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Broadband Access for Wireless and Fixed -WiMax

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***Abstracts* - A variety of broadband wireless and mobile access technologies are available which are suitable for various usages and offer different performances. One will be optimum for a given geographical situation. This papers aim is to offer the best access network available for users when and where they need it. This is not a single simplistic proposal, but a technology-agnostic strategy based on a wide choice of multi-access solutions.The radio access network is a masterpiece in the transport of ad hoc services and will demonstrate its flexibility to achieve the most stringent performance to-cost ratio objectives. It offers multi-access provisioning, the highest data rates, the lowest latency and best QoS in the nomadic and mobile environments**

***Keywords* -** AMC Adaptive Modulation and Coding, BWA Broadband Wireless Access, EDGE Enhanced Data Rate for GSM Evolution, TD-SCDMA Time Division Synchronous Code Division Multiple.

1. INTRODUCTION

A. General Introduction

The value-proposition offered by mobile operators is based on numerous multimedia services delivered over fixed or mobile networks, or the Internet. The aim is to provide the mobile operators with all the business and technical tools they require to put the Internet in each pocketusing the best broadband wireless technologies.

A user-centric broadband world will be built using selected technologies; Thetechnology is approach answers the key business, technical and strategic challenges. The key technologies are shown in *Figure 1*. The main driving forces for the success of broadband wireless and mobile are:

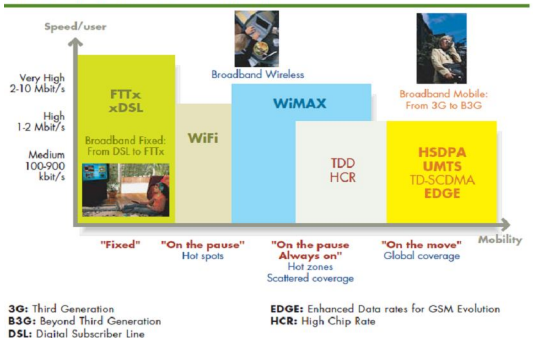
- All proposed services and solutions meet users' needs:
  - Broadband must be accessibleanywhere, in any situation
  - Access to personal broadband services should be easy.
  - Users want the services and bandwidth at attractive prices.
- Several criteria are crucial when selecting the right technology:
  - Optimization of coverage.
  - High spectral efficiencysolutions, to increase traffic throughput.
  - Reliable handover, roaming and security.
- Access must be cost-effective
- The operator's three major assets: Subscriber base, Base station sites Spectrum

The total cost of ownership at the access level must follow the general cost reduction trend, in line with devices and handsets, to ensure the widespread penetration of broadband services.

To achieve this, various approaches are being used.

- High re-use of existing base stationsites.
- Flexible capacity growth.
- Evolution to take advantage of newtechnologies.

Figure 1: Benefits of the key access technologies



B. Accessing network solutions are based on three key pillars:

Moving from multi-standard to multi-access:

A flexible, cost-effective base station architecture allows the deployment of not only GSM/EDGE and UMTS/HSDPA, but also WiMAX, TD-SCDMA, UMTS-TDD and satellite mobile broadcasting.

C. Cost optimization program every nine months:

To ensure the scalability needed to allow incremental investment in the infrastructure, hardware and software flexibility, and full backward compatibility to maximize the use of earlier investment.

D. Rapid introduction of new technologiesvia software upgrades.

EDGE is being introduced via software activation; once UMTS is deployed, it will be possible to introduce HSDPA by upgrading the software. The same is true for the smart antennas solutions being introduced in base stations.

E. Performance of Broadband Wireless Technologies

The technical characteristics of the various Broadband Wireless Access (BWA) solutions must be thoroughly assessed before one is chosen.

Various radio performance indicators are needed as inputs to the economic assessment that identifies the optimum operator strategy:

- Coverage and the number of sites that can be reused to minimize t costs.
- Average and peak throughput per sector to evaluate the system capacity

• Average and peak throughput per user, as this affects the types of service.

2. OVERVIEW OF BWA STANDARDS

Overview of the parameters gives in Table. 1 that influence the performance of frequency. The frequency band has a major impact on the cell radius.The higher the frequency band, the lower the range, which is why high data rate technologies have a smaller maximum reach than that offered by GSM900 systems.

The duplex mode defines the way in which bandwidth is shared between the downlink (base station to terminal) and the uplink (terminal to base station). It affects the system capacity and spectrum requirements. In FDD mode, the downlink and uplink use different frequency channels and are adapted to symmetric traffic. FDD requires paired spectrum allocation.

In contrast, in TDD mode the uplink and downlink share the same frequency channel intime. This mode is suitable for asymmetric traffic, since usually the ratio between uplink and down-link is adjustable. TDD can be deployed in unpaired and paired spectrum allocations.

Table 1: Main radio parameters for selected BWA systems

	GSM-EDGE	UMTS-FDD (HSDPA)	UMTS-TDD (HSDPA)	WiMAX	CDMA 2000 (EV DO)
Frequency band	2G (850/900/ 1800/1900 MHz)	3G (2.1 GHz)	3G+BWA	BWA (2.5/3.5GHz)	2G+3G+450 MHz
Duplex mode	FDD	FDD	TDD	TDD/FDD	FDD
Channel bandwidth	200 KHz	5 MHz	5 MHz 10 MHz (BWA)	1.25 to 20 MHz	1.25 MHz
Physical layer	AMC (GMSK/8PSK)	DS+SS+AMC (QPSK/ 16QAM)	DS+SS+AMC (QPSK/ 16QAM)	OFDM+AMC (QPSK/16QAM/ 64QAM)	DS+SS+AMC (QPSK/8PSK/ 16QAM)
Access layer	TDMA	CDMA	TD CDMA	TD OFDMA	CDMA
Frequency reuse	9 (traffic channel), 14 beacon channel	1	1	3	1
Minimum spectrum	2x4.6 MHz	2x5 MHz	1x5 MHz	30 MHz (for 10 MHz channel)	2x1.25 MHz

AM: Amplitude Modulation
QAM: Quadrature Amplitude Modulation
GMSK: Gaussian Minimum Shift Keying
QPSK: Quaternary Phase Shift Keying
PSK: Phase Shift Keying

Channel bandwidth directly affects the throughput on the air interface. The greater the channel bandwidth, the higher the data rate, which is why WiMAX systems have much higher throughputs than others.

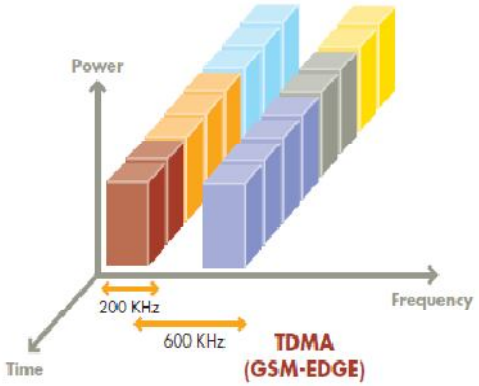
The physical layer of any BWA systems is based on Adaptive Modulation and Coding (AMC) mechanisms. This enables the fluctuating propagation channel characteristics to be efficiently exploited by selecting higher level modulation schemeswhen possible to increase the throughput per sector. In addition, the modulation technology affects the performance.

CDMA use Direct Sequence Spread Spectrum (DSSS): narrowband signals are spread over a larger bandwidth signal, which is more robust against interference and has improved sensitivity (processing gain). GSM and CDMA systems use single carrier modulation.

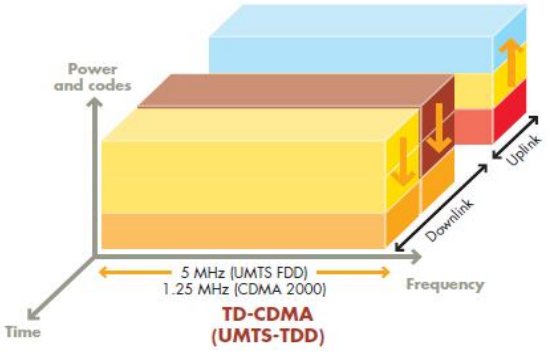
In contrast, WiMAX is based on OFDM, which is a multiple carrier modulation system. The high data rate information flow is transmitted in parallel on a higher number of orthogonal narrowband subcarriers. OFDM offers the best performance / complexity tradeoff for transmission bandwidths larger than 5 MHz.

A. The multiple access scheme

MAS indicate how the available bandwidth is shared between users and the system could be deployed. In the case of GSM/EDGE using Time Division Multiple Access (TDMA), the user data is divided between timeslots belonging to a given channel; the user data can be allocated to a maximum of four timeslots per TDMA frame; each timeslot can carry different user data.



However, in UMTS-FDD and CDMA2000 systems, which are based on CDMA, users share the whole system bandwidth and are allocated different codes and powers. The use of codes enables CDMA systems to operate with a high level of interference.



In WiMAX systemsfrequency reuse defines the minimum number of frequency blocks that are required for cellular deployments in BWA systems. Indeed, since BWA systems use AMC, the throughput per sector depends on the level of interference created by the cells transmitting at the same frequency. In CDMA systems, a frequency reuse of "1" is common, this generates a high level of interference acrossthe cell.

In the case of GSM/EDGE, a reuse of at least nine is required; the EDGE throughput can be optimized if EDGE carriers are deployed with higher frequency reuse (thanks to the reduction in the level of interference). WiMAX has, by its nature, similar requirements to GSM/EDGE systems in terms of interference levels.

However, adaptive antenna technology means that WiMAX can be deployed with a frequency reuse of just three.

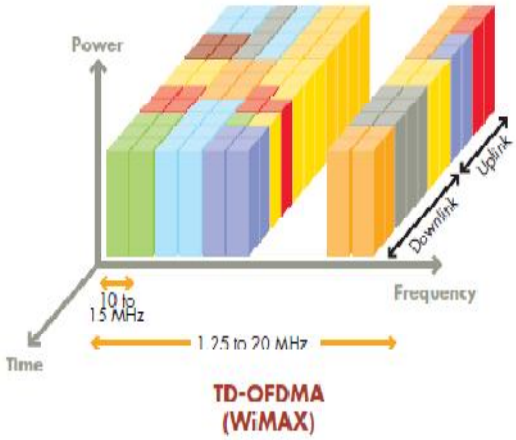
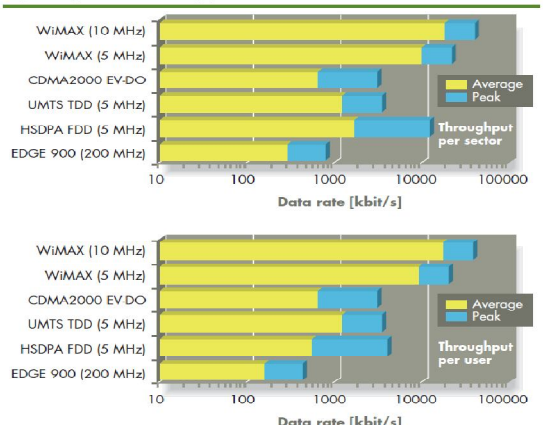


Table 1 shows the spectrum required for deploying a BWA solution, based on frequency reuse, channel bandwidth andduplex mode.

B.Radio throughputs of BWA technologies

The results synthesized in *Figure 5* assume that all the radio network resources are being utilized; the comparisons of same propagation conditions, same antenna height, same indoor penetration requirements about the radio environments. The average throughputs can then be seen as the minimum achievable throughputs.

Figure 5: Typical downlink throughputs



In addition, a downlink / uplink ratio of 3:1 is assumed for TDD systems (UMTS-TDD and WiMAX).

In terms of throughput per sector, three performance groups can be derived:

- *300 kbit/s:* 2G technology
- *700 kbit/s to 2 Mbit/s:* 3G technologies

In these systems, the ratio between the average and peak rates is rather low because of the high level of interference across the cell resulting from a frequency reuse of "1".

- > *10 Mbit/s:* WiMAX offers average data rates of around 15 Mbit/s, with peaks up to 22 Mbit/s.

Considering the available data rates per subscriber, the various BWA options support Asymmetric Digital Subscriber Line (ADSL) like services at the following speeds:

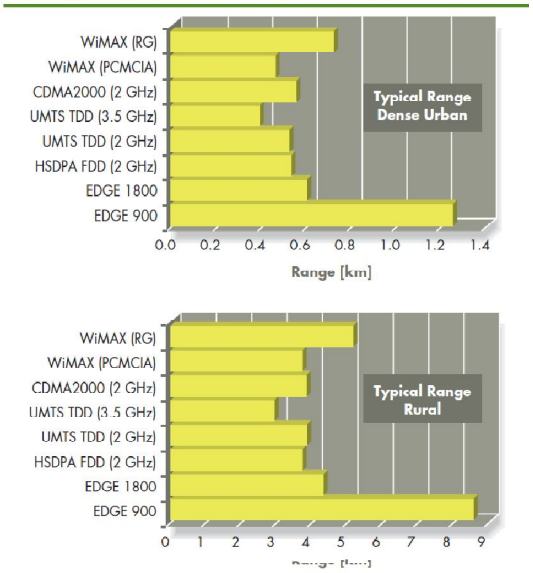
- Up to 128 kbit/s for GSM/EDGE.
- Up to 512 bit/s for 3G technologies
- Up to max. Mbit/s for WiMAX.

C. Coverage and site reuse

Coverage determines the number of sites that are required to serve the entire service area. It is thus of the utmost importance when considering the investment needed to introduce BWA. *Figure* 6 shows the cell rangesfor dense urban and rural environments with the following constraints:

- Deep indoor penetration, which is essential for BWA systems.
- Minimum uplink data rate per user at cell edge of 64 kbit/s.

Figure 6: Typical range (uplink data rate 64 kbit/s at the cell edge)



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Two scenarios are analyzed for the WiMAX system. The WiMAX residential gateway corresponds to a employment targeting "DSL-like" wireless with the terminal having an "ADSL modem" form factor, including a small embedded antenna, and hence capable of higher transmission powers. *Figure 6* clearly shows that the higher the frequency, the lower therange.

The GSM system provides the best coverage; EDGE coverage is the same as GSM coverage. For frequency bands of around 2 GHz and above, the range is at least halved compared with EDGE at 900 MHz. However,the ranges cited here are maximum ranges for GSM; Consequently, in dense urban areas, 2G sites can be used to deploy any BWA technology while providing complete coverage for BWA services. This is a key feature considering the difficulty of finding additional sites in urban areas.

Figure 7: Performance metrics for BWA technologies

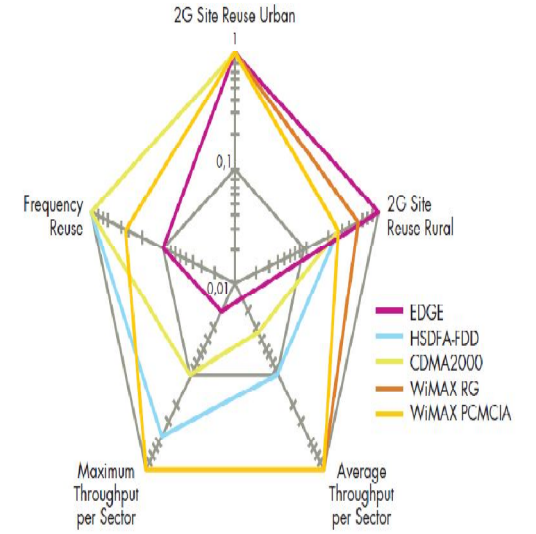


Figure 7 compares the performances of GSM/EDGE, UMTS-HSDPA, CDMA2000 and WiMAX; the followingconclusions can be reached:

- GSM/EDGE enables BWA to be introduced smoothly at low cost: no additional sites are required.
- EDGE can be introduced using a simple software upgrade; Services requiring data rates of up to 128 kbit/s can be introduced.
- UMTS/HSDPA technology to support more users and higher data rates for BWA services in urban areas. Users receive data throughputs of up to 512 kbit/s.
- WiMAX is a real "Internet in the Pocket" BWA solution, offering high data rates per sector, and data rates in excess of 1 Mbit/s per user.

The performance results outlined here are fed into the economic models used to select the most suitable technology based on the target market, the target area and the shortest return on investment period.

3. BROADBAND WIRELESS TECHNOLOGIES FOR RURAL AND URBAN ENVIRONMENTS

To help understand the positioning of the different solutions, two wireless technology groups are compared for both rural and urban areas:

- Data-oriented group using WiMAX
- Mobile-oriented group featuring EDGE, CDMA2000

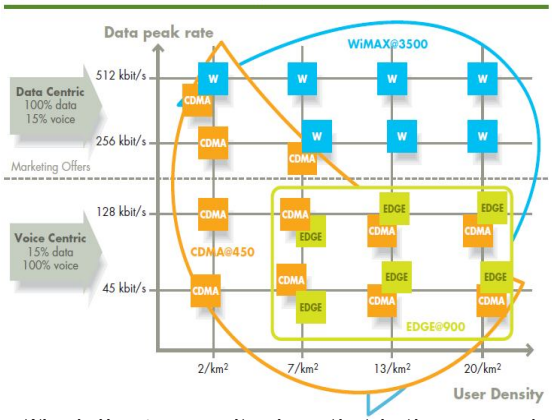
1xEV-DO using 450 MHz in rural areas (CDMA450) and UMTS/HSDPA CDMA2000 1xEV-DO in urban areas.

Two dimensions have been used to highlight the differences in profitability between the technologies:

- *Variations in density:* Four cases for rural fixed wireless access and threeurban cases: dense urban, urban and suburban.
- Variations in data rate requirements corresponding to different marketing packages
- *Rural case:* Four data rates corresponding to two voice-centric marketing offers (45and128kbit/s) and two data- centric offers (356 and 512 kbit/s).
- *Urban case:* Three data rates corresponding to three well known segments:

a full mobile offer up to 512 kbit/s; anomadic / hot-zone offer up to 1 Mbit/s, and a fixed wireless offer up to 2 Mbit/s.

Figure 8: Rural area cases: What technology best meets the service requirements



The following results show that both groups of wireless technologies offer specific benefits that are needed to offer a universal wireless service in any situation (full mobile, nomadic, fixed), in any area (rural or urban), at different bitrates, and whatever the subscriber density. The overall finding is that none of these technologies can provide the optimum solution for all the scenarios, hence they should to be used to complement one another, taking the best features from each.

A. Fixed wireless access technologies for rural areas

These three (WiMAX, EDGE and CDMA450A)wireless technologies were compared to assess how they perform economically in different density zones in a rural area while supporting the required voice + data capability. The results show that all three technologies can be used, taking full advantage of the benefits of each.

However, each solution has its limitations:

- WiMAX is not yet suited to voice-oriented services, mainly for handset availability reasons.
- GSM/EDGE and CDMA hardly achieve the data capacity needed to support high-speed Internet access.

Nevertheless, each solution has its advantages:

- CDMA 450 is the most economic answer in very low density rural areas. It fully supports the voice service, while offering an acceptable data rate. It could be deployed with a WiMAX implementation so that high bit rates can be offered where the user density exceedsbetween two and seven subscribers per square kilometer.
- EDGE and CDMA 450 are profitable in rural areas with medium to high population densities, with data rates limitedto 128 kbit/s.
- WiMAX is the best answer for data rates of up to 512 Mbit/s. This is no surprise as it is a data-built-in wireless technology.

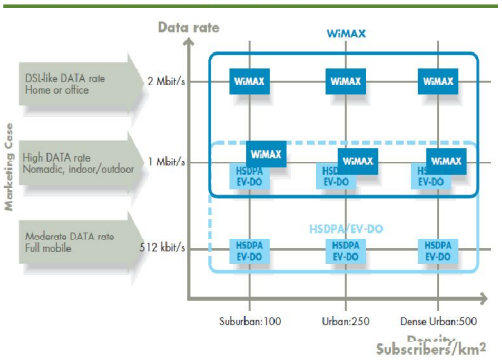
It can be deployed in overlay mode on top of either EDGE or CDMA, thus offering future-safe evolution. Increased demand for voice and data services could be met either using more WiMAX + EDGE or CDMA density extension, or simply by increasing WiMAX density, using

Voice over Internet Protocol (VoIP) to carry voice as soon as terminals become available.

B. Wireless technologies in urban areas

The two groups (WiMAX, UMTS/HSDPA and CDMA2000 1XEV-DO)of wireless technologies were compared to assess how they perform economically in the different density zones of an urban area while supporting the required voice + broadband data capacity. The results (see *Figure 9*) show that all three technologies can be used, taking advantage of their particular benefits.

Figure 9: Urban area cases: comparing service requirements



Economically speaking, the results show that all the technologies have limitations:

- WiMAX is not yet ready for a full mobile offer, primarily because of a lack of suitable handsets.
- HSDPA and CDMA EV-DO both achieve only limited profitability when addressing nomadic hot zones. Usingthem to offer a combined mobile data / nomadic package could be problematic, as the larger number of sites neededwould adversely affect the business case. Other drawbacks are that more equipment(and therefore investment) isneeded as the data rate increases (e.g. 2 Mbit/s instead of 1 Mbit/s for nomadic use would dramatically affect the business case), and that the peak rate at the cell edges is only 128 kbit/s, compared with around 4 Mbit/s for WiMAX.

Again, each solution has specific benefits.So they can be used to complement one another:

- UMTS-HSDPA and CDMA 1xEV-DO are definitely the best fit for full mobile services, and can support a healthy throughput of 512 kbit/s on top of regular voice. They also offer greater usage flexibility, thereby enabling the existing mobile infrastructure and frequency resources to be reused when adding mobile / moderate nomadic broadband data services.
- WiMAX appears to be the best broadband data technology for any operator thanks to its DSL-like capacity, in all data-oriented cases, as already observed in the rural case. Consequently, it is the natural complement to HSDPA or EV-DO for operators that want to address all the mobile, nomadic and fixed wireless segments.

WiMAX can be used for fixed wireless DSL application in areas with limited copper outside plant, as well as to provide a nomadic / hot zone wireless broadband service with HSDPA or EV-DO to meet the need for full mobility.

4. CONCLUSION

Several broadband wireless access technologies are available for different uses, providing different performances andsuited to different geographies. In all cases, the aim is to offer the best access network for users when and where needed.

It can help broadband andmobile service providers to choose thebest mix of these technologies asthere is no *"one fits all"* solution; it isessential that the technologies shouldcomplement one another. There are three main advantages:

- Its leading position in fixed andmobile broadband networks, applicationsand services, particularly in DSL.
- Its future-proof radio access networksolutions which enable major new technologies,such as HSDPA, to be deployedby upgrading the UMTS software.
- Its strong commitment to optimumnomadic usage and service ubiquitycombining open technology assessment,strong partnerships and networkintegration for the variouswireless access technologies, includingWiFi, WiMAX, UMTS TDD andmobile broadcast technologies.

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