployed on a one-to-one overlay of the existing GSM network to avoid any interference issues between the two systems. Site and antenna sharing was a critical issue because of the number of technologies that needed to be supported by each site (TDMA, GSM, and UMTS/HSDPA). It was essential to avoid adding further antennas and feeders so that civil works (the dominant) costs could be controlled. Where needed, antennas were sectorized (unidirectional propagation) to avoid HSDPA performance degradation

Because of the disparity in spectrum holdings from market to market and differences in available frequency bands, the network equipment was specified to operate in two bands: 850MHz and 1900MHz. Cingular required vendors to produce handsets and cards that operated in both bands to ensure that subscribers had a nationwide coverage.

Figure 23: Cingular Dual Band 1900/850 MHz HSDPA network with IMS



Source: Deutsche Bank

The rollout of HSDPA also went hand-in-hand with the firm's implementation of convergence services using IMS (IP Multimedia Subsystem). Lucent has been selected to provide the IMS-based platform that will be used to provide voice, video, data, and multimedia services that can be accessed over different types of end-user devices, and is expected to complete the network upgrade by early 2007.

Product Strategy

Cingular's decision to go directly to HSDPA on such an aggressive schedule is, in part, related to a desire to fight back against the success that Verizon Wireless has had with its (CDMA) EV-DO services, which offer downlink performance in the region of 300-600kbps in many US markets and has helped Verizon to emerge as the preferred brand for enterprise and wireless data services. Cingular's field engineers rigorously tested the HSDPA network to ascertain the data rates and latency it was delivering. It would be important in any service launch that customer expectations were set appropriately. Using Notebook PC cards, peak data rates would frequently reach 1.8Mbps. Even in average conditions, Cingular often measured speeds in excess of 1Mbps, yet informed customers that downlink speeds would average 400-700kbps. This was to take into account the disparity in network performances when moving from an outdoor to indoor environment, or if in an urban or suburban environment or if in the slightly slower 1900MHz band than in 850MHz.

Latency (the time between clicking on a link and the data being downloaded) was also measured, as this has as much bearing on the overall quality of service for video or audio as does the outright speed. The first wave of 3G networks, based on the 3GPP Release 99 standard, typically delivered round trip latency of 150 milliseconds. Cingular's results were just 80-100 milliseconds, ensuring that the network didn't impinge on the quality of streamed or real-time applications.

For the commercial launch of HSDPA, Cingular initially offered PC-card services for mobile broadband Internet access. This remains a popular option. Marketed as "BroadbandConnect for Business", data plans start at $19.99 a month for 5MB and rising to $59.99 a month for unlimited Internet access and voice minutes bundle. Additional functionality such as remote office, intranet access and push email are also available to enterprise users.

At 400-700kbps, the speeds available to PC card users compares favourably with entry level DSL and cable modem offerings. They are also superior to those readily delivered by EV-DO. A further compelling selling point was the backward compatibility with GSM/EDGE. Customers of CDMA networks, on the other hand, would require two separate data cards to achieve nationwide coverage. Cards are sourced from three vendors – Sierra, Novatel and

Option Wireless – and available in dual-band, tri-band and quad-band versions. The latter are compatible with UMTS networks in Europe. For large enterprise customers, Cingular offers full data roaming in Europe through its partnership with Orange Business Services. Shortly after the launch of PC cards services, in January 2006, Cingular released a range of UMTS/HSDPA multimedia and smartphones for both business and consumer users. While Cingular had already been offering next generation content services like full track music downloads and streaming mobile TV to EDGE subscribers, the improvements in data rates offered by UMTS/HSDPA, provided a vastly improved user experience, and boosted non-voice revenues considerably.

In January 2007, the much anticipated Apple iPhone, a quad band smartphone equipped with GSM/EDGE and WiFi for data access, was launched and would be supported exclusively (good for six months) on Cingular's nationwide network. The device has a widescreen format supporting landscape aspect ratios for digital video clips and a touch screen soft keyboard and interface, designed specifically for the finger, not a stylus. The iPhone has several communications-based applications in the phones, including a visual voicemail feature, an onboard email client, and mobile version of its Safari browser, which provides the added utility of connectivity and communication that current iPODs lack. Undoubtedly, Apple is working on a HSDPA enabled successor which will really set the cat amongst the pigeons in the handset industry.

Cingular had already lined up a considerable batch of talented content producers such as Billboard and HBO Mobile. The latter was made available to 3G customers at $4.99 per month, for unlimited downloads of favourite clips from series like Sex & the City, the Sopranos, the Entourage and Curb Your Enthusiasm. The majority of Cingular's next-generation content is accessible through the MEdia Net portal, which allows users to personalize their home screen. Subscribers can also check email, send/receive instant messages, get ringtones, games, graphics, and watch live streamed TV channels from Fox News, CNN, ESPN, The Weather Channel, and E! Entertainment.

Competitive Advantages

While rolling out HSDPA is critical in keeping ahead of its main rivals: the CDMA operators Verizon and Sprint, the other key differentiator is superior coverage and ensuring that if 3G service is unavailable, devices could fall back to other network offerings in its arsenal – EDGE, then GPRS.

Cingular has been building out its 3G network, focusing initially on major metropolitan areas identifying and prioritizing the geographic areas where employees work, live, and travel. It is carefully focusing on consumer behaviour while gaining experience with the content going over these networks, as opposed to leaping into another technology generation with an uncertain business case. A clear advantage of HSDPA over say EV-DO (Evolution Data Only) is that users can make phone calls and surf the Web, or use the phone as a modem at the same time. EV-DO devices make you choose between voice and data: HSDPA gives you both, simultaneously.

In the deployment of HSDPA, the operator ensured that there would be a simple upgrade path to increase the uplink speed with HSUPA technology in 2007. This would be beneficial to PC card users who need to send large files and attachments by email or for videoconferencing. HSUPA will also tap into the growing interest in user-generated content, such as home videos filmed on subscribers' 3G handsets and posted to the operators' portals. Improvements in the downlink are also planned, which will bring data rates up to 7.2Mbps - considerably faster than all but the high-end ADSL offerings. The next version of HSDPA will also support Quality of Services and IP Multimedia Subsystem (IMS) enabling the rapid and efficient creation and deployment of compelling new context-based services to a wide variety of users. The improved latency of HSDPA will allow Cingular in the future to add

VoIP (Voice over IP) to the RAN to enable users to use PC softphones services when convenient and combat the threat of losing voice minutes going over the public internet rather than their cellular network. The inherent qualities of HSDPA have offered Cingular, and its subscribers, a number of benefits including:

- Improved data rates eventually leading to 7.2Mbps
- Improved spectrum efficiency equating to 3-4 times the capacity of 3GPP Release 5 networks
- Reduced cost of delivering each byte meaning lower costs for subscribers
- Reduced delay so time-sensitive video and applications perform better
- Better coverage particularly within buildings.
- Roaming and backward compatibility with GSM/GPRS/EDGE

The success of the UMTS/HSDPA rollout has reinforced Cingular's commitment to their choice in the evolved GSM technology ecosystem. The US is highly fragmented with incompatible technologies, so making the right technological choice is extremely important to any US mobile operator, irrespective of their size. From GSM to HSDPA through GPRS, EDGE and UMTS, Cingular has had a logical upgrade path which can maximize its installed investment. While the new UMTS/HSDPA network was being rolled out, voice and data services were provided by EDGE and where it was unavailable, by GSM.

Risks

To date, only three operators are actively deploying W-CDMA for 850MHz - Cingular, Rogers Wireless and Telstra. Cingular operates on dual bands 850/1900MHz as these are unique to the USA and few other markets. This somewhat limits the roaming options for its users outside of the US. GSM countries work on four different set of frequency bands, with some counties operating on few common frequencies. These frequency bands are - 850MHz, 900MHz, 1800MHz and 1900MHz. While the GSM networks in North America, Canada and a few other countries nearby are operating on 850MHz and 1900MHz bands, the other countries in the world use entirely different set of frequency bands, making the GSM-based and 3G/WCDMA mobile phones in Americas incompatible with the mobile communication systems in major part of the world. Due to this incompatibility, mobile phones need to be equipped with multi-band operation to allow them to operate in other countries. The availability of suitable low-end multi-band handsets initially was an issue and vendors were challenged to deliver them at the same cost as 3G/2100MHz devices.

Although Cingular is off to a flying start with the rollout of its 3G/HSDPA service, it faces increased competition from its 3GPP2 counterpart. In the US, Verizon Wireless and Sprint Nextel have already rolled out their EVDO service -- Verizon to more than 180 major metropolitan area markets and Sprint Nextel to 219 with claimed download speeds averaging 400Kbps to 700Kbps, and both companies are quickly ramping up for near nationwide coverage by the end of 2006 or mid-2007. Many argue that there are few applications presently, aside from certain verticals that have the need for the data performance capabilities of HSDPA. The typical business traveller leaves the house, drives to the airport, and has maybe a few minutes at the airport to sit down and do some work. He typically uses his smartphone (e.g., BlackBerry) to make calls and to retrieve email. After getting off the plane, he typically rushes to his destination. For the notebook carrying road warrior, the use of public WiFi hot spots and BlackBerrys and their ilk may be just fine.

It will be up to the mobile operators such as Cingular to entice users with a new array of personalized context-related services which utilizes the blending of voice and data applications across both fixed and mobile networks rather than just a "me too" broadband wireless connected notebook offering.

Appendix B: Case study 2

NEXT G™ – 3G/HSPA coverage on steroids

About Telstra

Telstra is Australia's largest telecommunications company and until late 2006, was majority owned by the Australian Government. It has now been effectively privatized and is pursuing an aggressive strategy to provide next generation mobile wireless voice and data service across Australia. In October 2006, Telstra launched its NEXT G™ third-generation (3G) mobile broadband wireless network globally acknowledged for its superior breadth and depth of coverage. It is also geographically the largest 3G-based network in the world. Having taken only 10 months and a cost of AUD1bn, NEXT G™ delivers unequalled high-speed, wireless broadband access to mobile phones and notebooks across Australia.

Perhaps, it is the relatively underdeveloped nature of Australia's rural wireline network, or the relative youthfulness of the Australian population profile, that Australians have taken to mobile telecommunications (98% penetration) with such enthusiasm. This is irrespective of the fact that Australia is the least densely populated (2 people/km2) continent on the planet (except Antarctica), and is also the most urbanized -- 80% of its population resides in the narrow coastal strip from Brisbane in the north east to Adelaide in the south. These factors coupled with the unique geography makes Australia a prime candidate for a mobile "wireless" access future.

Spectrum

Telstra is the only operator in Australia to own spectrum in the 850, 900, 1800, and 2100MHz bands. It is also the only operator in Australia running the 850MHz frequency nationally, as they purchased it at the government wholesale auctions 10 years ago. Next G™ presently uses 3G/W-CDMA which operates at 850 MHz using 1 x 5MHz carrier. The other carriers will be activated when its CDMA 850 network is finally turned down. The deployment benefits of operating 3GSM at 850MHz are overwhelming. To match the same coverage area of a 3GSM cell in the 850 band would require four times as many 3GSM 2100 cells (spaced evenly over that area). The use of lower spectrum significantly reduces the number of cell sites required, deployment costs, complexity and the lower number of towers minimizes the impact to the environment.

Sub 900MHz is highly prized spectrum bands because their high-quality signals can travel 10 to 200 kilometres and have better penetration into buildings. One of the stipulations of the contract was that NEXT G™ had to match the coverage footprint of the present CDMA network. No mean feat as CDMA is renowned for its exceptional coverage. Telstra's use of Nortel's boomer site technology regularly transmits up to distances of 200km a feature which the outback Australians have come to rely on. At 850MHz, the coverage and performance of CDMA and W-CDMA are fundamentally the same. While W-CDMA has the advantage of greater cost savings through global economies of scale, this wasn't the case in 2000, when the CDMA network was first deployed.

Technology and Vendors

Telstra presently operates both GSM (900/1800MHz) and CDMA (850 MHz) networks as well as a joint 3G (2100MHz) network which it shares with 3 (Hutchinson). The CDMA network operating at 850MHz was initially built to replace the ageing analogue (AMPS) network and because of its exceptional coverage capabilities. Mainly used by rural regions, CDMA covers 98% of the population and is scheduled to be phased out in 2008 to make way for the final phase of the NEXT G™ network rollout.

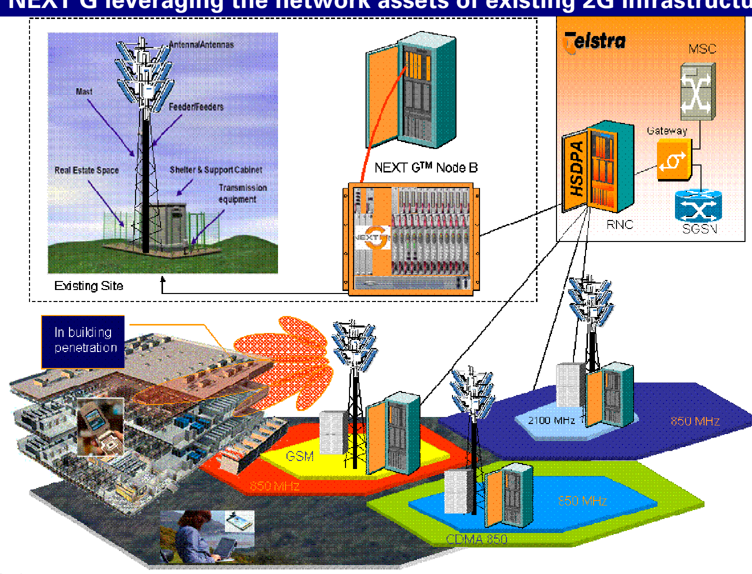
Recent technology breakthroughs and economics mean that the 3GSM services that are today delivered on the 2100MHz radio spectrum can now be delivered viably on the 850MHz spectrum, which allows propagation over far greater distances. Telstra's decision to replace its CDMA network with a 3G/W-CDMA network was based mainly on its belief that 3GSM, as part of the evolved GSM technology ecosystem, is a superior technology path. 3GSM's huge global footprint, market share and volume economics will provide evolved access to higher speeds, greater anticipated end-user device availability, and better access to applications in the future. Networking vendor Ericsson was appointed to head the construction of the NEXT G™ network footprint. The turnkey contract included the delivery and deployment of radio access equipment, core infrastructure and services in support of Telstra including design, installation, integration and project management. In order to meet Telstra's gruelling 10-month schedule for construction of the NEXT G™ mobile network, outside specialist infrastructure contractors were also required.

NEXT G Network Rollout & Costs

The NEXT G™ network is more than 100 times larger than any other 3G network in Australia with a geographical coverage footprint of approximately 1.6m km2; around 40% of Australia's area (or 96% of the population). By 2007, it will cover 98% of the population, the same as the existing CDMA network which was a contractual and political requirement. To meet the aggressive rollout schedule and dramatically reduce deployment costs, Telstra leveraged over 2000 of its existing 2G (GSM/CDMA) base station sites necessitating only an additional 100 brand new NEXT G™ sites to be built. Co-locating NEXT G™ RAN equipment with existing CDMA and GSM equipment, and utilizing the existing shelters, towers, antennas, feeders, power supplies and transmission facilities. The ability to use existing cell sites significantly reduced deployment capex costs and greatly accelerated the implementation timeline. It is doubtful that such a rollout could have been achieved in only 10 months without leveraging the existing infrastructure.

Telstra and Ericsson will continue to extend network coverage and upgrade software for faster speeds throughout 2007 in readiness for the closure of the CDMA network in 2008, by which time NEXT G™ will match the coverage footprint of 98% of the population. Over time, it is conceivable that NEXT G™ equipment will be collocated at every one of Telstra's 7000 base station locations where it ultimately will become the predominant mobile network in its fleet providing access to mobile broadband services to 9m Australians.

Figure 24: NEXT G leveraging the network assets of existing 2G infrastructures



Source: Deutsche Bank

Supped up with HSPA

Telstra was the 46th Operator to launch HSDPA and NEXT G™ is turbo charged with the High Speed Packet Access technology, providing data speeds more than 50 times faster than dial-up and up to five times faster than other 3G networks. Telstra users experience network download speeds averaging 550kbps to 1.5Mbps, and peak network speeds of up to 3.6Mbps. Independent tests have shown that users regularly obtain average speeds of 650kbps while moving around and up to 1.5Mbps while in the proximity of an office environment faster than many ADSL services.

Just two weeks after launching its NEXT G network in record time, Telstra began trials of the software upgrade that it hopes will boost the peak data rate up to 14.4Mbps by early 2007. The NEXT G core network will be upgraded with the most advanced version of Ericsson software which will enable the radio network to operate at the higher peak download speeds and will increase the peak upload speed from the current 384kbps to 1.8Mbps using High Speed Uplink Packet Access (HSUPA).

Product Strategy

In less than a year, Telstra has grown from a non-existent player to technological leader in the 3G arena. Even its product name NEXT G™ conjures up a perpetually contemporary, if not cutting-edge connotation, that alleviates the need to re-designate the technology in the future. Although the implementation of HSPA is not unique to 850MHz, Telstra has simply chosen to implement it here first and nowhere else for that matter (not even on its joint 3G 2100 MHz network). It was purely a commercial decision that enabled Telstra to secure the first-mover advantage and differentiate NEXT G™ superior coverage from other broadband wireless services. By the company's own admission, it has idled slowly until now with the NEXT G™ train running up to a full head of steam. Only Vodafone has since launched limited HSDPA (21000MHz) services in Sydney and Melbourne with Optus and 3 (Hutchinson) planning to do the same sometime in early 2007. There are already an estimated 40,000 customers on NEXT G in only three months since its launch, twice as many as that on Personal Broadband's iBurst wireless broadband service.

Both consumers and businesses are being alerted to NEXT G's promise of far reaching mobile broadband speeds. Product packages are targeting both consumers and businesses, and user options of pay by the hour, or pay by the volume. While business users have been catered to with mobile broadband speeds in excess of ADSL appealing to many notebook carrying road warriors, Telstra has clearly focused on consumers by offering exclusive Foxtel (Pay TV) on mobile, in an attempt to boost content and stand out. In contrast, Vodafone has targeted the business users offering wireless broadband for notebooks although the company has yet to launch a HSDPA capable mobile phone. Prices for NEXT G start at a very reasonable $29.95 for 10 hours of credit. Alternatively, users can pay by volume with $49.95 for 200 MB, $79.95 for 400 MB, $199.95 for 3 GB then $0.30 per MB if you exceed your limit. Plus a $0.50 connection charge. Key to HSPA success will be its usability in the rural regions especially to those disgruntled CDMA users particularly those obtaining broadband via Telstra's EVDO service that uses the CDMA network who are forcibly being migrated across. To make the transition a bit easier, these users will be given NEXT G handsets for free and attractive pricing plans.

Competitive Advantages

Telstra is the only operator in Australia to own 850MHz nationally. Consequently, it is pulling out all stops to differentiate NEXT G™'s superior coverage capabilities, from other broadband wireless services offerings. Commercials are being aired on TV showing users maintaining their connection while travelling, in and out of building, in lifts, between floors and in underground car parks, insinuating that it is almost impossible to not have coverage whilst on NEXT G™.

Some users travelling in vehicles down from Sydney to Canberra and further at highway speeds, obtained data rates of well over 1.5Mbps with latency of 100-120 milliseconds and no dropouts – truly worthy of the title mobile broadband! Telstra's focus on consumers and exclusive content is highlighted by its commitment to having 3G/HSDPA enabled smartphones available at launch each with the capabilities of viewing mobile TV and video services content. The FOXTEL by Mobile service takes pay TV out of the lounge room and onto users NEXT G™ handset and delivers 12 channels (including Sky News, CNN, Comedy Channel, FOX8, and Fox Sports) for just $12.00 per month.

In an attempt to overcome the scars left by previous attempts to access and display web content, NEXT G™ offers a simpler way to make the most frequented content accessible within 'one-click' of the top screen. By clustering the top nine services in one place, ensures a quicker experience than having to dig though menus or trawl the WAP portal. Australian businesses have long suffered from not having access to high speed mobile broadband for notebooks and smartphones that has the necessary geographical coverage to enable anywhere anytime access to their key information systems, their corporate emails and the internet. The notebook carrying road warrior has not been neglected with all NEXT G™ phones capable of being used as tethered broadband modems. There are also a range of PC card and USB modem options available for notebook PC data access.

As part of the global community of 3GPP operators, serving over 2.5bn users, NEXT G™ as part of this ecosystem has one of the world's best international roaming footprints. Not only can Telstra customers make voice calls on their Australian NEXT G™ mobile phone in more than 140 countries, but can access 3G services such as video calling and high speed data in over 50 countries. Network vendor Ericsson has confirmed that up to 10 other operators are evaluating 3GSM 850 elsewhere in the world. A number of handset manufacturers have released multi-band (850, 1900, 2100 MHz) as well as backwardly compatible (GSM/GPRS/EDGE) smartphones which will ensure that users are not left wanting for connectivity.

Risks

Presently, only two other operators, US operator Cingular Wireless and Rogers Wireless, Canada's largest voice and data operator, have deployed 3GSM networks utilizing the 850MHz spectrum. Telstra is also the only operator in the world having rolled out 3G networks using 2100MHz & 850MHz in combination. Consequently, there will be an initial challenge for them in terms of handset availability. There are some who argue that the global roadmap from manufacturers does not include many low to mid range 850MHz handsets. At the launch, only six handsets were supported on NEXT G™. Ironically, Nokia and Sony Ericsson were not amongst them. However, Sony Ericsson will have phones that will support the UMTS 850 band with HSDPA support towards the middle of 2007. That will also be the time frame for the release of handsets from Nokia. Presently there are nine supported handsets, two PC cards and two USB modems on NEXT G™.

However, the superior coverage and reach capabilities of the sub 900MHz bands and the release of the said spectrum and the availability of other networks (e.g., Cingular's 58m users) will be an incentive to ensure that many 850 and/or multi-band 3G end-user devices become available over the next 18 months. NEXT G™ is performing very well now under moderate user loads and itinerant usage and will only get better as the rollout is completed. But as with any new technology it is prone to over zealous marketing of its capacity and coverage raising customers' expectations. No mobile broadband wireless network has endless capacity, nor should NEXT G™ be seen as a wireless substitute for Telstra's NGN Fibre-to-the-Node broadband access network strategy (currently on hold because of regulatory reasons). Overzealous marketing of NEXT G™ as a cure-all for permanent broadband access to all and sundry will exhaust network capacity and degrade the performance necessitating the rollout of more network infrastructure.

Appendix C: Case study 3

Mobilkom Austria first European into the 3G/HSPA pool

About Mobilkom Austria

Austria is one of the most strongly competitive mobile markets in Europe and continues to enjoy one of the highest mobile penetration rates (110.9%). The country's subscriber base is fiercely contested by five network operators and a growing number of MVNOs, with the result that Austrians have some of Europe's lowest tariffs.

The incumbent's mobile division, Mobilkom Austria, is the dominant operator with a 38.8% market share. Mobilkom is looking outside Austria for its growth opportunities because mobile penetration has reached the saturation point and has expanded to Eastern Europe to incorporate lucrative neighbouring markets.

Land-locked by eight other countries, Austria's more than 8m inhabitants can truly say they live in the centre of Europe. The geographical terrain of the country provides varied challenges for network coverage. These range from low lying valleys beside the famous River Danube that crosses the north-east of the country through to the high, snow-capped Alpine mountains in the west that are shared with Switzerland and Italy.

Regardless, Mobilkom Austria was driven by a singular goal to become the first 3G/UMTS operator in Europe, which it did. It then set out to become the first to deploy HSDPA services only to be beaten to the punch by two months by Cingular. It launched HSDPA services in January 23 2006.

Spectrum

In 2000, Austria auctioned six UMTS licences. The auction raised around US$604m, rather than the US$2.5bn the Austrian government was said to have been hoping for. The companies that took the licences were: Mobilkom Austria AG (14.8MHz), Mannesmann 3G Mobilfunk GmbH (which was taken over by Vodafone), Connect Austria Gesellschaft für Telekommunikation GmbH (in which Orange has a 17.5 percent stake, and which is now called One), Hutchison 3G Austria GmbH, max.mobil Telekommunikation Service GmbH (which is owned by T-Mobile), and 3G Mobile Telecommunications GmbH, a joint venture between Telefonica and Sonera.

As the size of the Austrian market suggests, not all of the licence holders could actually build a business on the spectrum they acquired. Only Mobilkom, max.mobil, Hutchison 3G and One were expected to offer UMTS/3G services. Mobilkom launched its offering on April 25, 2003, and Hutchison followed suit on April 5. max.mobil and One are now up and running as well.

Technology, Vendors and Network Rollout

In April 2003, Mobilkom Austria realized its goal and became the first operator to commercially launch UMTS services in Europe and across Austria.

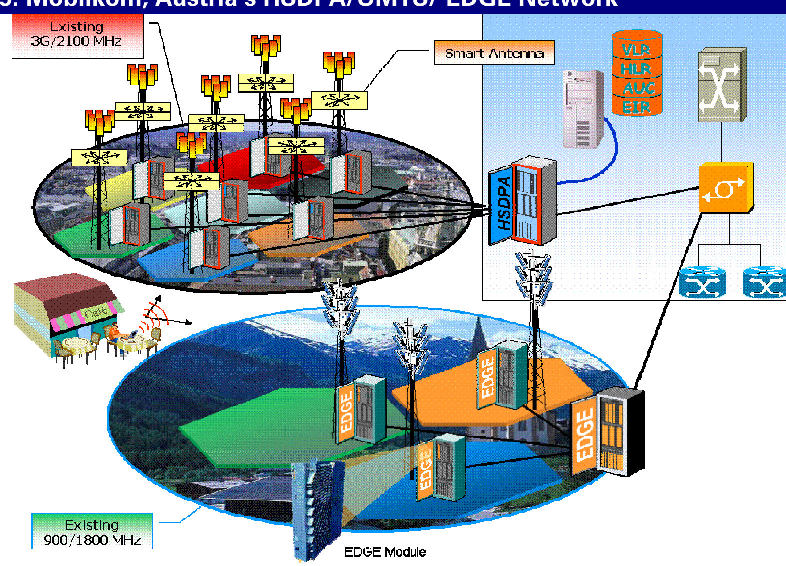
Deploying a nationwide UMTS network was an immense challenge as Austria's geographic constitution poses a number of challenges to the operator as mountains can potentially cause base station signal interference. Mobikom Austria's objective was to quickly provide coverage for the population, and therefore, these involved choosing suppliers with the experience and organization to deliver.

In June 2001, Mobilkom Austria signed one of Ericsson's first UMTS contracts. The first roll-out comprised a core network and UMTS Radio Access Network (UTRAN) and was deployed in September 2002. This was followed by a contract with Nortel Networks selected to deploy the UMTS base stations with approximately 95 percent reuse of Mobilkom Austria's existing sites. The single cabinet UMTS node B solution enabled mobilkom Austria to achieve this high rate of reuse, and thus, resulted in reducing new site acquisition costs. Nortel Networks also provided the packet and circuit core technology. CarrierCom AG undertook system integration and infrastructure deployment of Nortel Networks technology.

What's interesting about the RAN network is the use "Smart" antenna technology in combination with monitoring equipment (Symena) used to optimize UMTS base stations while expanding network capacity with existing radio equipment hardware. Symena's CAPESSO technology integrates more parameters into BS signal strength calculation, and hence, identifies how to increase network efficiency and capacity by using smart antennas at critical points to eliminate the need for higher base station density.

In January 2006, Mobilkom made an even stronger pitch to it growing base of business data customers (by then at 38.8% market share) by announcing the launch of the first commercial HSDPA service in Austria. Although not the first to do so, it was amongst the first four. Ericsson was selected by Mobilkom Austria to deploy the HSDPA network (including project management, network integration and installation, system support and optimization services). An upgrade of the network followed in June 2006, bringing download speeds up to 3.6Mbps.

Figure 25: Mobilkom, Austria's HSDPA/UMTS/ EDGE Network



Source: Deutsche Bank

One of the important initial investment decisions in rolling out the network was to offer high quality coverage, for data services, to as many people as possible. The rationale behind this decision was that the urban user would benefit from 3G/UMTS technology; and the suburban user from EDGE (Enhanced Data Rates for GSM Evolution). Today, the combined UMTS + EDGE network offers 98% nationwide coverage, with UMTS coverage amounting to 60% of the population.

On November 16th 2006, there had been a European technological premiere in Vienna. For the first time a live demonstration of video up-load via the HSUPA technology (High Speed Uplink Packet Access) was realized. This technology allows for up-load transmission rates of up to 1.4Mbps, which represent the highest up-load speeds currently available in the UMTS-mobile communication networks. Mobilkom Austria is said to planning a HSUPA trial to commence in early 2007.

Product Strategy

The interesting slant on the introduction of HSDPA is that it has not been marketed as a unique service but rather a continuation of what business users have gotten to now on their notebooks. Since the time of the commercial network launch, Mobilkom Austria aspired to offer simple price plans for usage of advanced voice and data services. Using a 3G service will incur the user no additional monthly rental and 3G voice call charges as well as SMS and MMS tariffs are equal to tariffs charged for the same services under 2G. Hence, data services can be used at much higher speeds than under 2G while incurring the same, familiar charges.

The pricing model eventually decided upon was a monthly flat rate. Following the 'KISS' (Keep It Simple, Stupid) approach, it reflected the pricing philosophy that customers were used to for their ADSL service but was positioned at a level that charged a premium for mobile access. The downlink data rates were increased in July 2006 with the launch of the 3.6Mbps connect cards and a new logo and strapline: 'As quick as lightning – web surfing at 3.6Mbps'.

Video telephony services introduced with 3G are charged at €0.50 and upwards, determined by the type of content streamed, i.e., video telephone calls, short movie trailers or sports scenes etc., without incurring extra access charges.

The investments have proved successful. The company's analysis shows that data usage has increased which is reflected in the increase of the data share of voice and data packet revenues. By the end of September 2006, 109,000 PC cards had been sold. There are special corporate pricing packages as well to further encourage the business user.

The profile of data usage is also very interesting. Network traffic analysis shows that data sessions are still increasing and follow about two hours after the peak voice traffic time. Interestingly, many of the data sessions are in the evening, implying that users are taking the office home with them and catching up on email and other work at home.

Mobilkom Austria has a service reseller partnership with Vodafone. So, the first HSDPA service utilized the Vodafone Mobile Connect Card PC cards (supporting HSDPA/UMTS/EDGE), which was launched with the initial offering in Vienna, professing initial downlink speeds up to 1.8Mbps and upload speeds around 184Kbps. In the first quarter of 2006, the service was swiftly rolled-out to more of the provincial centres. The price of the HSDPA/UMTS/EDGE card is €99 but a free software upgrade is available to those with a UMTS/EDGE card. So far, around 2,000 data cards have been sold by Mobilkom with about 1,000 further cards having the software upgrade.

The sales campaign for HSUPA is due to start in the first half of 2007. For some users, the faster uplink speeds will make a positive change to their business or operational processes. For example, film crews will no longer have to drive to a studio to upload video or use expensive satellite equipment. Soon, they will be able to send in edited news flashes transmitted directly from a notebook computer.

As of August 2006, 1.2m Austrians were already using VoIP. In response, to the threat of losing minutes of use Mobilkom recently announced a friendly customer trial called A1 over IP, which integrates the mobile phone network with over 3m customers and the world of SIP-based VoIP-telephony. The “A1 over IP” friendly customer trial enables end-users the ability to make voice over the Internet calls with a softphone application on their PCs or notebooks and also choose to receive mobile telephone calls on their softphone. This is an important step towards satisfying market needs concerning IP-based communication services. By receiving calls directed to their mobile number or by making calls on their mobility number with the softphone, customers have more flexibility and comfort in handling incoming and outgoing calls. At the same time, they can enjoy all the advantages that VoIP offers, including real-time multimedia communications, fixed mobile convergence, and increased cost savings.

Competitive Advantages

Superior network coverage is seen as the magic ingredient for mobile broadband success. Mobilkom Austria is constantly testing the quality of its network using independent institutes to ensure it always stays one step ahead. The positive combination of coverage and speed produce a significant competitive advantage, and one that will command a premium price – but it needs to be a pricing package that is simple to understand and has to be convergent with previous pricing approaches as well as alternative solutions to the mobile approach.

Mobilkom Austria has some of the lowest tariffs in Europe and combined with the philosophy of simplicity makes the entrée to high speed data services very enticing to users. Mobilkom Austria has recognized that the rapid uptake of HSDPA services depends on progressive flat-rate, unlimited-usage service plans and as such all data — GPRS, EDGE, UMTS, HSDPA, is treated the same.

Mobilkom Austria’s commitment to convergence and coverage integration is highlighted by its UMTS PLUS service. UMTS PLUS ensures that users are always able to obtain a high speed connection in any environment by combining the respective assets of both EDGE and UMTS technology to achieve the following:

- Keeping notebook PC users connected on the move
- Offering ultimate web surfing at high speeds and…
- …meeting the need to keep in contact for business efficiency and personal pleasure, wherever they were in Austria.

Risks

The country’s subscriber base is fiercely contested by five network operators and a growing number of MVNOs and has arguably reached saturation in its mobile phone market. Coupled with competitive HSDPA offerings from max.mobil, Hutchison 3G and One will put pressure on Mobilkom for it to continue offering innovative services to retain its customer base.

Mobile operators have, to date, resisted moving to flat-rate models, but if mobile operators really aspire to the data traffic volumes of the fixed world, they must also recognize the factors that have so successfully underpinned growth for fixed broadband providers.

Mobilkom’s commercial proposition was based upon a simple formula, speed and coverage for the large population of ‘mobile workers’ – those that took and used their PC on the move. A lack of market acceptance and/or failure of these users to recognize the value of mobile broadband services may impede growth in the nascent mobile data market and affect future network enhancements.

Technological substitution effects could see increased competition and/or render existing technologies obsolete necessitating substantial additional investment in network infrastructure.

Appendix D: Case study 4

Sprint Nextel attempting to marry WiMAX and CDMA

About Sprint Nextel

Sprint Nextel Corp. is one of the largest telecommunications companies in the world. With 53.7m subscribers, Sprint Nextel operates the third largest wireless telecommunications network in the United States (based on total wireless subscribers), behind Cingular Wireless and Verizon Wireless.

Last year, in August 2006, Sprint Nextel Corp. announced that it intended to build a nationwide WiMAX based BWA (Broadband Wireless Access) network to provide broadband services to customers across the United States.

Sprint Nextel, has placed a $3bn chance on the nascent mobile WiMAX (802.16e) standard as the means to provide customers with advanced broadband wireless services needed for next-generation applications.

Spectrum

Currently, the combined Sprint Nextel operation has licenses in the 800MHz spectrum, in nearly contiguous holdings, from which they operate their two voice (Sprint PCS and Nextel iDEN) networks.

Sprint Nextel also has the largest portfolio of licensed frequencies potentially usable for WiMAX -- most of those acquired in an early-90's buying spree that cost Sprint more than $1bn. These frequencies were bought not for WiMAX, which hadn't even been thought of, but for the now defunct Multipoint Multi-channel Distribution Service (MMDS), then known as "wireless cable TV." In short, it didn't work. Sprint recast the service as fixed-wireless Internet, but the same problems remained and eventually that service, too, was shut down with Sprint taking a large loss.

When combined, Sprint and Nextel's holding will also comprise a total 90MHz of the 2.5GHz spectrum region, from which it will launch services in 80 of the prime US markets.

Sprint's decision to utilise the 2.5GHz spectrum for WiMAX is obviously due to a lack of both free capacity and WiMAX profiles at the 800MHz band. Operating at 2.5GHz will reduce the cell sizes and require a greater number of cell sites to provide the same coverage as their resultant combined 2G/EVDO network footprint. This fact is overlooked amid the press hype surrounding the project.

Technology and Vendors

In order to build this network, Sprint has contracted four principal vendors as suppliers, and who are key members of the WiMAX forum, namely, Intel, Motorola, Samsung and recently Nokia. They will supply the major parts of the infrastructure ranging from chipsets to wireless network infrastructure equipment.

Intel which virtually drives the WiMAX standards initiative will be bringing to bear its expertise in silicon by way of its latest Mobile WiMAX product, the "WiMAX Connection 2250"; a dual-mode baseband chip that supports IEEE 802.16-2004 (although it is unclear whether it will initially implement the mobile standard, IEEE 802.16e-2005). Intel will be providing chipsets and design support to terminal manufacturers to bring their WiMAX-compatible end-user devices to market in this new network environment.

Motorola has also been a long-standing supporter of WiMAX and a long-time supplier to Sprint Nextel. It is the exclusive supplier of its own iDEN technology as well as of CDMA and EV-DO Revision A technology to Sprint Nextel's existing wireless telephony and data networks. It is proposed that Motorola will offer single and multimode devices which will be designed so as to enable seamless mobility for users, while playing a major role in the WiMAX infrastructure rollout.

Samsung's participation will be as a primary Mobile WiMAX infrastructure supplier and will also develop (using the Intel chipset) and provide dual-mode end-user devices which will support both CDMA2000 1xEV-DO and (future) Mobile WiMAX (802.16e) air-interfaces as well as other consumer electronics devices.

Nokia is the most recent participant (January 2007) who will be providing their own indoor/outdoor "Flexi" WiMAX BTS equipment a compact and modular unit that uses the same chassis as its UMTS base stations. It also intends to develop WiMAX-capable mobile devices such as handsets and Internet tablets.

WiMax Network Rollout & Costs

Whereas any new WiMAX service provide (e.g., Clearwire) would have to build towers or lease space on them and install or purchase antennas to place on those towers, Sprint Nextel already has a national cellular network in place with thousands of towers in hundreds of cities, all connected through an existing fibre-optic backhaul network.

Sprint is currently supporting two cellular-based networks (CDMA and iDEN). The Sprint PCS mobile network is a 3GPP2-based wireless network which utilizes the 1xRTT part of the CDMA2000 standard and the Nextel network, which runs Motorola's iDEN protocol, using time division multiple access (TDMA) based technology. Concurrently, Sprint is undertaking an aggressive upgrade of its network to offer a higher speed wireless service over the CDMA network, using EV-DO (Evolution Data Optimised) technology.

Sprint also has a network of over 2100 WiFi hotspots deployed in a range of locations throughout the Unites States including convention centres, hotels and other public venues for its cellular and enterprise customers.

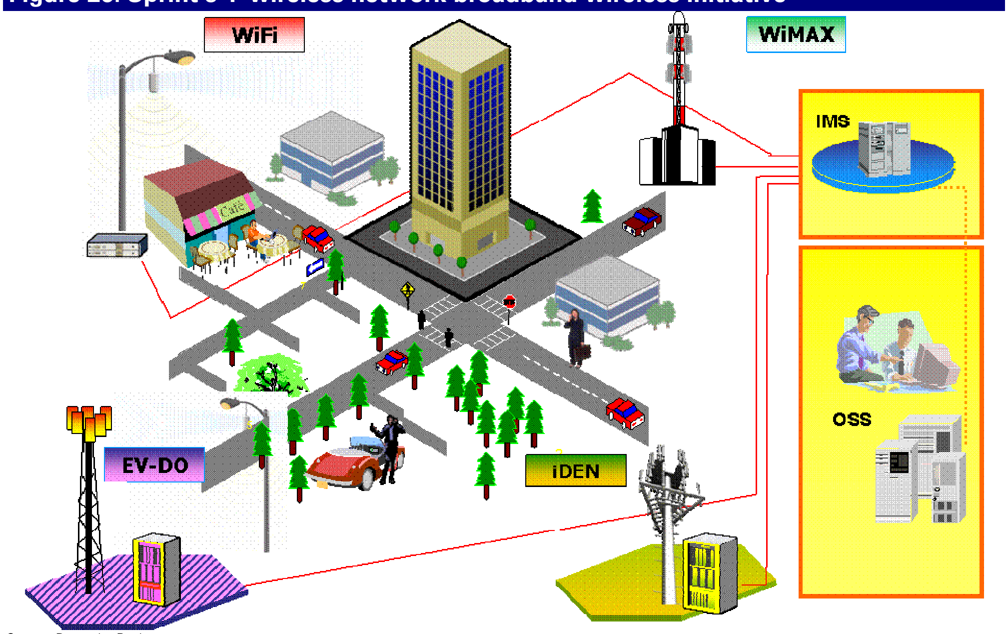
Sprint intends to roll out its WiMAX network, using an aggressive schedule, to cover a major portion of the US addressable market. It will be relying on the existing base station sites of both the Sprint and Nextel networks, which are spread across most cities of the US, in which to co-locate the new WiMAX radio access network equipment. Its efforts will initially focus on the major cities, towns and highways, in the nominated trial markets for 2007. From then, Sprint is aiming to enhance the network to serve 100m people by the end of 2008 and that this expansion may reach 170m people by the end of 2010. Sprint claims that its spectrum holdings allow it to cover "85 percent of the households in the top 100 US markets".

What is not readily apparent is the extent to which Sprint can leverage the existing cell sites to deploy WiMAX. Both CDMA and iDEN operate at 800MHz where the coverage footprint is significantly larger and which WiMAX, operating at 2.5GHz, could ever hope to achieve. Clearly, Sprint will need to "infill" the radio coverage gaps with a lot more antennas between the footprint offered by the lower frequency CDMA & iDEN voice networks, and that proposed for the 2.5GHz WiMAX implementation.

According to one of the vendors' own tests, propagation at 2.5GHz is limited to a range of approximately 3kms, for an assumed throughput of 2Mbps, using a fixed wireless configuration (with 802.16e) and including the use of smart antennas. Contrast this with the range of some 10's of kms obtained by conventional CDMA, at the lower frequencies currently in use by Sprint. This suggests that a significant number of additional base station and tower positions will be required to achieve similar coverage to that of CDMA /iDEN using WiMAX. The operator says it will spend $1bn in 2007 and $1.5bn to $2bn in 2008 to build its WiMAX network. It will be interesting to see if this cost parameter is met with an appropriate coverage level.

The company's strategy, if successful, will be both notable and the world's first. There is an optimistic rollout, which seeks to integrate four separate networks under the over-arching control of IMS and their back-end operational support systems (OSS) [(See Figure 26)x – Sprint's 4 -network broadband wireless initiative below] They will be attempting to provide a "seamless" customer experience for broadband wireless users using four disparate, separate wireless access technologies (WiFi, WiMAX, EV-DO and iDEN). They will be completely reliant, on the user terminal to provide convergence of services; the IMS will form the nexus for the provision and delivery of services across the networks. This will not be a simple exercise.

Figure 26: Sprint's 4–wireless network broadband wireless initiative



Source: Deutsche Bank

Product Strategy

Sprint Nextel have announced that its WiMAX service will be significantly different to services presently offered in the marketplace. It has boldly stated that it will deliver much faster data speeds across greater distances than cellular and Wi-Fi.

Sprint's stated product strategy rests on a core suite of technologies. These include a common internet protocol (IP) core, an IP multimedia subsystem (IMS) intelligent IT architecture, its existing cellular network infrastructure and a suite of yet-to-be-developed multi-mode devices. It intends to rely on at least two of its prime vendors, Motorola and Samsung, to develop multimode devices that will support services on the 3G CDMA network (where it will be used to will provide voice services), and on the enhanced EV-DO part of the same network for data applications. The WiMAX network, in areas where it is installed, will be used to offer a high-bandwidth service driven by data centric applications, and utilised by new multimode devices.

Assuming Sprint Nextel can overcome the challenges of implementing the new technology, businesses and consumers could see a new class of mobile devices supporting bandwidth-intensive services such as video, video calling, and hefty data transfers with a stated bandwidth availability of "between 2Mbps and 4Mbps"as early as 2008. It is aiming at developing a number of market areas with new technologies; namely the road warrior (with multimedia handsets & portable computing devices) and the home/SOHO market (with fixed broadband modems & portable consumer electronics).

Sprint has taken the unique product positioning of WiMAX as complementary to the existing 2G and WiFi services in its portfolio. In fact, it may find that WiMAX can fulfil more uses than it originally plans - it could provide a backhaul for its cellular network and for the WiMAX hotzones" it builds. It will be directly targeting the nomadic "road warrior", who needs broadband access through his/her laptop and the ability to make VoIP calls from the same device. Notwithstanding the marketing hype, the real challenge for Sprint will be to bring together, on the same device, truly converged fixed/mobile applications from both their WiMAX and other 2G platforms.

Competitive Advantages

Sprint Nextel's proposed WiMAX service will be different from its competitors in that the company will operate in licensed frequencies that it already owns in the 2.5GHz band, so the effective cost of acquiring them is nothing. Further, Sprint Nextel retains a significant holding, through either licence or leasehold, of wireless spectrum in the 2.5GHz band. This is of great material and strategic benefit to Sprint in being able to combine their holdings when they acquired Nextel. This asset alone will greatly aid their ability to stage a network and deliver a service offering where it presents a significant barrier to entry for competitors.

Most competing WiMAX Service providers that intend to use licensed frequencies have to pay for those frequencies, which constitute a large part of their network budget or use unlicensed spectrum with its inferior performance. The other important aspect is that Sprint can leverage the large install base cells with towers close to end-users and a core network set-up

Sprint also has a significant market advantage over any stand-up start, non-telco or WISP competitor as it can leverage the large install base of cell sites with towers close to end-users. It also owns a significant asset in the form of a Core Network and Operational Support Systems (OSS) that underpins its PCS business and allows roaming across separately managed administrative domains. Here lies the key benefits to Sprint in that it can leverage off the extensive suite of Authentication, Authorization, and Accounting (AAA) applications already embedded as part its CDMA (IS-41) core network. In bringing these systems to bear on the new WiMAX overlay, it will provide the necessary protocols, signalling and other mechanisms to authenticate, administer and allow users to roam freely across the disparate wireless access networks, something which the WiMAX standards do not define and remains a major barrier to entry for any would-be WISP competitors.

Risks

Sprint is chancing that consumer demand for wireless Internet access and other data services (i.e., multimedia content in the form of music downloads and video clips) will continue to grow in the future. One significant source of competition is already widespread across the US in the form of WiFi "hotspots" in places like airports and coffee shops (Starbucks), and some cities deploying wireless mesh networks.

The WiMAX service won't be available everywhere and will have patchy reception. Despite Sprint's intentions to overlay the new infrastructure across their existing topology, a significant capital injection will be required for radio coverage "infill" to achieve coverage parity with the mobile telephony network. What will happen, in reality, is that in areas of inadequate WiMAX coverage, users will "fall back" to the lower speed EV-DO. This strategy is, of course, highly dependent upon the availability of dual-function WiMAX/EVDO devices or interface cards.

In the meantime, competitors Verizon (EVDO) and Cingular (HSDPA) have launched mobile broadband services available in many cities and more than adequately serving the vast majority of users whose appetites are for much higher data rates.

Although there are a number of technology risks associated with Sprint's RAN rollout program, the biggest is the execution risk of integration. Firstly, integration of businesses, networks and brands with its betrothed Nextel and then in integrating the separate radio access networks into a holistic network fabric. The question that is raised is whether Sprint intends to do this or take the far simpler route of treating them as separate stovepipes addressing different market needs.

Early indications and its previous track record suggest that Sprint is taking the former approach banking on IP and IMS being able to provide the glue-point that enable seamless mobility and roaming between fixed and mobile networks and delivers on its promises. While it is true that IMS allows key network resources to be shared by a wide range of services, thereby enabling the any access technology to connect to the packet based core network, it also requires a major structural business transformation.

Sprint will have to move away from vertical 'stovepipe' implementations and eliminate the costly and complex traditional network structure of overlapping functionality for charging, presence, group and list management, routing and provisioning that plagues network operators to a flattened horizontal layered architecture of IMS that enables common features and functions to be reused for multiple applications. However, Sprint is faced with the classic dilemma that investing in IMS infrastructure is costly and difficult without understanding the user acceptance for new services and end-user acceptance of these new services will be impacted by the performance of the radio network.

Sprint has taken a chance on being the first telco in the world to undertake such a large rollout of a new emerging wireless technology, particularly with the level of pre-standardisation status of the radio access equipment. More significant is the risk from the unavailability of handsets and end-user devices. There are simply no multimode handsets (CDMA/EVDO/WiMAX) available today and they will be reliant on their vendors' (Motorola and Samsung's) ability to deliver devices on-time, within budget, and to a set of specifications for user services which are not yet known to the market. Moreover with feature/functionality and form factors which end-users will find appealing and have become accustomed to with 3G devices.

If Sprint manages to pull it off as well as integrate the four separate wireless access networks into a seamless pool of connectivity resources, cooperating in a manner such that end-users are blissfully unaware of the wireless technology they are using, they will be the envy of operators the world over.

Appendix E: Case study 5

Mobile City – Muni WiFly hotzone but where's WiMAX?

Background

Taiwan's capital city, Taipei, has been undergoing a gigantic public infrastructure project to provide almost ubiquitous wireless coverage to the public, of more than 2.6m residents, using city-wide Wireless Local Area Network (WLAN) mesh architecture using WiFi.

The M-City, or Mobile-City, project has been heralded as a world first, and the biggest metro wireless mesh network in the world, with over 10,000 access points covering 90 percent of the city. This initiative followed the Taipei government's successful completion of an earlier wireless-mesh infrastructure project in Taipei's southern city of Kaohsiung.

The aim of the M-City project, marketed as "WiFly", is to provide convenient broadband wireless access for Taipei residents, to government departments and businesses in Taipei as well as to provide individual users similar, convenient access to the Internet with their WiFi-enabled notebook computers, personal digital assistants (PDAs) - wherever they are in Taipei. WiFly would also be available for businesses to offer any form of electronic service that could interest Taipei residents. It is one of two extensive WiFi networks in Taipei; the other belonging to Taiwan's largest phone company, Chunghwa Telecom.

This case study is included to highlight that alternatives for illuminated, city-wide hotzones can be deployed using very cheap mesh architectures which, in turn, can dramatically alter the economics of network evolution. This is because it can avoid the high initial cost of base station infrastructure installation; and it allows the network to grow and evolve incrementally with demand. It also serves to highlight how various wireless access networks (WiFi-WLAN and Cellular -WWAN) can cooperate in a manner such that a user, who wants to connect to a service, is able to choose accesses and devices in a way that best suits his or her needs, and to change when something better becomes available.

Although M-City is often held up by proponents of WiMAX as a shining example of cost effectively, illuminating an entire city into a wireless hotzone, there is almost no involvement of WiMAX per se in the mesh network. That is to say that other than perhaps some backhaul (as used by Chunghwa Telecom), or the fact that it is being trialled for potential consideration in later stages of the project, WiMAX is not present.

Technology and Vendors

The successful bidder for the M-City project implementation was Q-ware Systems. As project developer and lead ISP, it planned to invest a total of US$70m to build the wireless infrastructure around Taipei and to provide content, as well as incentives, for other business to do similarly.

Nortel was appointed as the prime vendor of the WiFi mesh technology, which comprises the "fabric" of the overall network. It provided elements from its Wireless LAN portfolio of products, namely, the WLAN 2300 series (WLAN infrastructure hardware and software) and the 7200 product series, its Wireless Mesh Network solution. Their product is a multi-protocol system which can utilize a/b/g/h variants of the 802.11 air-interface with the WiFly network assigned to operate in the 2.4GHz unlicensed band.

In the first stage of WiFly, HP as principal consultant, would head-up a team of other consultants, including Intel Corp, Microsoft Corp and Cisco. The group would provide advice on design and implementation of in-premise networks, to allow the participating government departments and agencies to apply wireless Internet access to their operations and facilitate e-commerce applications which serve the residents of Taipei.

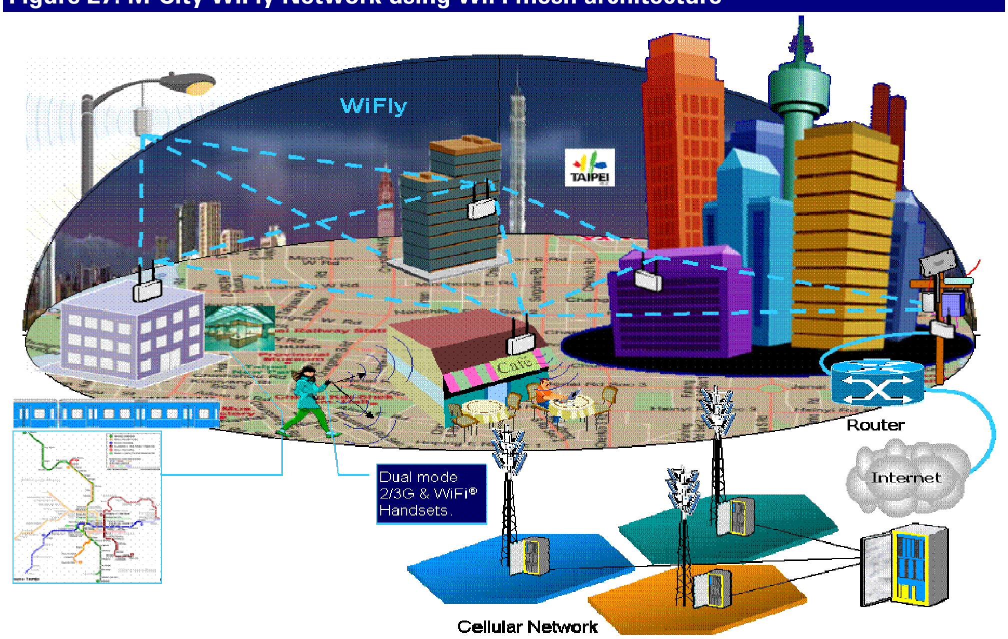
Network Rollout & Costs

Within mesh networking there are two different architectural options - infra-structure based and premise-based. Infrastructure-based is where wireless transmitters are placed on pole-tops and end-nodes connect to them wirelessly – this is similar to a corporate WLAN network. Premise-based (or infrastructure-less) is a self-configuring network where the participants own the equipment and the network grows organically; every node becomes a router in much the same way that the Internet was built. The M-City network is an example of an infrastructure-based network.

Unlike 'traditional' WiFi hotspot networks, where each access point or small group of them has its own fixed line to carry internet traffic to the cloud, M-City is relying on a mesh network, where each access point, as well as being open to WiFi devices, backhauls traffic from the next access point. Should there be interference or unexpected outages, the access point should automatically search for another access point to peer to. There will, of course, be connections to the fixed core network, but these interconnections will be kept to a minimum.

The biggest engineering challenge for connecting such a large number of access points throughout Taipei City is identifying where each point needs to be placed, then ensuring that each location allows transmission of a clear signal without interference.

Figure 27: M-City WiFly Network using WiFi mesh architecture



Source: Deutsche Bank

This implementation would be completed to access points controlled by the city, including power & lighting poles along streets, positions alongside building structures and within public buildings as hotspots, by the creation of hotspots at public places (e.g., parks, etc.) as well as being implemented by a number of business franchises within their own premises (including Burger King, Starbucks and IS Coffee chains).

The rollout was divided into three stages:

Stage 1 – covering 20% of the population in which the implementation is around Taipei's MRT, including 30 MRT stations, neighbouring Metro Malls, Beitou Machinery Workshop and business districts near the MRT stations to a radius of 100 meters (or more).

Stage 2 - the implementation for main areas in Taipei. This included completing the infrastructure for the rest of the MRT stations (64 in total) and Taipei City's major business district (estimated 50% of total population coverage, or 1.3m people, over 28.2 km2). This was scheduled for completion by H1 2006, but completed at the end of 2005.

Stage 3 - the implementation for the high population density, residential areas of Taipei and throughout the 12 administrative districts in Taipei City covering 90% of the population.

Stage 3 was completed at the end of July, 2006, including nine Taipei City Hospital Campuses, 53 Taipei public libraries, 12 district administration buildings and 600 7-Eleven stores within Taipei City.

Ultimately, the WiFly network will have more than 10,000 access points, covering an area of 270 km2 city and 90% of the population.

Product Strategy

The original plan was to use the WiFly network to make government and business services more "accessible", to make Taipei "a city full of instant responses, free network resources, and valuable information with nearly free communication and interaction costs". Owing to this network, these "customers" would develop services that were not previously available electronically. As the principal driving force for the project, the Taipei city government would use the network as a tool to communicate with the residents, even to the point where the public could be involved in policy decisions in an open, transparent, electronic environment.

This strategy has worked for the government, with many agencies now communicating almost exclusively online, saving significantly on expenditure. As an incentive to use the network, many residents have also been given free email accounts and computer lessons in order to be able to access these services.

Many believe there is demand for such networks and services, but the level of that demand and how the product should be packaged are still open for debate - something that Wifly, has learned in its first year of operation.

The proposition for businesses is to create services that were similar to conventional Internet offerings, but were unique to the WiFly network and would appeal to the nomadic or mobile user. Q-ware Systems itself proposed a number of paid, value-added services, including online TV viewing, online learning, ring tone downloading, short message sending and online gaming (among others), which allow subscribers to kill time while waiting for MRT trains or at cafes. Further, in a move designed to entice a larger subscriber base, Q-ware has also developed a low-priced VoIP service and offers a handset costing around US$200. It allows users to call other mobile phones for just over a 1¢ a minute, while calls to a traditional phone costs less than 0.5¢.

Competitive Advantages

The WiFly Network, officially launched in June, has acquired the certificate of accreditation by Jiwire, an international organization, to become the first city in the world to run a public access WiFi network.

It would therefore be fair to say that WiFly had the first-mover advantage in the Taipei marketplace that would make it difficult for any alternate technology or new entrant to compete. It also had the support of cashed-up participants in the form of the Taipei city government and vendors with no risk of bankruptcy or failure.

The Taiwanese population is very tech savvy. They not only produce but use a large number of technology devices in their everyday lives. Already having one of the highest mobile phone penetrations in the world, the introduction of a pervasive broadband wireless network, and its attendant applications, should find little or no resistance to widespread adoption.

There is clearly a benefit to cities to build out the infrastructure and see what business innovations can come on top of it. Already, similar projects are being planned and deployed in Singapore, Moscow, and Minneapolis as it allows state governments to move more services online, since everyone can gain easy online access and should attract business, and thus, tax revenues.

To attract more users, WiFly is introducing lower price rates, such as a seven-day card for NT$200 and a 110-minute card for NT$99. In July 2006, it launched a service called Easy Call which allows mobile phone users equipped with a suitable dual mode (2/3G and WiFi) handset to switch between using the WiFi network and available cellular networks. Portable online games are another future possibility.

Risks

Although not new, mesh networks have a somewhat chequered history. Self-configuring systems where entire neighbourhoods or municipalities become effectively "hot" zones require physical infrastructure build-out of wireless access points every few hundred metres or so. Consequently, back-haul costs for such distributed picocellular architecture can be quite high. Furthermore, it is not clear as to how the frequency coordination amongst competing unlicensed 2.4GHz hotspots is going to work.

Taipei hopes to use their new networks to help less affluent people get online and to make their cities more business friendly. Yet, as it has already found out, just building a citywide network does not guarantee that people will use it. Taipei is a tech savvy metropolis with one of the highest mobile and 5th highest broadband penetration in the world. Most people already have plenty of access to the Internet in their offices and at home, while wireless data services let them get online anywhere using mobile phones, laptops and P.D.A.'s.

Despite the pervasiveness of WiFly, the service has proven to be not nearly as popular as the owners hoped. Only 50,000 of Taipei's 2.6m residents have taken up the reasonably priced service after a fee was introduced in January 2006. The slow take-up may be attributed to the surfeit of competitive offerings where, for the price of a cup of coffee, anyone can log onto a number of free WiFi networks available from the city's many cafes. So, at approximately USD12.50 per month, WiFly is finding it hard to compete with these alternatives.

Content will be key to the success of WiFly. Today, it merely provides a cheap alternate form of access to the internet. Consequently, WiFly does not seem to have built a large customer base as statistics compiled by the city suggests. It stands to lose a great deal if it doesn't put significant effort into developing unique and attractive range of content services for its users.

On a wider note, it raises the issue of the commercial viability of the "muni" network or hotzone concept that has become so popular worldwide amongst local municipalities and civic leaders. The question is whether a standalone city-wide hotzone is viable on its own or does it need an operator-driven business model to succeed. In much the same way as the business case for WiFi, hotspots as standalone opportunities (ala Starbucks) was unviable.

They only became viable when mobile network operators integrated them into their portfolio of services and consolidate the charges on the same bill.

To take a slight digression, the technology platform of 3G/HSPA, discussed throughout this paper, represents an extension of the mobile service provider model, one where service providers own and manage the infrastructure (including the spectrum) and sell services on it. Their mindset is on long-lived capital assets, ubiquitous coverage, and service integration.

3G/HSPA has become the technology of choice for mobile network operator's since mobile data services is provided as part of a bundled service offering. Consequently, taking advantage of opportunities to implement price discrimination strategies and to exploit consumers' preferences for "one stop" shopping and offer a simplified single bill service (this is highlighted in other case studies in this paper).

By contrast WiFi, or WiMAX for that matter, comes out of the data communications industry, which in turn is a by-product of the Internet industry. The basic business model is one of equipment vendors who sell their boxes to consumers. End-user customers buy the equipment and then self-install it and interconnect it to their access or enterprise network facilities. For the customers, the equipment represents a capital asset that is depreciated. The services provided by the equipment are free to the equipment owners.

While WiFi can be used as a short ranged access link, it has not previously been thought of as an end-to-end service in its own right. Only relatively recently have WLANs moved out of the enterprise and been targeted as a mass market offering to home and public users. In the past these were installed, most typically, in corporate or university campus settings. Typically, the users of WiFi networks are not charged directly for access. Service is provided free to the closed user-community, with the costs of providing wireless access subsidized by the firm, university or municipality.

The attractiveness of subscribers forking out additional spend to gain incremental online access when cafes, libraries, etc., offer free connectivity seems rather thin. For the impoverished areas that can't get broadband services from wireline operators and cable companies, it may be a different story, but most citywide WiFi networks don't adequately penetrate into homes, and those lower disposable income households may not see the value of paying even subsidized rates for connections.

At present, city-wide WiFi-based "muni" networks while relatively cheaper to deploy is nice to have, but not a must. Ultimately, for these networks to succeed commercially, will require a different business model, one which involves bundling content and other services already being paid for by users similar to that offered by the mobile network operators.

Appendix F – Glossary

Figure 28: Glossary of terms

3G	This term is short for third-generation telephone technology and also refers to mobile telephony standards. The services associated with 3G provide the ability to transfer both voice and data such as downloading information, email, instant messaging and MMS (multimedia Messaging Service, including video) simultaneously.
3GPP	Third Generation Partnership Project – standardisation structure producing UMTS specifications (UTRA FDD and TDD modes including TDSCDMA) and GSM evolution (including GPRS and EDGE)
802.x	A suite of standards offering an alternative to wired 'last-mile' access links for broadband voice, data and video.
ARPU	Average Revenue Per User
AuC	The Authentication Centre is a system processor and function that authenticates each user SIM card that attempts to connect to the GSM core network
Bluetooth	A wireless personal area network (WPAN) air interface that allows a network for interconnecting devices (within about 10 metres) centred around an individual person - in which the connections are wireless.
BSC	Base Station Controller manages and controls radio resource management and handover between cells.
BSS	Business Support Systems. The customer facing IT systems that run the front office of the operator.
BTS	Base Transceiver Station. Transmits, receives and manages the radio air interface between base station and user device.
BWA	Broadband Wireless Access – describes technology based on IEEE
CDMA	Code Division Multiple Access
CDMA (IS-95)	second generation mobile system using CDMA access
CDMA2000	3G technologies evolved from CDMA (IS-95) – also known as CDMA MC (multi carrier). A 'family' of technologies, namely 1xRTT (using 1.25 MHz duplex channels), 1xEV-DO and 1xEV-DV. Multi-carrier solutions (e.g., 3xRTT) are included in principle, but not currently pursued.
EDGE	Enhanced Data rates for Global Evolution – enhanced radio modulation method for GSM and TDMA (IS-136) networks to achieve significantly higher data rates. Combines circuit mode and data.
ENUM	(E164 Number Mapping) is a standard that uses the Domain Name System (DNS) to translate telephone numbers to internet addresses.
EUDCH	Enhanced Uplink Data Channel - Under development in 3GPP Release 6, provides GSM operators with a 4Mbps upstream and downstream data capability.
EV-DO	Evolution- Data Only
FDMA	Frequency Division Multiple Access. One way for multiple radio transmitters to share the radio spectrum.
FMC	Fixed Mobile Convergence
GERAN	GSM / EDGE Radio Access Network - Radio access technology that provides an evolutionary path for operators of GSM/GPRS systems.
GGSN	Gateway GPRS Serving Node
GHz	Giga Hertz – 1000MHz equates to 1GHz
GPRS	General Packet Radio Service – evolution of GSM for packet data transmission – a packet-switched data service which operates in the GSM frequency bands.
GSM	Global System for Mobile Communication; second generation mobile system originally developed in Europe, using a TDMA access radio interface combined with frequency division multiple access (FDMA). Oriented to voice and circuit mode data.
HC-SDMA	High Capacity Spatial Division Multiple Access. A Time Division Duplexing air-interface technique used by iBurst.
HLR	Home Location Register is a central database that contains details of each user that is authorised to use the GSM core network.
HSDPA	High Speed Downlink Packet Access – modulation method based on WCDMA evolution, standardised as part of 3GPP Release 5, that improves the peak data rate and throughput (dependent on radio conditions) to enhance spectral efficiency.
HSUPA	High Speed Uplink Packet Access – complementary to HSDPA, offering similar enhancements in uplink performance between terminal device and base station.
i-Burst	The brand name for a HC-SDMA technology developed by Arraycomm.

Source: Deutsche Bank

Figure 28: Glossary of terms (continued)

ICT	Information Communications Technologies.
IMS	IP Multimedia Subsystem – standardised architecture enabling converged voice and data services in the mobile environment, built on Internet services, applications and protocols.
IMT-2000	ITU term for third generation mobile family
IPv6	Internet Protocol version 6 – 'next generation' Internet protocol overcoming limitations of IPv4 – notably limited address space – and offering other improvements in routing and network configuration.
ITU	International Telecommunication Union
LMDS	LMDS -Local Multipoint Distribution System. The term "Local" indicates that the signals range is limited to a local radius of about 4-5km since LMDS operates at high Gigahertz RF signals within small cells of typically 4km radius.
MAC	Medium Access Layer responsible for regulating the usage of the physical (radio) medium
MAP	Mobile Access Part
MIMO	Multiple Input, Multiple Output (MIMO). Antenna systems that use spatial multiplexing techniques to boost the performance of wireless networks.
MOU	Minutes of Use
MSC	Handles the call routing and roaming capabilities and manages 3 main databases: the visitor location register (VLR), the home location register (HLR), and the Authentication Centre (AuC).
multipath	This is the radio propagation phenomenon whereby radio signals reach a receiving antenna by two or more paths.
NGN	Next Generation Network – An integrated All-IP based full services broadband network capable of transporting any type of service.
NSS	Network Subsystem which performs the core switching of all calls between the mobile user and other fixed or mobile network users. It comprises the mobile switching centre (MSC) and a number of network databases
OFDM	Orthogonal Frequency Division Multiplexing – coding scheme that splits signals into several narrowband channels at different frequencies. Benefits include high spectral efficiency with resistance to interference and reduced multi-path distortion.
OMA	Open Mobile Alliance – organisation facilitating global user adoption of mobile data services by ensuring interoperability across devices, geographies, service providers, operators and networks.
OSS	Operational Support Systems. The Network facing IT systems that run the operator's network.
PSTN	Public Switched Telephone Network – 'conventional' telephone system based on circuit switched connections carrying voice-oriented information.
QoS	Quality of Service – measurement of transmission rates, error rates, priority, dedicated bandwidth and other parameters relating to performance of data networks.
RAN	Radio Access Network – 'wire-free' segment of a communications network based on radio technology that connects other devices via a standardised air interface to the main network.
RNC	Radio Network Controller, the 3G network equivalent to the 2G BSC.
SGSN	Serving GPRS Support Node – a packet switching element
SIP	Session Initiation Protocol – Application-layer signalling protocol for managing sessions with one or more participants that may include Internet multimedia conferences, Internet telephony, presence and messaging.
SSC	Site Support Cabinet – housing for base station equipment and may also accommodate power supplies, rectifiers, DC distribution, and battery backup.
TD-CDMA	Time Division-Code Division Multiple Access – a hybrid access technology combining TDMA and CDMA, as applied for the TDD Mode of UMTS, and using a 5 MHz frequency band.
TDMA	Time Division Multiple Access – radio access mode used for second generation mobile (GSM, PDC, IS-136)
TDMA (IS-136)	Second generation mobile system used mainly in US (formerly known as D-AMPS)
TD-SCDMA	Time Division-Synchronous Code Division Multiple Access – a hybrid access technology combining TDMA and SCDMA, a CDMA scheme that contains an additional mechanism for synchronisation, using a 1.6MHz channel.
UMA	Unlicensed Mobile Access – provides seamless access to mobile services via various unlicensed spectrum technologies.

Source: Deutsche Bank

Figure 28: Glossary of terms (continued)

UMTS	Universal Mobile Telecommunications System – 3G system standardised by ETSI under 3GPP along with other regional standards organisations
UTRAN	UMTS Terrestrial Radio Access Network - Air interface portion of UMTS networks as specified within 3GPP.
VLR	Visitors Location Register is a database containing temporary entries of the users who have roamed into the particular service area.
VoIP	Voice over Internet Protocol - a two-way transmission of audio signals over a broadband IP network.
WCDMA	Wideband CDMA – also known as CDMA DS (Direct Sequence) within the IMT-2000 framework – is the radio access technology for one of the UMTS access modes (UTRA FDD) using 5MHz duplex channels. Combines
WiBRO	Broadband Wireless Access technology being developed by the Korean telecoms industry using OFDM.
WiFi	Branded abbreviation for "Wireless Fidelity"; a commonly used synonym for IEEE 802.11 or WLAN
WiMAX	Branded abbreviation for "Worldwide Interoperability for Microwave Access" which describes broadband wireless networks offering fixed, nomadic and portable access based on the IEEE 802.16 family of standards.
WISP	Wireless Internet Service Provider.
WLAN	Wireless Local Area Network – generic term for different high speed radio access modes in the 2.4GHz to 5GHz frequency bands.
WWAN	Wireless Wide Area Network. Typically refers to cellular mobile technologies that provide continuous coverage over a large geographic area.

Source: Deutsche Bank

Appendix 1

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Ericsson	ERICb.ST	27.40 (SEK) 1 Feb 07	2,6,8,14
Alcatel-Lucent	ALU.PA	9.87 (EUR) 1 Feb 07	2,6,8,14
Nokia	NOK1V.HE	16.96 (EUR) 1 Feb 07	2,6,7,8,14,15

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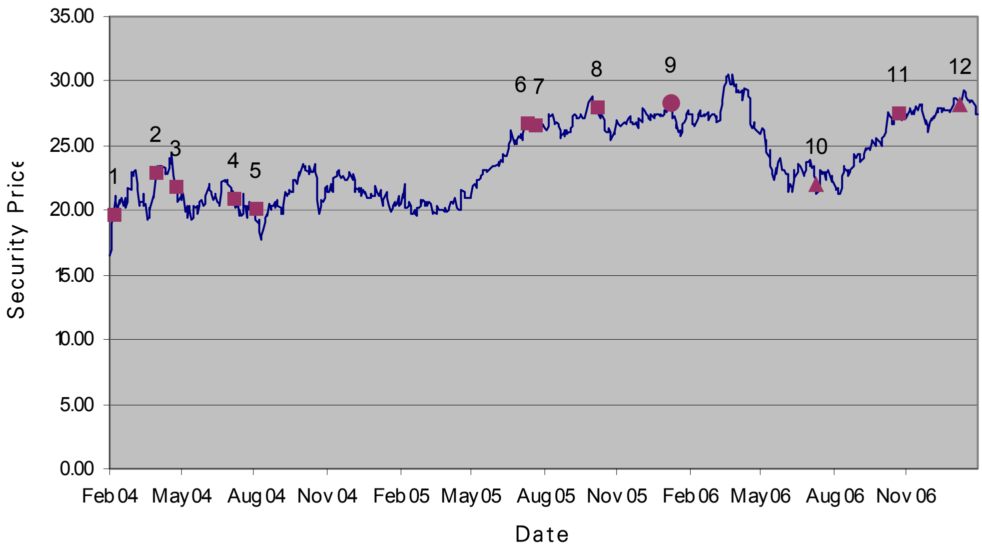
(as of 2/1/2007)



Previous Recommendations

Strong Buy
Buy
Market Perform
Underperform
Not Rated
Suspended Rating

Current Recommendations

Buy
Hold
Sell
Not Rated
Suspended Rating

*New Recommendation Structure as of September 9, 2002

1.	9/2/2004:	Hold, Target Price Change SEK19.00	7.	22/7/2005:	Hold, Target Price Change SEK24.00
2.	2/4/2004:	Hold, Target Price Change SEK21.00	8.	10/10/2005:	Hold, Target Price Change SEK25.00
3.	26/4/2004:	Hold, Target Price Change SEK22.00	9.	11/1/2006:	Downgrade to Sell, SEK25.00
4.	9/7/2004:	Hold, Target Price Change SEK20.00	10.	13/7/2006:	Upgrade to Hold, Target Price Change SEK23.50
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6.	13/7/2005:	Hold, Target Price Change SEK22.00	12.	10/1/2007:	Upgrade to Buy, Target Price Change SEK32.50

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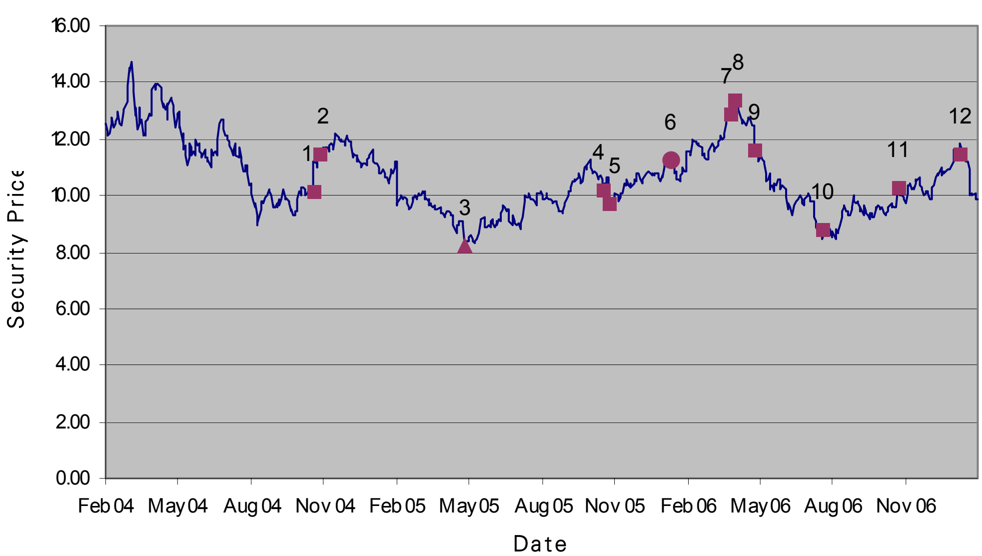

Previous Recommendations

Strong Buy
Buy
Market Perform
Underperform
Not Rated
Suspended Rating

Current Recommendations

Buy
Hold
Sell
Not Rated
Suspended Rating

*New Recommendation Structure as of September 9, 2002

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5.	27/10/2005:	Buy, Target Price Change EUR11.00	11.	24/10/2006:	Hold, Target Price Change EUR9.70
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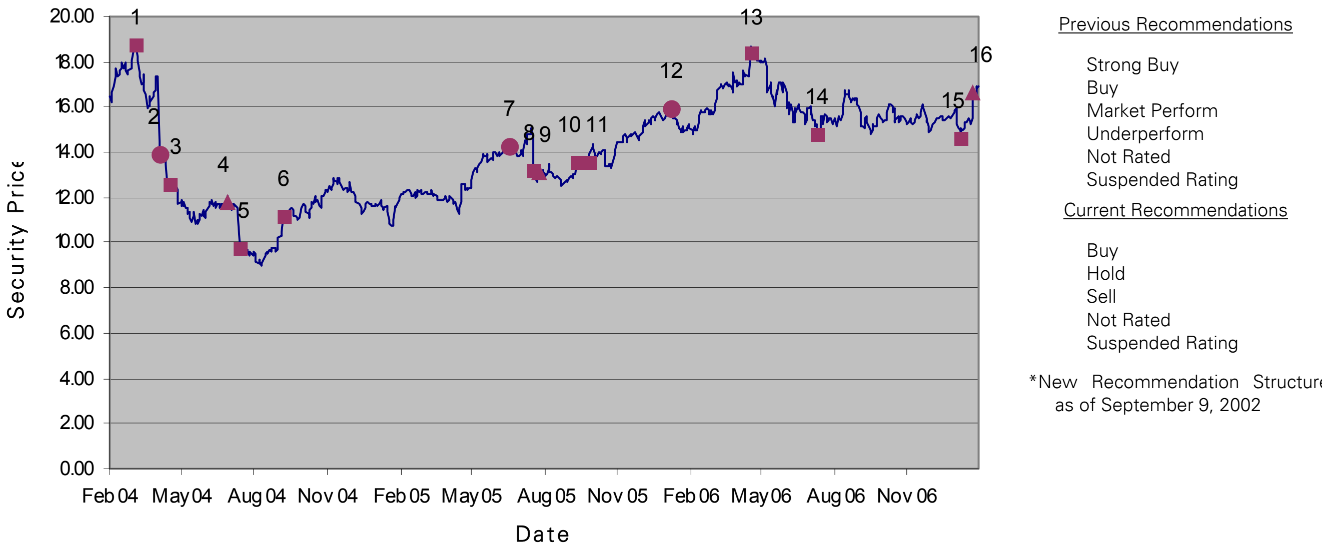
(as of 2/1/2007)



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2.	7/4/2004:	Downgrade to Hold, Target Price Change EUR15.60	10.	13/9/2005:	Buy, Target Price Change EUR14.70
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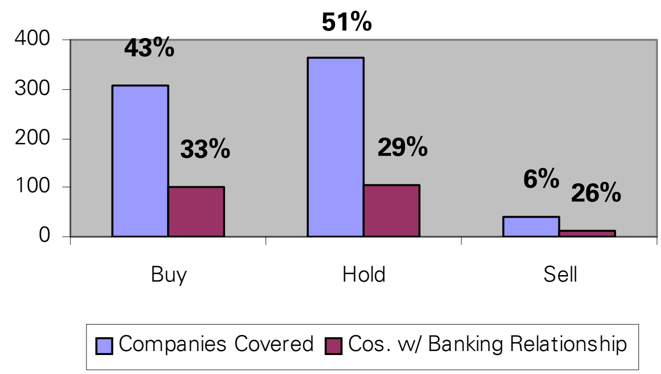

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