Rural WCDMA – Aiming for nationwide coverage with one network, one technology, and one service offering

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WCDMA is quickly establishing itself as the dominant technology for global third-generation mobile systems (3G), giving operators the means of delivering advanced communication and broadband services to mobile and fixed users alike. These services are already a commercial reality in many cities and urban centers around the world. And now, with the broadband capabilities made possible by high-speed packet access (HSPA), 3G is set to bring cost-effective coverage to rural areas as well. For the first time, end users in rural areas will thus be able to obtain true, cost-effective fixed and mobile broadband services with international roaming capability.

A 3G network is more than an enhanced mobile telephone network. In addition to voice service, it also delivers video telephony, mobile small-screen television, a wide range of data services, and broadband internet connectivity for fixed and mobile users. This multiservice capability (and associated revenue streams) is what makes rural 3G an attractive and strategic investment for mobile operators, because they need only deploy and manage one network based on one technology that delivers a homogenous service offering at unprecedented cost levels.

Broadband for all

Efforts to bring mass-market broadband services to rural areas coincide with an initiative announced by the European Commission.[1] The initiative, called *Bridging the broadband gap*, is intended to bring high-speed broadband internet to all Europeans, in particular to EU's less-developed areas. The understated rural capability of 3G is a key enabler for realizing this vision of *Broadband for all* in which broadband internet connections are a prerequisite for e-business, growth and jobs throughout the economy. Ericsson fully agrees with the Commission's conclusion that an environment in which open market forces stimulate competition among players benefits not only the telecommunications industry but also consumers and society as a whole.

The issue of rural broadband is not limited to Europe, however – it is a common global challenge. In this context, Telstra, which operates in Australia, a country with huge geographical expanses and low population densities, is at the forefront of global technological innovation, providing great strategic insight into how 3G networks can serve as commercially viable enablers of communication and broadband services, even in areas with extremely low population density.

Rural 3G service offering

Being an evolution of the GSM standard (2G), one might wrongly assume that WCDMA is merely enhanced technology for mobile telephony services. But in reality, WCDMA networks are true multiservice networks whose capabilities are unmatched by any other technology. A WCDMA network is nothing less than a wireless broadband network with full support for mobility, which among other things, can also deliver traditional mobile telephony. Therefore in rural areas, a WCDMA network constitutes a cost-effective way of rapidly deploying residential broadband services. Third-generation services with mass-market potential include

- mobile telephony;
- video telephony;
- basic data services, such as SMS and MMS;
- advanced data applications, including music downloads to a mobile handset;
- mobile broadband targeting laptop users;
- fixed-wireless broadband (ADSL alternative);
- mobile small-screen TV streaming;
- fixed PSTN-equivalent telephony; and
- government, health and educational services.

Many of these services target traditional mobile handset terminals, while others, such as mobile broadband, are primarily used by laptop users who require fast, always-on internet access with full mobility and everywhere availability. Fixed-wireless broadband and PSTN telephony give mobile operators the means of delivering non-mobile residential services over wireless mobile networks.

3G terminals

A wide variety of 3G terminals currently target every user segment. During the first quarter of 2006, there were 315 models of WCDMA/HSPA terminals from 38 different vendors on the market.[2] Because WCDMA is being deployed on a limited set of frequency bands that are harmonized around the world, manufacturers and operators can easily ensure the roaming capabilities of their terminals. The 2.1GHz band is most dominant in Europe and most other

BOX A, TERMS AND ABBREVIATIONS

2G	Second-generation mobile system
3G	Third-generation mobile system
3GPP	Third Generation Partnership Project
ADSL	Asymmetrical DSL
ARPU	Average revenue per user
CAPEX	Capital expenditure
dBi	Decibels isotropic
DSL	Digital subscriber line
DVB-H	Digital video broadcast – handheld (digital TV)
EUL	Enhanced uplink
GPRS	General packet radio service
GSM	Global system for mobile communication
HSPA	High-speed packet access (downlink and uplink)
MHGA	Modular high-gain antenna
MMS	Multimedia messaging service
OPEX	Operating expense
PSTN	Public switched telephone network
RBS	Radio base station
SMS	Short message service
WCDMA	Wideband code-division multiple access
WiFi	Wireless fidelity (wireless LAN)
WiMAX	Worldwide Interoperability for Microwave Access, Inc. (group promoting IEEE 802.16 wireless broadband standard)

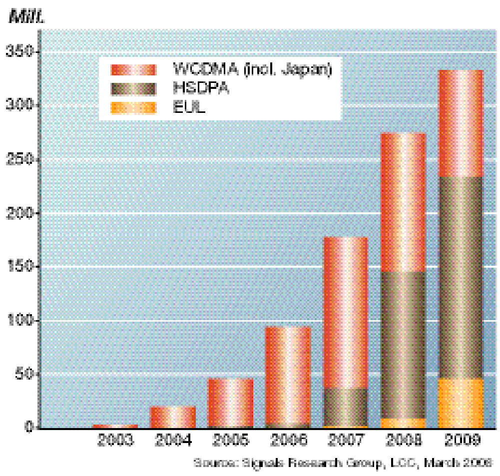


Figure 1
WCDMA/HSDPA market forecast.

markets; 1.7GHz is primarily used in Japan; 850MHz in the US and to some extent in Australia.

The prices of WCDMA terminals are falling and will continue to fall as volumes increase. Soon HSPA will become a standard feature (much as GPRS is for GSM) and HSPA-enabled terminals will become commonplace. In addition, new kinds of terminals will soon also benefit from the capabilities of 3G networks. Indeed, the very same chipsets will find their way into 3G modems for fixed-wireless broadband access, PC cards, and as embedded modules in laptops. This will result in unmatched economies of scale for chipset manufacturers and terminal vendors alike, giving rise to a wide range of low-price terminals.

The Signals Research Group estimates that the global market for HSPA chipsets (including phones, PC cards and embedded modules) will be close to 150 million units in 2008, surpassing the market for ordinary WCDMA chipsets (130 million units).[3] No other existing or proposed broadband technology, fixed or wireless, has the potential to reach such a level of penetration. By the same token, no other technology can ensure the availability of low-cost, mass-market terminals for mobile and fixed broadband services. To put these figures into perspective, the market forecast for xDSL modems (the dominant fixed broadband technology, including ADSL, ADSL2, ADSL2plus, VDSL and VDSL2) in 2008 is 91 million units.[4]

Today's commercially available 3G terminals, especially those which rely on power class 3 (found in many handsets and PC cards) are already especially well-suited for rural services because they provide greater uplink radio power, making it easier for the base station to receive their signals.

Fixed-wireless terminals

Fixed-wireless broadband enabled by WCDMA is a broadband service delivered over a mobile 3G network. At present, it is the most cost-effective wireless alternative to ADSL. The service is terminated in a fixed-wireless terminal, which in reality, is a 3G modem whose functionality is equivalent to a traditional ADSL or cable modem, giving multiple users simultaneous access to HSPA data service from one location.

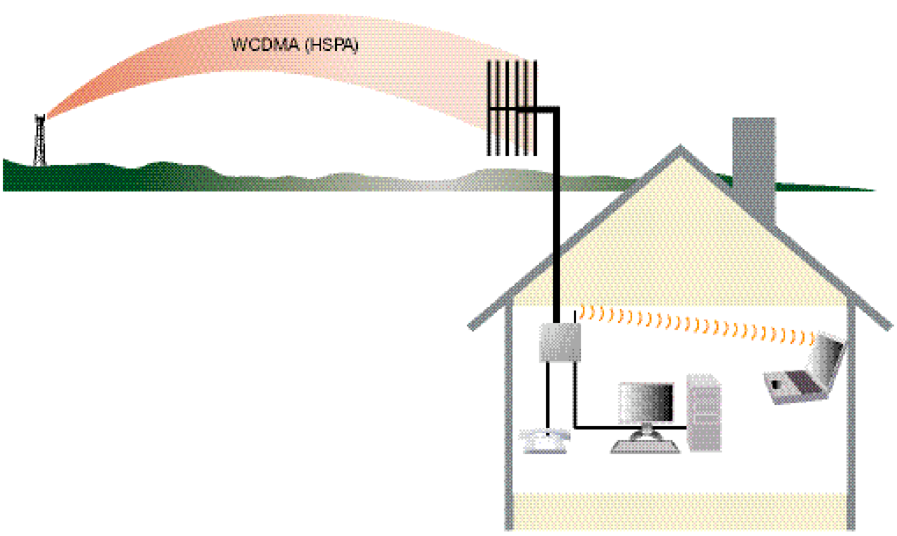
As with ADSL modems, fixed-wireless terminals are more than just a modem. They also serve as router, WiFi access point, and telephony and fax gateway for traditional PSTN-like services.

In summary, fixed-wireless terminal and 3G network technology is ideal for providing premium, cost-effective broadband services to residential and small business users in rural areas (Figure 2). In many countries and regions where infrastructure is limited or inadequate, fixed-wireless access is the ultimate solution to giving millions of users always-on, high-speed internet access and high-quality voice communication.

Improving performance in rural areas

The performance of a wireless broadband

Figure 2
Fixed wireless broadband delivers both voice and broadband internet connectivity over great distances in rural areas.



service is determined by the available link budget between the base station and terminal unit. The link budget determines HSPA data rates and the general ability to deliver services when users are at the cell edge or indoors. Operators can improve the link budget associated with fixed-wireless terminals by installing high-gain directive antennas in windows, on rooftops or on outside walls. External antennas can significantly improve coverage and capacity, ensuring performance even where radio conditions are bad, for example, in remote areas where signal strength is too weak for ordinary handheld terminals.

The extent to which the link budget can be improved depends on the type of antenna used. Compared with an indoor power class 3 (+24dBm) handheld terminal, an indoor window-mounted omnidirectional antenna can improve the link budget by about 12dB. Likewise, thanks to greater height (vertical direction gain), an omnidirectional antenna mounted on a rooftop can improve the link budget by about 47dB. And an outdoor, tower-mounted directional antenna can improve the link budget by as much as 65dB compared with indoor use of a 24dBm terminal. At a given cell radius, a directed antenna can provide a higher cell-edge bit rate than an omnidirectional or handheld terminal (reference case).

Figure 3 shows that it is possible to deliver very high bit rates over great distances with 3G. This is especially beneficial to rural service delivery. A relative comparison of antenna options shows that window and outdoor antenna configurations increase coverage. A directional antenna increases coverage and capacity. Therefore, an operator who builds a WCDMA2100 network on an existing GSM900 site grid can convert these gains into

- improved cell-edge bit rate for broadband service; or
- increased number of users served in the cell.

The rural WCDMA site

Coverage and capacity in a WCDMA network are determined by the total link budget. This, in turn, is dependent on factors such as frequency band, output power, mast height, the types of terminals used in the network, and special technical features, such as four-way receive diversity or six-sector antenna configurations.

Site reduction strategies

By reusing existing GSM sites, operators can reduce costs and the time it takes to roll out rural 3G coverage. A comparison of link budgets for GSM900 and WCDMA2100 with standard antennas shows a link budget deficit of between 1dB and 3dB for WCDMA2100 and a surplus of up to 6dB for WCDMA850. Several methods can be employed to combat the deficit on the WCDMA2100 side; for example, by

- increasing the height of antennas;
- improving receive sensitivity at the base station;
- deploying six-sector instead of traditional three-sector antenna configuration; and
- using high-gain antennas.

Tower height

Tall antenna towers are costly and might be perceived as having a negative esthetic impact. However, in extreme rural areas, such as desert environments and emerging markets, tall, low-cost, guyed towers can be used to efficiently reduce site costs and significantly improve coverage.

Receive sensitivity

Operators can improve uplink receive sensitivity by employing four-way receive diversity techniques to combine signals from four antennas. Being a broad-spectrum technology, WCDMA already has a built-in element of diversity gain. Therefore, the gain from four-way receive diversity is quite modest or only up to about 2.5dB. This is unlike GSM, where the gain from four-way receive diversity is as much as 4.5dB. In extreme rural areas, this technique has thus been used very successfully for deploying GSM coverage. For deployments of rural WCDMA, however, four-way receive diversity has a number of drawbacks that make it less suitable, especially where capacity is also required. One major drawback is the cost of additional radio base station (RBS) equipment, feeders and antennas. In addition, it only offers improvement in the uplink, whereas in most cases, an equal improvement is required in the downlink. What rural WCDMA sites really need is a cost-effective way of improving the link

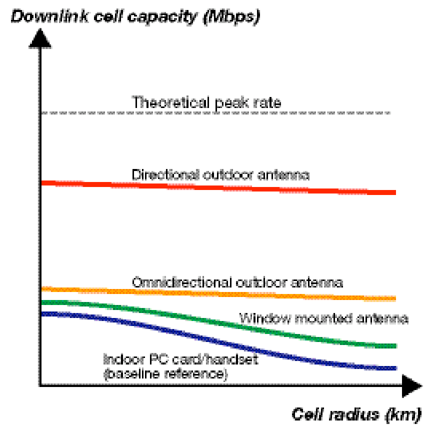


Figure 3
With a directional antenna it is possible to deliver very high bit rates over great distances.

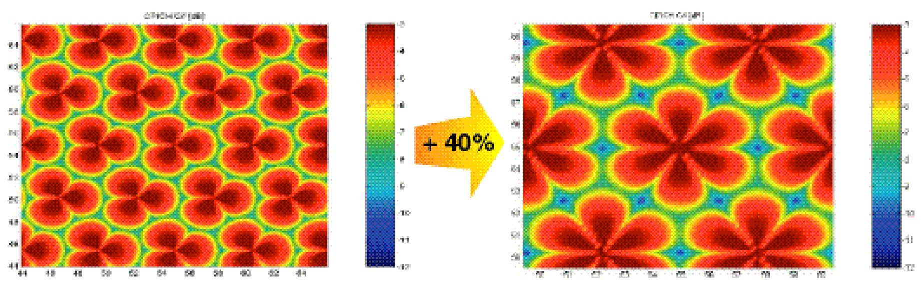


Figure 4
Six-sector antenna configurations give a 40% increase in coverage compared with three-sector antenna configurations.

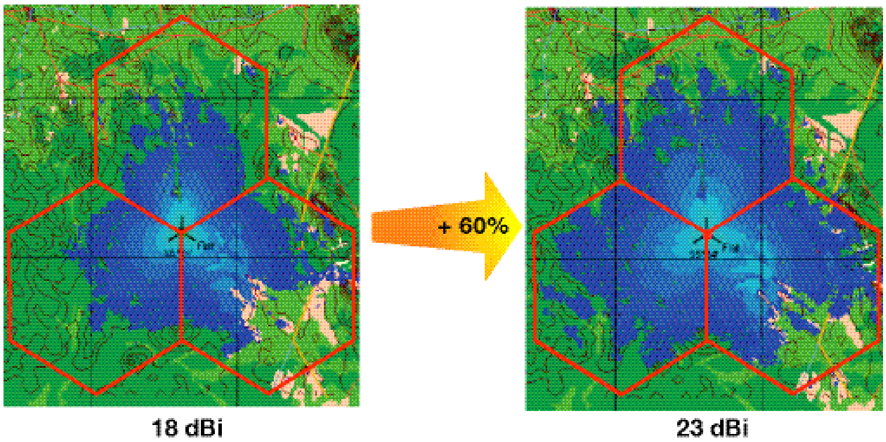


Figure 5
For greenfield deployments, the improved coverage enabled by MHGA can significantly reduce the number of sites compared with GSM900 site grids.

budget for both the uplink and downlink without affecting the site configuration or its esthetic profile.

Six-sector antenna configurations

At present, most cellular site antenna configurations rely on three directional antennas with 120 degree separation. These configurations are adequate for most typical applications, providing a good tradeoff between gain and capacity. In semi-rural or suburban areas that combine large cells with high-capacity utilization, even higher gain can be achieved from six antenna sectors separated by only 60 degrees. The additional 3dB gain from the smaller lobe antennas translates into a 40% increase in coverage (Figure 4). This, in turn, translates into a potential 30% reduction in number of sites. As broadband penetration increases, broadband IP traffic will quickly overtake voice as the dominant type of traffic in 3G networks. This IP/broadband paradigm will especially benefit from the combined effect of better coverage (enabling higher speeds) and increased capacity (to serve more users).

Modular high-gain antennas

A modular high-gain antenna (MHGA) consists of a vertically arranged array of two or three standard antenna panels connected by a special feed network that enables the array to function as one antenna. An MHGA has the same excellent performance as a standard antenna but with significantly higher gain. By introducing MHGAs into the network, operators can improve the link budget and increase coverage by up to 60%. These antennas are therefore ideal for providing coverage in rural areas, over flat ground or seas, and along highways. MHGAs improve the link budget from 2.5dB to 4.1dB in both the uplink and downlink. Also, by using null-filling techniques, they can maintain sufficient coverage below the horizon.

For greenfield deployments, the improved coverage enabled by MHGA can significantly reduce the number of sites compared with GSM900 site grids (Figure 5).

Lower frequency bands

In some markets, lower frequency bands are being made available for WCDMA, which also improves the link budget. For example, the link budget of WCDMA850 or 900 is about 6dB better than that of GSM900. With this gain, operators can

- improve coverage for urban indoor users; and
- minimize the number of sites needed to provide coverage to rural areas.

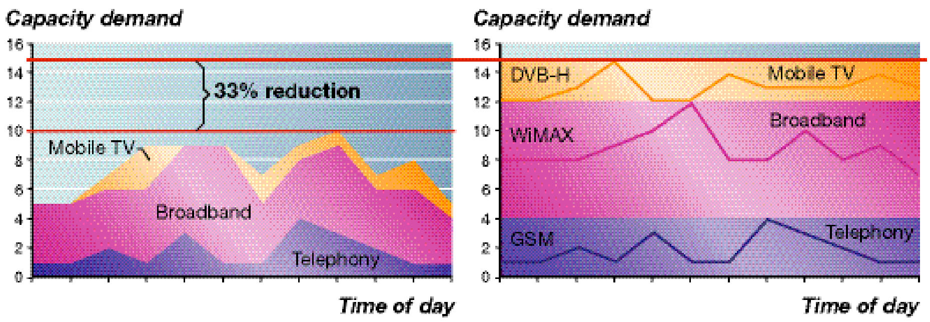
Extended range

The range or reach of a cell is often limited by terrain or the radio horizon. Therefore, the normal theoretical limitations of the radio network, typically 35km, seldom actually come into play. Occasionally, operators want or need to extend the cell range, in some cases up to 200km. Ericsson has thus developed a special function called “extended range” that enables cells to increase their measuring range in several steps to up to 80, 150 or 200km. This feature is suitable for extreme coverage applications over flat terrain, such as desert regions, and over large bodies of water.

Greater output power

Because the downlink capacity in WCDMA networks is determined by the available output power of the base station, one final way of increasing the link budget in the downlink is to increase base station output power. Given the great distance between base stations, this is not likely to increase interference significantly as would be the case in an urban environment.

Figure 6
Illustrative example of multiservice synergy.



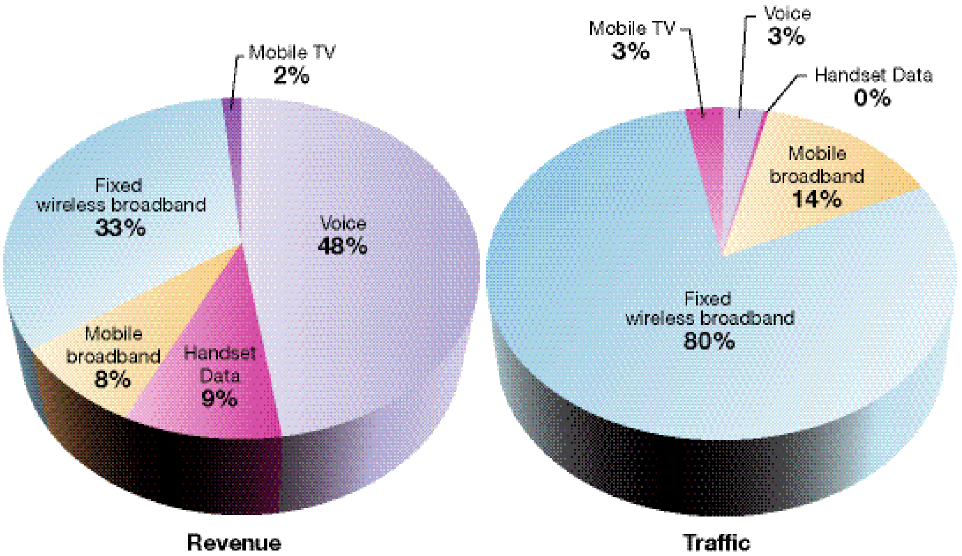


Figure 7
Left: More than 50% of rural site revenues are set to originate from data-based services where fixed-wireless broadband will become a key contributor.
Right: A WCDMA network is better characterized as a broadband access network than a mobile telephone network because broadband IP traffic is poised to become the dominant type of traffic.

The combined effect of greater output power from the base station and six-sector antenna configurations relying on MHGA aerials, enables operators to easily improve rural service performance. Indeed, they can match or surpass the link budget of the existing GSM network.

Rural 3G transmission, broadband to the site

Mobile sites designed for longer reach and greater coverage also have longer transport connections. A very cost-effective solution (where there is no fiber backhaul infrastructure in place or where the length of available copper is too great or provides only limited throughput) is to deploy microwave transmission.

Charges for leased copper connections are typically based on capacity and distance, which in the case of rural WCDMA is uneconomical. A typical microwave network, on the other hand, can be rolled out for less than one-tenth the cost of laying fiber the same distance and still easily support the capacity and range requirements imposed by rural WCDMA. In addition, microwave can be rolled out much faster, and thanks to preconfigured site solutions, it is almost plug-and-play. Microwave networks can be configured and managed from a central location. They also support flexible growth and a variety of bandwidths and connections, which helps keep the costs of operating remote sites at a minimum.

These advantages are well known. Today, 60% of all GSM base stations are linked with microwave connections. The advantage of owning one's own microwave network becomes even more obvious as transport capacity increases per link.

Notwithstanding, rural applications introduce new requirements and challenges. How, for instance, does one overcome the issue of distance and keep costs down? Obviously, one must pay careful attention to transmission network design, adapting network topology, frequencies, antenna size, and so forth, to available infrastructure. One must also aggregate traffic at hub sites, for instance on cost-effective IP. And in the long term, operators will introduce adaptive modulation, enabling links to dynamically adjust (based on radio propagation conditions) to bandwidth. Indeed, the combination of Ethernet interfaces on Node Bs and microwave transport using adaptive modulation has the potential to increase available transport capacity by up to 400% and to double the range (coverage) of a given configuration. This will become increasingly important as operators strive to combine large service areas with a rapidly growing broadband penetration.

Operator strategies

WCDMA is emerging as the obvious technology of choice for converging traditional telecommunications services on a single network that is based on a global standard with an established, smooth evolution path toward even greater broadband capabilities in years to come. Strategic and political forces are pushing for nationwide broadband connectivity and new, rich communication services. At the same time, it is understood that rural operator strategies must allow for a positive return on investment.

Assessing multiservice synergies

The ability to deliver multiple services via a single network translates into multiple streams of revenue and reduced costs thanks to greater efficiency and better use of network investments. This is best understood when one analyzes the traffic pattern of individual services and the diverse busy-hour distribution that these services have over time. By aggregating diverging and often uncorrelated peak busy hours, operators can minimize the cost of delivering a portfolio consisting of multiple services by maximizing the use of costly network resources, such as

- baseband processing capacity:
- protocol stacks and physical interfaces;
- antenna systems and filter units; and
- radio power amplifiers.

Multiservice delivery also gives operators an unmatched competitive advantage when pitted against alternative players who rely on single-service technologies, such as WiMAX or DVB-H. While also present in urban environments, this competitive advantage becomes especially significant in the rural domain where providing coverage (not capacity) is the primary challenge (Figure 6).

Revenue model

Cell radius: 12km
Cell area: 280km²

Population density: 15 inhabitants/km²
4210 inhabitants in cell
1684 households in cell (2.5 people per household)

Handset services

Based on population: Mobile penetration: 80%, Operator marketshare: 50%, 3G penetration: 50% = 842 subscribers

842

Service	Usage factor		ARPU
Voice telephony	100%	MOU: 300 x 5 cent/month	EUR 15/month
Handset data	60%	10 MB x EUR 0,5/MB	3/month
Mobile TV	12%	Flat fee: EUR 8/month	1/month
			Total ARPU: EUR 21/month

Annual site revenue = subscribers x ARPU x 12 (= 842 x 21 x 12) = **EUR 212,184/year**

Mobile broadband services

Based on population: Laptop penetration: 10%, Mobile broadband penetration: 30%, Operator marketshare: 50% = 63 subscribers

63

Service	Content ratio		ARPU
1 Mbps peak rate	30:1	8 busy hours/day	EUR 35/month
			Total ARPU: EUR 35/month

Annual site revenue = subscribers x ARPU x 12 (= 63 x 35 x 12) = **EUR 26,515/year**

Fixed wireless broadband services

Based on households: Broadband penetration: 35%, Operator marketshare: 50% = 295 subscribers

295

Service	Content ratio		ARPU
2 Mbps peak rate	50:1	10 busy hours/day	EUR 30/month
			Total ARPU: EUR 30/month

Annual site revenue = subscribers x ARPU x 12 (= 295 x 30 x 12) = **EUR 106,064/year**

Total annual site revenue = EUR 321,963/year. Annual revenue per square kilometer = EUR 1,152/km²

Profitability

Total cost of site ownership (EUR)

CAPEX:	240,000	Upgrade of GSM site to WCDMA (incl. transmission and capitalized expenses)
Depreciation:	40,000/year	Based on six-year depreciation
OPEX:	40,000/year	Assumed to be 100% of annual CAPEX depreciation
TCO:	**80,000**/year	Total cost of site ownership (CAPEX depreciation + OPEX)
TCO/km²	**285**/km²	Assuming site coverage of 280 square kilometers

Total Cost of Site Ownership = EUR 285/sqare kilometer

Site profitability (EUR)

Revenue per square kilometer: 1,152/year
Total cost per square kilometer: 285/year
Rural gross margin = (1152 – 285) / 1152 =**75%**

Rural site gross margin = 75%

Table 1
Three revenue-contributing services: handset services, mobile broadband services, and fixed-wireless broadbnad services.

Access exclusivity benefits rural users

The regulatory environment, which regulates the unbundling of the local loop, presents another competitive advantage that can play into the hands of many combined fixed and mobile operators. In most deregulated markets, incumbent operators must share copper access with competitors. Not surprisingly, this has led to a situation where incumbent operators are reluctant to make further investments to bring broadband connectivity to rural areas, because any investments they make in the rural fixed copper network will automatically benefit competing broadband service providers. As a consequence, operators are instead turning to WCDMA – an operator's rural investments help achieve market exclusivity, because the radio network is not subject to loop unbundling and is not therefore accessible to direct competitors.

Market exclusivity has traditionally hampered competition and been perceived as being disadvantageous for rural consumers. However, because of the ubiquity of mobile services, operators are most likely to offer a single, homogenous, nationwide service, which actually benefits urban and rural consumers alike. This is because highly competitive mobile and broadband markets in dense urban areas will drive the price of the entire nationwide 3G service offering. And no operator will risk its position in these densely populated areas in order to extract higher prices from less-populated areas. Rural consumers will thus benefit from price competition in urban environments, and 3G operators will benefit from the ability to pursue a viable rural 3G strategy. The ultimate winners are the rural communities, which for the first time can now obtain advanced broadband and communication services.

The ability to reduce risk and protect broadband investments in the challenging rural domain is in itself reason enough to make WCDMA a strategic choice. Add to this the multiservice synergies of WCDMA and you have a future-proof platform for growth across all product segments.

Example business case

To illustrate the viability of 3G to cost-effectively deliver a wide range of services in the rural domain, we examine a realistic market and site scenario that represents rural European environments. Our analysis applies to a rural WCDMA2100 site built for a 150dB link budget. According to the standard three-sector cell-area formula, a cell radius of 12km yields a cell area of 280km²:

$$9/8 \times \sqrt{3} \times r^2$$

Given a population density of 15 inhabitants per square kilometer, the total population in the cell should be about 4,200. By applying conservative service penetration and realistic average revenue per user

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(ARPU) levels to this population, we can calculate annual site revenue. Table 1 shows the three revenue-contributing services: mobile telephony/data/mobile TV, mobile broadband and fixed-wireless broadband. Together, these services should generate an annual revenue of more than EUR 1100/km^2.

On the cost side, we assume a site-related capital expenditure (CAPEX) of EUR 0.24 million for upgrading an existing GSM900 site to WCDMA and of upgrading transmission network capability to support broadband services. Recurring annual operating expenses (OPEX) are assumed to amount to 100% of annual CAPEX depreciation. The annual total cost of ownership calculated with six-year depreciation is thus no more than EUR 285/km^2 of coverage (Figure 7), resulting in a gross operator margin of more than 75% for the combined 3G service offering. Figure 8 gives a breakdown of revenue and traffic distribution. Note how broadband and data services are set to become significant contributors, especially as revenues from mobile voice service is expected to decline over time.

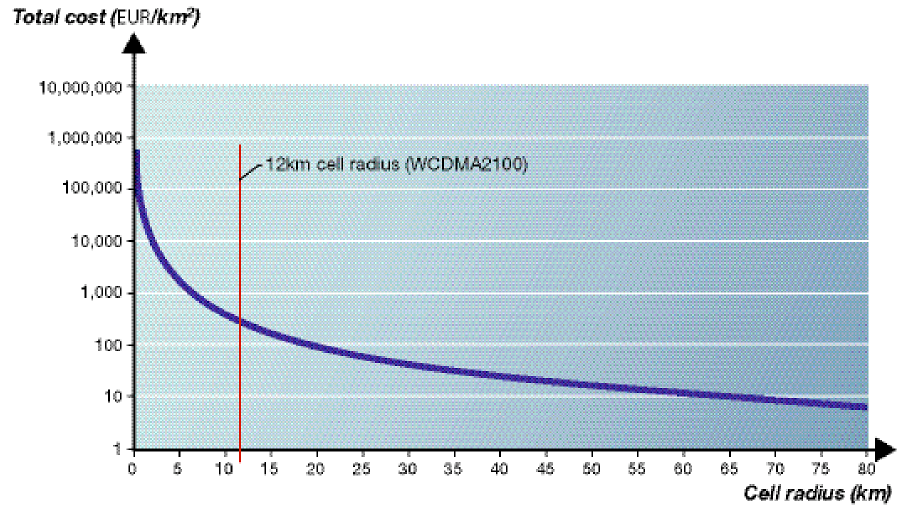

Figure 8
Improved coverage reduces costs to a level that makes for profitable rural deployments.

Competitive advantage

Extensive modeling and analysis have shown that it is possible to deliver broadband capacity via WCDMA/HSPA at an end-to-end cost of about EUR 1/GB. Therefore, we see that 3G-enabled fixed-wireless broadband has the potential to become a cost-effective alternative to ADSL, assuming the average volume of consumed traffic is low to moderate. This is because fixed DSL service providers must pay a fixed, regulated monthly fee to rent the copper access through local loop unbundling. Although this permanent, recurring fee differs from market to market, it is often equivalent to the total cost of providing an end user with a monthly data volume of 10GB or more via WCDMA/HSPA.[5]

Best practice from Telstra

Telstra demonstrated great vision and unique strategic insight when, in 2005, it chose WCDMA technology for its next nationwide telecommunication network. As a result, cities, towns and even small communities and villages with as little as a few hundred inhabitants in remote outback areas will soon benefit from advanced communication and internet services. This move will benefit and improve the lives of consumers and businesses and have a long-term, far-reaching impact on productivity and quality of life. For the first time, consumers and small businesses in remote outback areas will obtain true internet connectivity and be able to benefit from a wide range of state-of-the-art yet inexpensive 3G handsets.

Telstra's WCDMA network, which primarily operates in the 850MHz frequency band, is expected to cover 98% of the Australian population. Typical rural sites have a cell radius of 50 to 60km, but this distance can be extended to meet market demand. Some cells will benefit from the *extended range* feature, delivering service to special offshore and aerial applications at distances of up to 200km.

Conclusion

Mobile telephony and broadband services are a prerequisite for trade, economic growth, employment, education and quality of life.

A new world has emerged in the wake of the internet revolution. Ironically, however, this new world, popularly called the "global village," often excludes rural villages and communities. This exclusion is not due to lack of demand but rather the prohibitive cost of delivering broadband services in rural areas with traditional single-service technologies. Until now, wired technologies were the sole means of delivering efficient, high-performance services. However, major advances in mobile 3G wireless technology have resulted in a new generation of networks that effectively level the playing field and can eliminate the digital divide by bringing advanced broadband and communication services to all citizens, even those in remote and inaccessible regions.

WCDMA technology has emerged as the only dominant, global 3G standard that can live up to and deliver on the promise of one network, one technology, and one service offering.

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