Technology White Paper

WiMAX: From Fixed Wireless Access to Internet in the Pocket

Imagine a radio access network that provides broadband access to users at home, in the office, in areas under-served by wireline services and even to users on the pause or on the move equipped with portable devices like laptops, PDAs and smartphones. WiMAX, which is based on IEEE 802.16e, can provide a flexible radio access solution that offers these features, based on an attractive full IP architecture delivering the capacity required to support wireless broadband services. After the emergence and wide acceptance by users of Internet, broadband and mobile services, we can anticipate a future need for nomadic broadband wireless services. By addressing multiple market segments through the standardization and interoperability efforts of the WiMAX Forum, volume production of WiMAX certified equipment will become possible, driving down the total cost of ownership and opening up new opportunities for the delivery of broadband services to bridge the digital divide.

ALCATEL

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WiMAX: FROM FIXED WIRELESS ACCESS TO INTERNET IN THE POCKET

WiMAX access can provide new service opportunities to fixed and mobile operators thanks to its flexible radio technology and innovative features.

WiMAX is at the center of the emergence of new market and technology opportunities. The widespread deployment of high-speed Internet at home has opened the door to the introduction of new services, such as video, audio, gaming and e-commerce. Today, the availability of portable devices like laptops, Personal Digital Assistants (PDA) and smartphones, is generating interest in providing similar services in nomadic conditions.

In developed regions, the deployment of broadband services in remote areas is lagging behind that in (sub)urban areas. In emerging countries, low penetration of the traditional fixed telephone service and the low quality of the copper pairs is hindering large scale broadband deployment and fostering a demand for alternative wireless technologies.

Broadband wireless access has been serving enterprises and operators for some years, to the great satisfaction of its users. However, the new IP-based standard developed by the Institute of Electrical and Electronics Engineers (IEEE) 802.16 and the WiMAX Forum is likely to accelerate its adoption. WiMAX will boost today's fragmented broadband wireless access market thanks to standardization and interoperability, state-of-the-art radio efficiency with non-line-of-sight capability, and strong support from radio equipment and chipset manufacturers.

By defining a generic full Internet Protocol (IP) radio access network with compelling new radio features, WiMAX can address the fixed wireless access and portable Internet markets, complementing other broadband wireless technologies (see *Figure 1*). This has been achieved by providing access to new spectrum resources and by offering higher bandwidth when required. WiMAX access can be easily integrated within both fixed and mobile architectures, enabling operators to integrate it within a single converged core network, thereby providing new capabilities for a user-centric broadband world.

Technology

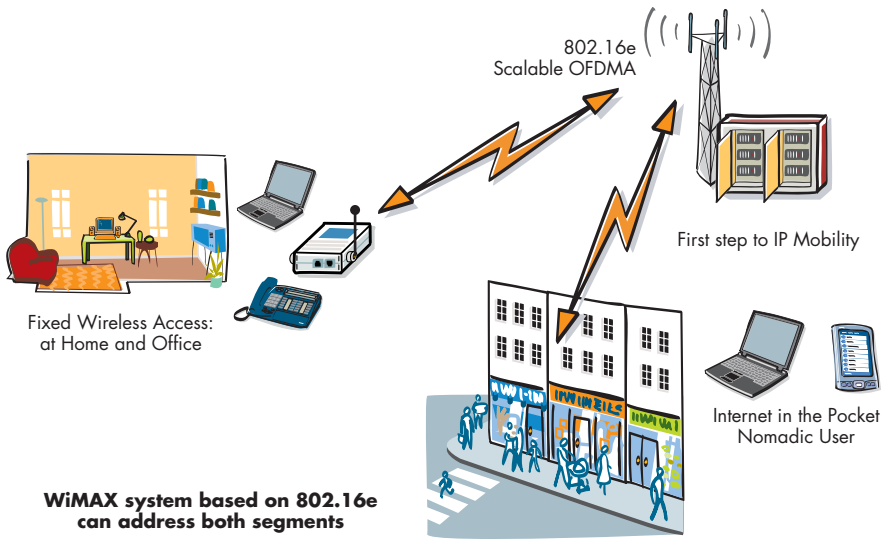
Standardization

The IEEE is facilitating the deployment of broadband wireless access by specifying the air interface for wireless metropolitan area networks. The original IEEE 802.16 standard, which was published in April 2002, focused on the frequency range between 10 and 66 GHz and required line-of-sight propagation. This proved to be a key drawback which prevented cost-effective mass deployment. Consequently, a new version, which underwent several evolutions up to 802.16-2004, has been developed to expand the scope to licensed and license-exempt bands from 2 to 11 GHz. IEEE 802.16-2004 specifies the air interface, including the Media Access Control (MAC) of wireless access for fixed operation in metropolitan area networks.

> Overview on IEEE802.16 standardization: http://www.ieee802.org/16/

New market segments will be opened up by introducing handover between the radio cells. Support for this type of mobility is being defined in a working group for amendment 802.16e, the publication of which is

Figure 1: Flexible WiMAX solution – from wireless DSL to Internet in the pocket



OFDMA: Orthogonal Frequency Division Multiple Access

expected before the end of 2005. In general, the introduction and implementation of this version will greatly increase its attractiveness for broadband wireless access. Alcatel is strongly supporting the development of the 802.16e amendment based on its broad experience in the field of mobile cellular system technologies. Future Alcatel products offering 802.16e features are expected to open up new market opportunities by meeting the users' need for more and more nomadic communication.

> WiMAX Forum : http://www.wimaxforum.org/home

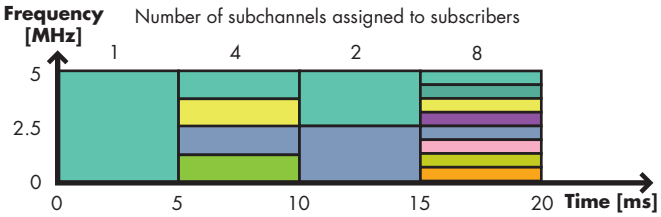
A key issue in the 802.16 standards is the numerous options for parameter selection. Consequently, ***a major objective of the WiMAX Forum is to simplify interoperability between system components by defining a limited number of profiles (sets of parameters) and to grant a "WiMAX certified" label.*** Harmonization of end-to-end architectures, including different types of core network, is also being defined in a specific Network architecture Working Group (NWG) within the WiMAX Forum.

The strong presence of operators and equipment manufacturers in the WiMAX Forum is supporting the IEEE 802.16 standardization process and pushing forward the promotion and deployment of broadband wireless access in general.

Innovative approach based on 802.16e

Alcatel considers mobility and broadband applications as basic features to be implemented in the WiMAX product. The 802.16e standard provides mobility and supports the most flexible and efficient usage of the radio channels by combining the advanced Orthogonal Frequency Division Multiplexing (OFDM) scheme with the Scalable Orthogonal Frequency Division Multiple Access (SOFDMA) technique. OFDM is an optimum solution for robust radio wave transmission under the selective fading conditions that are typical of the non-line-of-sight environment with multipath propagation, for very high data rates using low complexity modulators and demodulators. Subchannel-individual adaptive modulation (QPSK, 16QAM, 64QAM) increases the spectral efficiency up to 3.75 bit/s/Hz under good propagating conditions. In real non-line-of-sight conditions with a mix of modulation formats, the average spectral efficiency is about 2 bit/s/Hz.

Figure 2: Scalable OFDMA: dynamic assignment of different numbers of subcarriers to subscribers

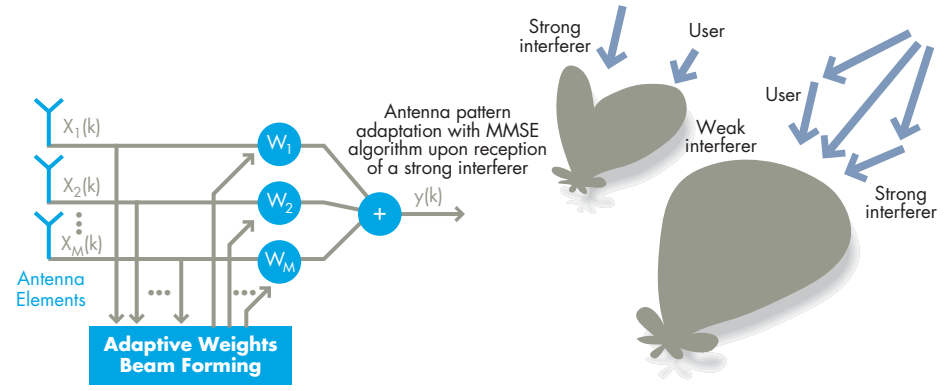


SOFDMA provides additional resource allocation flexibility in the time and frequency domains (see *Figure 2*). Dynamically assigning the number of subchannels (SOFDMA) makes capacity allocation more flexible.

Concerning the downlink and uplink capacities of WiMAX, the classical Frequency Division Duplex (FDD) mode leads to symmetrical systems. However, in the short and medium terms, asymmetric traffic is likely to be more common, making Time Division Duplex (TDD) the preferred mode. Moreover, TDD systems are more flexible, less complex and more cost-effective. In the longer term, and in view of the correlated need for more extended multi-cell coverage, FDD may become more suitable.

The standard allows various bandwidths to be allocated to the radio channel: 1.5 MHz (or 1.75 MHz in Europe) and multiples up to about 20 MHz. Thus ***the WiMAX system and the spectrum resources can be adapted to the needs of both densely and sparsely populated regions, making it suitable for use in rural and urban areas for both fixed access and portable usage.*** In particular, smart antenna and beam forming techniques (see *Figure 3*) can play a key part in enhancing performance in order to ensure compatibility with the radio sites grid of cellular operators (up to 10 km in rural areas and around 1 km in urban areas). The achievable performance in terms of distance depends on various parameters, including the environment, modulation scheme, antenna gain, transmit power, antenna height and frequency band.

Figure 3: The principle of adaptive beamforming and the use of null steering to suppress interference



Further evolutions are planned to enhance performance, particularly the coverage area and bitrates. This will be achieved by implementing cost-effective Multiple Input Multiple Output (MIMO) antenna techniques adapted to WiMAX and by introducing smooth handover mechanisms for real-time services.

Network Architecture

Introducing WiMAX in the network architecture

WiMAX is of interest to all kinds of operators – fixed and mobile, incumbent and alternative.

By deploying a WiMAX access network, fixed operators will not only be able to offer wireless access, but also to offer nomadic and portable Internet services to complement their DSL and WiFi bundles.

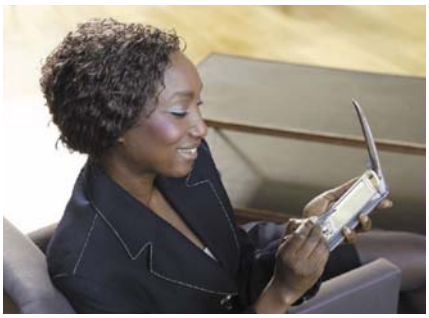
Mobile operators can integrate WiMAX into their networks to boost their portfolios by adding high bandwidth services to complement their existing data services. Access to the same applications (messaging, agenda, portal, etc) over different radio accesses is offered with a single bill and a single subscriber profile.

One key requirement for WiMAX network architectures is to seamlessly integrate fixed and nomadic subscribers into the existing fixed and mobile network architectures. Alcatel's WiMAX strategy is aimed at providing a comprehensive end-to-end solution tailored for all types of operator.

WiMAX integration into a global seamless roaming solution for nomadic users

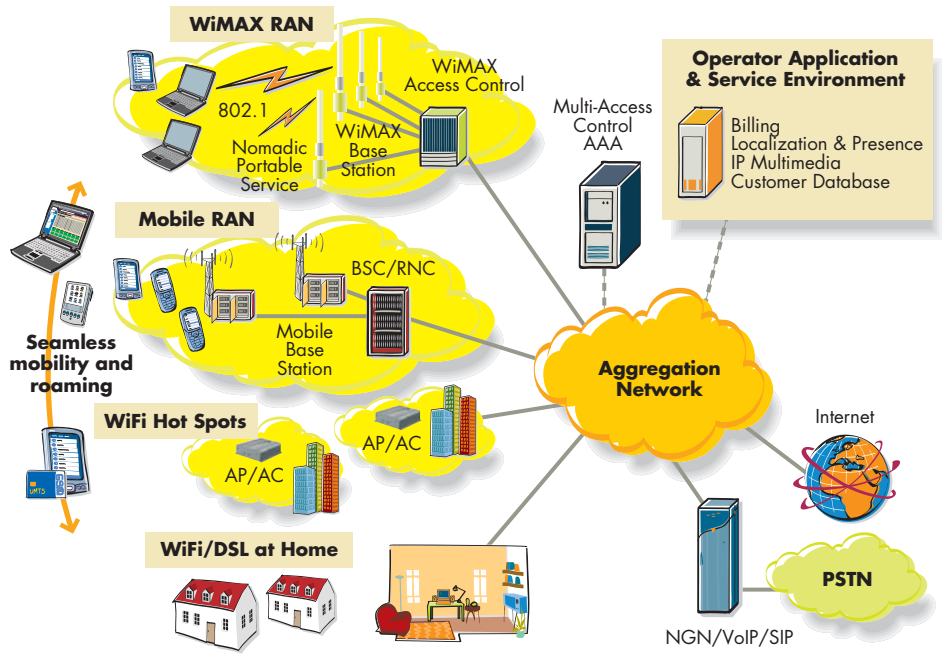
The common services architecture approach should provide users with the following features, irrespective of the type of access network:

- *Common access control and authentication:* Users can have a single subscription and receive a single bill even though they use different access networks. The solution is based on Authentication, Authorization and Accounting (AAA) mechanisms.
- *Access to common services:* All flows are routed through the home network by using tunneling mechanisms. This interworking scenario gives the home operator full control of the service offering (including billing, policy control), and provides the user with all the services to which he or she has subscribed whatever the access network.
- *Service continuity* across different access networks through support for mobile IP.



Initially users will simply want to access their usual services, but will rapidly come to demand service continuity while on the move and passing from one cell to another. The solution enables them to enjoy an "always best connected" experience when accessing their applications via the best available network when at home, away from home or on the move (see *Figure 4*).

Figure 4: WiMAX integration into a global seamless roaming solution



AC: Access Controller (WiFi)
AP: Access Point (WiFi)
BSC: Base Station Controller
NGN: Next Generation Network
PSTN: Public Switched Telephone Network
RAN: Radio Access Network
RNC: Radio Network Controller
SIP: Session Initiation Protocol

Integration in a DSL network environment

WiMAX enables operators to deploy wireless DSL services on their existing infrastructures:

- in areas where a copper infrastructure is either not available or is of poor quality;
- in sparsely populated areas where a wired infrastructure would not be cost-effective.

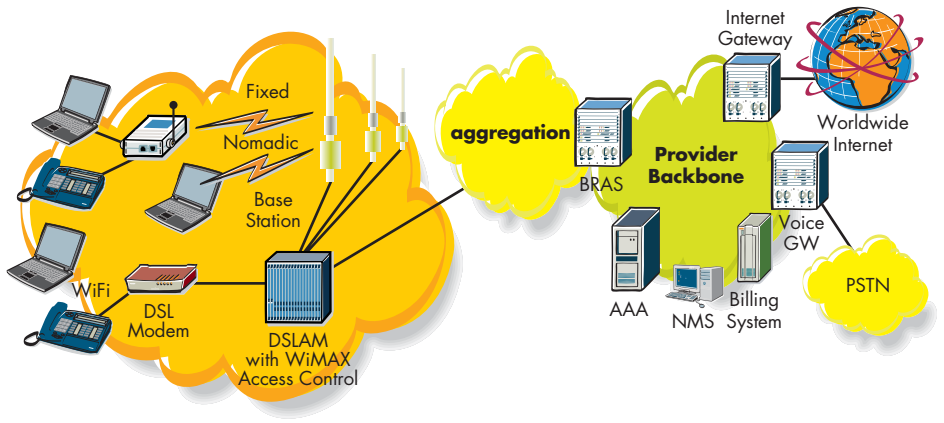
As illustrated in *Figure 5*, connecting the WiMAX base station to the DSL Access Multiplexer (DSLAM) enables wireless DSL to be offered in the same way as Asymmetric Digital Subscriber Line (ADSL) today by reusing both the DSL access and aggregation networks as well as the existing management and provisioning platforms.

WiMAX base stations can be deployed either in the central office or near remote DSLAMs, thereby making use of the infrastructure that is already owned by the operator. Collocating the base station with the DSLAM and connecting it via fast Ethernet eliminates the need for

expensive backhaul links. However, other techniques could also be used to connect the base station to the DSLAM.

This architecture has the advantage that existing Point-to-Point Protocol (PPP) and IP / DHCP (Dynamic Host Configuration Protocol) models can be used to provide high-speed Internet and Voice over Internet Protocol (VoIP) services. Owning a wireless "first-mile" connection enables operators to offer nomadic use, giving their subscribers the freedom to connect in the same way to the same services when at home, at work or in a hot zone. By opting to interconnect the base station to the DSLAM, both wired and wireless, fixed and nomadic services can be offered from a single platform, providing the freedom to deploy the technology best suited to a specific service and situation, thereby extending the broadband reach and the service offer.

Figure 5: WiMAX integrated in a DSL architecture



BRAS: Broadband Remote Access Server

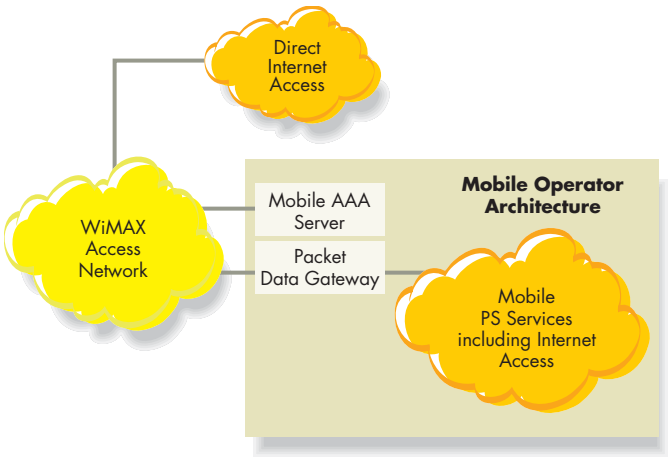
NMS: Network Management System

Integration in a mobile network environment

The globally proposed strategy is to use similar mechanisms to those developed for integrating wireless Local Area Networks (LAN) in the mobile architecture, Third Generation Partnership Project (3GPP) and 3GPP2 (see *Figure 6*). This integration aims to provide:

- WiMAX access, authentication and authorization through the mobile system,
- IP access, meaning that as well as accessing a locally connected IP network from the wireless LAN, the user can connect through the operator's core network.

Figure 6: WiMAX integrated in a mobile architecture



Such an approach enables the user to access operator services and have identical access and authorization mechanisms based on a Subscriber Identification Module (SIM) and Universal SIM (USIM).

The main function of the Packet Data Gateway (PDG) interworking unit is to provide a Tunnel Termination Gateway (TTG) between the WiMAX access network and the mobile core network. It also provides the following functions: charging gateway interfaces, IP address allocation, authentication in external networks, and single access to mobile core network packet data domain services. These can be seen as a subset of the Gateway GPRS Support Node (GGSN) functions in the 3GPP case.

Evolution towards portability and Internet in the pocket

The main added value of a WiMAX access network is to facilitate the evolution to a portability service for data applications or "Internet in the Pocket", making it a natural complement to mobile and WiFi networks.

Portability will offer some simple mobility functions through handover capabilities between access points, while delivering the same user experience as fixed access or nomadic use when the user is stationary. Handover will be based on IEEE 802.16e and best-effort mechanisms, leading to simpler network and user device architectures and software. All delay-tolerant applications will be able to resume IP connections or reconnect on notification of a new point-of-attachment. This portability service does not presume a particular range of mobility speeds, but by relaxing the constraints on handover latency it makes this mode of operation more suitable for reduced mobility rates and for supporting IP services that can tolerate some performance degradation during handovers (non-real-time services).

This portability function relies on handover mechanisms embedded in the 802.16e air interface, on mobile IP principles and on the introduction of *home agents* in the network (see *Figure 7*). Both micro-mobility (handover between WiMAX base stations managed by the same access control) and macro-mobility (handover between WiMAX base stations managed by different access controls) are supported.

Furthermore, inter-technology mobility functions enable the access network to change (between WiMAX, WiFi, and Mobile 2G or 3G networks) while an application session is ongoing. This feature is the cornerstone of the integration of multiple radio access networks with a single converged core network.

Radio Access Network

Challenges

Operators deploying radio access networks for broadband services face several challenges that WiMAX radio infrastructure suppliers should answer. Two main challenges are:

- Minimizing the operator's investment by reducing the number of radio sites.
- Containing costs for backhauling.

Reduced number of radio sites

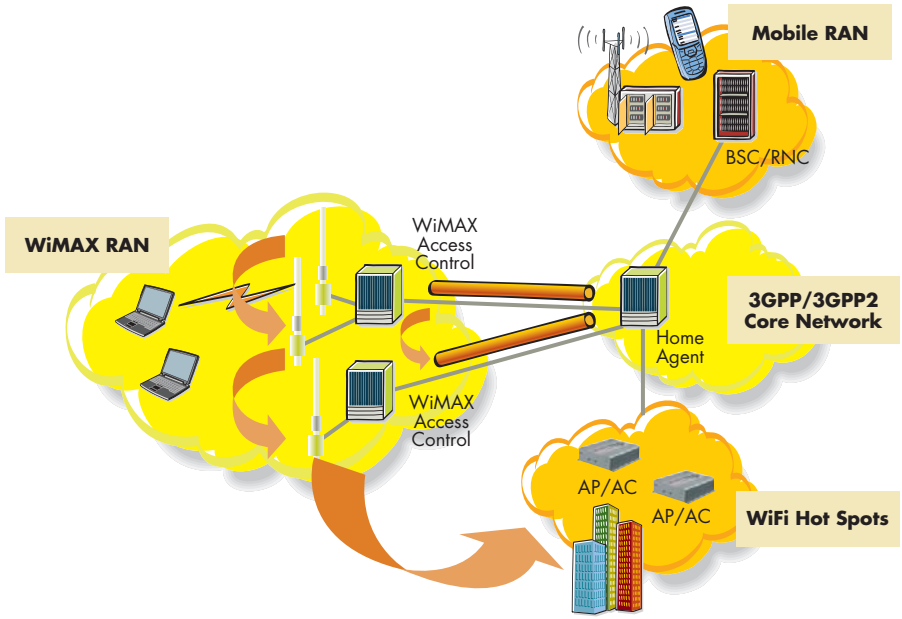
Overall, the WiMAX network deployment strategy is to deliver broadband nomadic services with a large coverage. When deploying any new radio technology and new services, minimizing the required capital expenditure is a key factor for successful implementation as it allows the operator to achieve its financial targets. Because the major part of an operator's network investment is in installing the radio sites, it is essential to achieve the required coverage with the minimum number of sites.

As environmental concerns are leading to sites becoming a scare resource, an appropriate strategy would be to reuse the existing cellular network grid and to favor solutions for sharing sites between existing cellular network sites and WiMAX networks. Compared with existing cellular systems, WiMAX systems implement advanced radio features that compensate for the extra attenuation resulting from:

- *Higher carrier frequency:* the first WiMAX deployments will be in the 2.5 and 3.5 GHz bands.
- *Larger transmission bandwidth:* a typical WiMAX bandwidth is 10 MHz, compared with 200 kHz for GSM systems and 5 MHz for wideband code division multiple access systems.
- *Deep indoor penetration:* indoor coverage is mandatory for WiMAX in any environment, whereas with cellular systems it is only essential in urban areas.

The IEEE 802.16 standards define advanced radio features, including smart antenna technologies and uplink subchannelling to realize the desired performance, that is, high data rates of several Mbit/s in a cellular environment.

Figure 7: Mobility in WiMAX



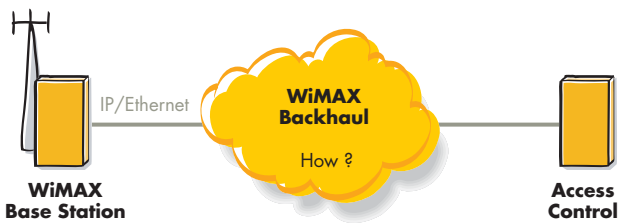
Backhauling

Introducing WiMAX at radio sites makes it necessary to backhaul the traffic generated at this point (around 20 Mbit/s per cell), as shown in *Figure 8*. Thus the launch of nomadic broadband services raises new technological challenges, including questions related to the capacity and cost of different backhauling methods and technologies.

Alcatel's WiMAX systems are based on an all-IP network architecture relying on IP/Ethernet transport. The cost advantages of this approach are considerable; converging voice and data onto a single network reduces both the initial capital expenditure and the operating expenses.

WiMAX solutions should include radio site backhauling options for different kinds of physical interfaces, mainly a wireless solution (e.g. point-to-point or WiMAX self-backhauling), a copper solution (e.g. bonding, that is, combining symmetric high speed DSL copper pairs, could offer the required throughput) and a fiber solution.

Figure 8: Backhauling



Conclusion

The latest developments of the IEEE 802.16 standard based on revision *e* together with the end-to-end standardization initiatives now integrated in the WiMAX Forum through the Network Working Group are driving the emergence of innovative broadband wireless access solutions. At the same time, the success of the WiMAX Forum, with more than 200 members and backed by industry leaders, including operators, component suppliers and infrastructure suppliers, is confirming the promising future of WiMAX as an access technology.

The combination of both advanced radio features and flexible end-to-end architectures makes WiMAX an attractive solution for diverse operators: fixed (including DSL), mobile and wireless Internet service providers. It can help to bridge the digital divide and make portable Internet a reality with

WiMAX chipsets being embedded in laptops, PDAs and other portable devices. Integrated mobility and roaming solutions between various accesses will enable users to enjoy an “always best connected” experience.

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Abbreviations

3GPP 3rd Generation Partnership Project
AP/AC ????
BRAS Broadband Remote Access Server
BSC Base Station Controller
BSC Base Station Controller
DSLAM Digital Subscriber Line Access Multiplexer
FDD Frequency Division Multiplex
GGSN Gateway GPRS Support Node
GW GateWay
HA Home Agent
LAN Local Area Network
MAC Media Access Control
MIMO Multiple Input Multiple Output
NGN Next Generation Network
NMS Network Management System
OFDM Orthogonal Frequency Division Multiplex
PDG Packet Data Gateway
PSTN Public Switched Telephone Network
RAN Radio Access Network
RAN Radio Access Network
RNC Radio Network Controller
SHDSL Symmetric High Speed DSL
SIM Subscriber Identification Module
SIP Session Initiation Protocol
SOFDMA Scalable Orthogonal Frequency Division Multiple Access
TDD Time Division Duplex
USIM Universal SIM

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