STRATEGY WHITE PAPER

# WiMAX, making ubiquitous high-speed data services a reality

Imagine a single wireless technology that can:

- make portable Internet a reality by extending public WLAN hotspots to metropolitan area coverage for mobile data-centric service delivery,
- connect enterprises and residential users in urban and suburban environments where access to copper plant is difficult,
- bridge the digital divide by delivering broadband in low-density areas.

Thanks to its innovative technology, WiMAX will offer broadband wireless access at data rates of multiple Mbit/s to the end-user and within a range of several kilometers. The same radio technology will also offer high-speed data services to all nomadic terminals (laptops, PDAs, etc.) with an optimized trade off between throughput and coverage. Ultimately it will enable the "Portable Internet" usage replicating on the move the same user experience as at home or at the office.

Given its huge benefits, WiMAX will develop as a powerful radio access solution with many integration synergies in mobile or fixed network architecture. WiMAX will also enable end-users to benefit from an "Always Best Connected" experience when accessing their applications via the best available network, at home, on the pause, or on the move. WiMAX particularly fits in Alcatel's vision for a User-Centric Broadband World in full complementarity with the other broadband access technologies: from ADSL to UMTS and their evolutions towards higher speed and data efficiency.

ALCATEL

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## Introduction

Broadband Wireless Access (BWA) has been serving enterprises and operators for years, to the great satisfaction of its users. However, the new IP-based standard developed by the IEEE 802.16 is likely to accelerate adoption of the technology. It will expand the scope of usage thanks to: the possibility of operating in licensed and unlicensed frequency bands, unique performance under Non-Line-of-Sight (NLOS) conditions, Quality of Service (QoS) awareness, extension to nomadicity, and more.

In parallel, the WiMAX forum, backed by industry leaders, will encourage the widespread adoption of broadband wireless access by establishing a brand for the technology and pushing interoperability between products.

The purpose of this White Paper is to highlight and assess the value of WiMAX as the right solution to:

- extend the currently limited coverage of public WLAN (hotspots) to citywide coverage (hot zones) - the same technology being usable at home and on the move,
- blanket metropolitan areas for mobile data-centric service delivery,
- offer fixed broadband access in urban and suburban areas where copper quality is poor or unbundling difficult,
- bridge the digital divide in low-density areas where technical and economic factors make broadband deployment very challenging.

In addition to these uses, this paper will highlight other potential applications, such as telephony or an effective point-to-multipoint backhauling solution for operators or enterprises.

## What is WiMAX?

### Standards associated to WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) is the common name associated to the IEEE 802.16a/REVd/e standards. These standards are issued by the IEEE 802.16 subgroup that originally covered the Wireless Local Loop (WLL) technologies with radio spectrum from 10 to 66 GHz. Recently, these specifications were extended below 10 GHz.

- In January 2003, the IEEE approved 802.16a as an amendment to IEEE 802.16-2001, defining (Near) Line-Of-Sight capability.
- In July 2004, IEEE 802.16REVd, now published under the name IEEE 802.16-2004, introduces support for indoor CPE (NLOS) through additional radio capabilities such as antenna beam forming and OFDM sub-channeling.
- Early 2005, an IEEE 802.16e variant will introduce support for mobility.

See Figure 1 for the applications associated with each of these standards.

The WiMAX Forum intends to do for 802.16 what the Wi-Fi Alliance did for 802.11:

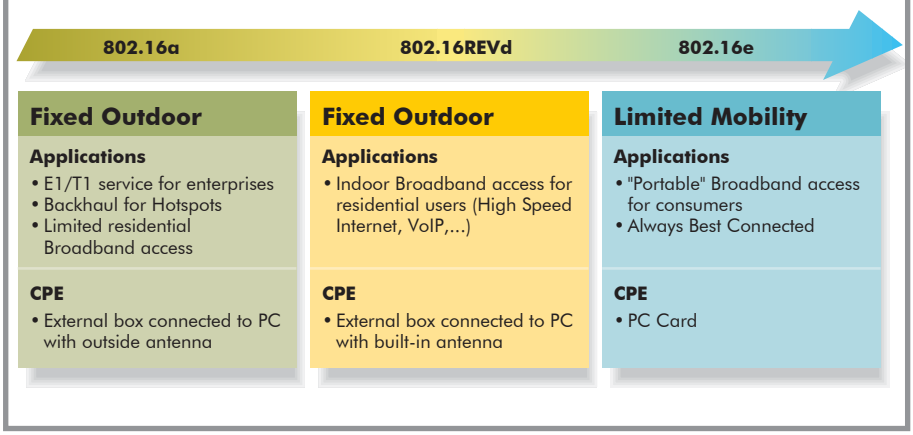
- harmonize standards and certify interoperability between equipment from different vendors. Standardized interoperable solutions will result in mass volume and bring down costs,
- promote and establish a brand for the technology.

### WiMAX, the reality beyond the hype

As mentioned above, WiMAX can offer very high data rates and extended coverage. However,

- 75 Mbit/s capacity for the base station is achievable with a 20 MHz channel in best propagation conditions. But regulators will often allow only smaller channels (10 MHz or less) reducing the maximum bandwidth.
- Even though 50 km is achievable under optimal conditions and with a reduced data rate (a few Mbit/s), the typical coverage will be around 5 km with indoor CPE (NLOS) and around 15 km with a CPE connected to an external antenna (LOS).

**Fig. 1** The different flavors of WiMAX



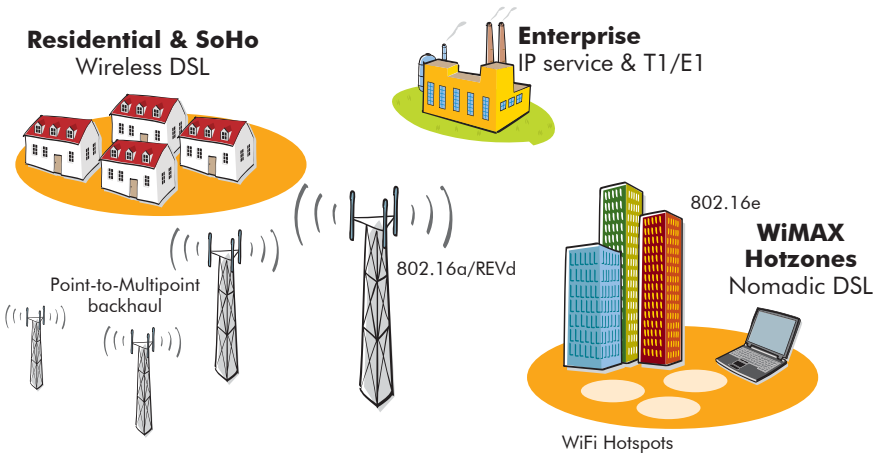
### WiMAX product availability

Mass deployment of WiMAX products is planned in two main steps:

- mid-2005, availability of the 802.16REVd chipset, allowing the development of cost-optimized CPE operating indoors (NLOS),
- in 2006, availability of 802.16e chipsets embedded in laptops and later on in other mobile devices, enabling Portable Internet.

We believe that current pre-WiMAX products and initial 802.16a WiMAX products available in early 2005, operating similarly to current proprietary equipment (LOS, not cost-optimized CPE) and at similar cost, will not be widely deployed, because the operator needs to go and install the antenna at the customer premise, which is uneconomical for residential customer as proved in the early days of ADSL installation. This said, 802.16a will certainly be used for at least two years on the market window of backhauling of operators sites: wireless transmission of WiFi hotspot traffic to the nearest ISP point of presence, or data leased lines concentration, or 3G new small site backhauling.

**Fig. 2** Markets for WiMAX




## Market for WiMAX

WiMAX will boost today's highly fragmented BWA market thanks to standardization and interoperability, state-of-the-art radio efficiency with NLOS capability, and strong support from the radio equipment manufacturers and chipset industries.

WiMAX will also target the data-centric mobility market with the introduction of lower power-consumption chipsets. The strong support from some of the most important chipsets manufacturers such as Intel is a key enabler for the success of WiMAX, since it will lead to wide availability of affordable WiMAX-enabled terminals (e.g., laptops, PDAs, etc.).

## WiMAX, a complement to fixed and mobile access

WiMAX integrates perfectly into existing fixed and mobile networks, complementing them when needed.

This section gives a more detailed analysis of WiMAX integration into fixed and the mobile markets.

### WiMAX for fixed wireless access

Nationwide broadband access has become a priority in many countries. In most developed countries, the average broadband coverage will reach 90% in the coming years. Still, in some rural areas of such countries, broadband coverage will not exceed 50%.

The service gap can be categorized by two characteristics: the type of area (rural or urban) and the level of national development (see Table 1).

In developed countries, DSL service deployment has been massive in urban and sub-urban deployments, whereas coverage of remote areas - smaller towns and rural areas - is lagging behind. Hurdles to overcome are the poor line quality of the installed copper base, the large distances to the central offices or cabinets, or the low population density. In this context, WiMAX, with its QoS support, longer reach, and data rates similar to DSL, is naturally positioned as a viable first mile option to offer broadband access to residential users.

**Tab. 1** The service gap

| | Rural access in developed countries | Urban & suburban access in developing countries |
|---|---|---|
| **Scope** | Focus on residential services | Scattered market, residential and enterprise market equally important |
| **Service** | High-speed Internet and voice services | High-speed Internet and/or voice service, E1/T1 |

In emerging countries, the main focus of broadband deployment is on urban and sub-urban areas, and will remain so in the near future. The low POTS penetration and the low quality of the copper pair prevent mass scale DSL deployment and foster the need for alternate broadband technologies. In this context, WiMAX is positioned as an excellent option. Moreover, the possibility of offering broadband services in combination with voice services will gradually lead to narrowband WLL substitution.

Parameters such as availability of the copper, distance to the remote unit/central office, backhauling costs, and teledensity will drive the choice for one or other of these solutions. For further details, refer to the article "Providing Always-on Broadband Access to Under-served Areas" in the Alcatel Telecommunication Review (Q4 2003).

WiMax is of interest for large enterprises with several locations in the same metropolitan area. WiMax will permit Operator's bypass under license conditions: building a metropolitan private network of IP lines at a very low cost (no civil works). The comparison to leased lines rental fee is in favor of Wimax even for two sites only.

## Deployment topologies

Several topology and backhauling options are to be supported on the WiMAX base stations: wireline backhauling (typically over Ethernet), microwave Point-to-Point connection, as well as WiMAX backhaul. See Figure 3. With the latter option, the base station has the capability to backhaul itself. This can be achieved by reserving part of the bandwidth normally used for the end-user traffic and using it for backhauling purposes.

## WiMAX for Portable Internet

### *WiMAX, the natural complement to mobile and Wi-Fi networks*

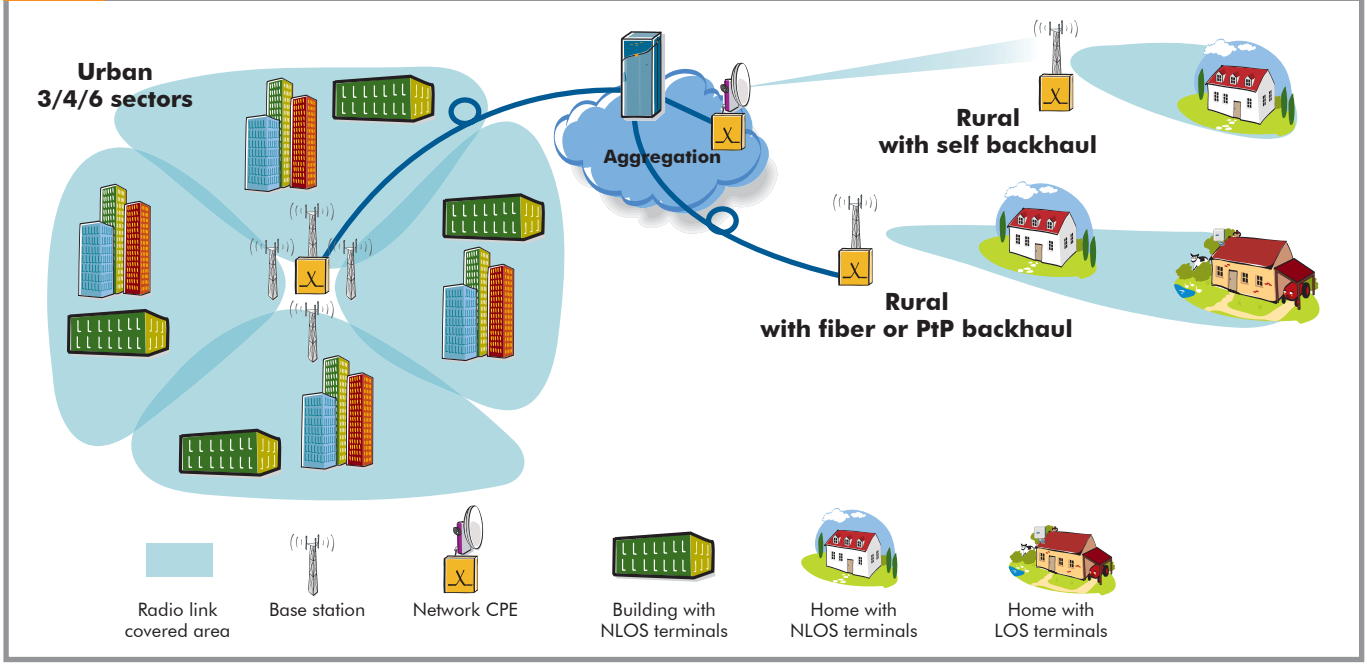
Mobile networks offer full mobility, nation-wide coverage voice support and moderate data rates. WiMAX can then be positioned as a complementary solution by offering higher bandwidth when required, in particular in dense urban areas.

Public WLAN, while offering clear benefits, is limited in coverage and mobility capabilities. WiMAX by-passes these limitations and offers broadband connectivity in larger areas (hotzones). Wi-Fi and WiMAX solutions are also complementary, with Wi-Fi being more adapted for short-range, indoor connections (in particular in the enterprise and at home) and WiMAX for long- range outdoor connections.

### *From nomadicity to Portable Internet*

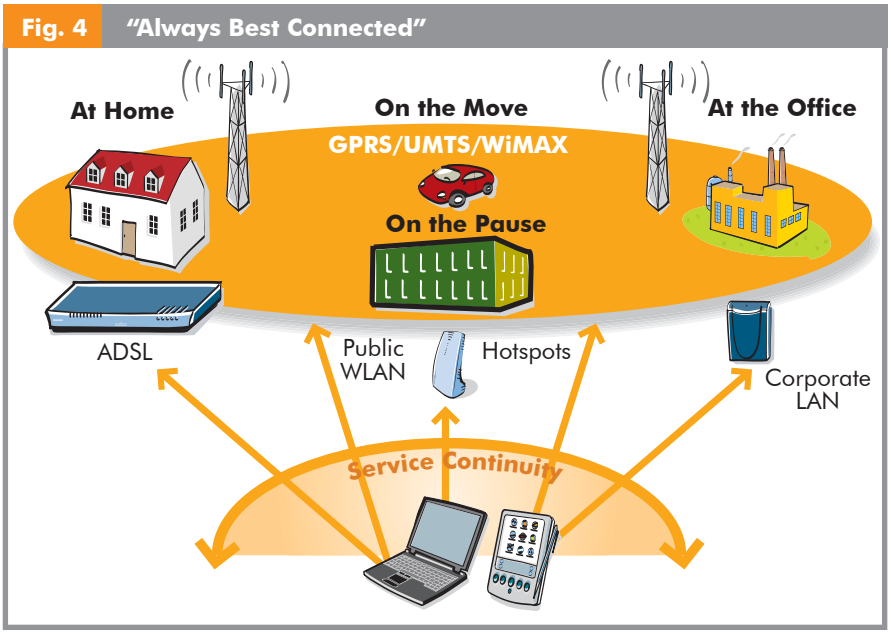
While nomadicity offers connectivity within the coverage area of a single base station, Portable Internet implies session continuity throughout the network. In addition a new generation of networks with multi-access (3G, Wi-Fi, WiMAX, DSL, FTTU,

**Fig. 3** Topologies in urban and rural areas



etc.) enable end-users to enjoy an "Always Best Connected" experience when accessing their applications via the best available network at home, on the pause, or on the move. See Figure 4. WiMAX becomes an additional radio access solution in the global network architecture.

**Fig. 4** "Always Best Connected"




*The WiMAX CPE*

In most case, a simple plug and play terminal, similar to a DSL modem, provides connectivity. See Figure 5. For customers located several kilometers from the WiMAX base station, a self-install outdoor antenna may be required to improve transmission quality. To serve isolated customers, a directive antenna pointing to the WiMAX base station may be required.

For customers requesting voice in addition to broadband services, specific CPE will allow the connection of standard or VoIP phones.

Ultimately, WiMAX chipset will be embedded in data-centric devices.

*Operator's business case*

WiMAX is of interest for incumbent, alternate, and mobile operators. Some business cases are possible.

- The incumbent operators can use the wireless technology as a complement to DSL, allowing them to offer DSL-like services in remote, low-density areas that cannot be served with DSL.
- For alternate operators, the wireless technology is the solution for a competitive high-speed Internet and voice offering bypassing the landline facilities, with applicability in urban or sub-urban areas.
- The larger opportunity will come with the Portable Internet usage, complementing fixed and mobile solution in urban and suburban areas. Therefore it will enhance the business case by giving access to a large potential of end users.

*WiMAX, the obvious choice for operators*

By integrating WiMAX into their networks, mobile operators can boost their service with high bandwidth, when necessary, the same applications (messaging, agenda, location-based services, ...) being offered on both networks with a single billing and subscriber profile. Mobile operators can also reuse existing radio sites and backhauling equipment to facilitate the deployment of WiMAX.

Fixed operators, incumbent or alternate, will offer nomadic and Portable Internet usage as an addition to their fixed access offering to complement their DSL and Wi-Fi bundle. For those having deployed WiMAX for fixed access, this is also a natural evolution of their offering.

**Fig. 5** WiMAX CPE for fixed access, WiMAX PC card and WiMAX PC enabled for Portable Internet

## WiMAX Technology Challenge

### WiMAX, more flexibility and security

Unlike WLAN, WiMAX provides a media access control (MAC) layer that uses a grant-request mechanism to authorize the exchange of data. This feature allows better exploitation of the radio resources, in particular with smart antennas, and independent management of the traffic of every user. This simplifies the support of real-time and voice applications.

One of the inhibitors to widespread deployment of WLAN was the poor security feature of the first releases. WiMAX proposes the full range of security features to ensure secured data exchange:

- terminal authentication by exchanging certificates to prevent rogue devices,
- user authentication using the Extensible Authentication Protocol (EAP),
- data encryption using the Data Encryption Standard (DES) or Advanced Encryption Standard (AES), both much more robust than the Wireless Equivalent Privacy (WEP) initially used by WLAN. Furthermore, each service is encrypted with its own security association and private keys.

### WiMAX, a very efficient radio solution

WiMAX must be able to provide a reliable service over long distances to customers using indoor terminals or PC cards (like today's WLAN cards). These requirements, with limited transmit power to comply with health requirements, will limit the link budget. Subchannelling in uplink and smart antennas at the base station has to overcome these constraints.

The WiMAX system relies on a new radio physical (PHY) layer and appropriate MAC layer to support all demands driven by the target applications.

The PHY layer modulation is based on OFDMA, in combination with a centralized MAC layer for optimized resource allocation and support of QoS for different types of services (VoIP, real-time and non real-time services, best effort). The OFDMA PHY layer is well adapted to the NLOS propagation environment in the 2 - 11 GHz frequency range. It is inherently robust when it comes to handling the significant delay spread caused by the typical NLOS reflections. Together with adaptive modulation, which is applied to each subscriber individually according to the radio channel capability, OFDMA can provide a high spectral efficiency of about 3 - 4 bit/s/Hz.

However, in contrast to single carrier modulation, the OFDMA signal has an increased peak: average ratio and increased frequency accuracy requirements. Therefore, selection of appropriate power amplifiers and frequency recovery concepts are crucial.

WiMAX provides flexibility in terms of channelization, carrier frequency, and duplex mode (TDD and FDD) to meet a variety of requirements for available spectrum resources and targeted services.

An important and very challenging function of the WiMAX system is the support of various advanced antenna techniques, which are essential to provide high spectral efficiency, capacity, system performance, and reliability:

- beam forming using smart antennas provides additional gain to bridge long distances or to increase indoor coverage; it reduces inter-cell interference and improves frequency reuse,
- transmit diversity and MIMO techniques using multiple antennas take advantage of multipath reflections to improve reliability and capacity.

### System performance

Table 2 gives typical cell size and throughput at 3.5 GHz in various configuration and environments.

**Tab. 2 Typical cell size and throughput**

| Environment | Typical cell size | Sector throughput |
|---|---|---|
| Urban indoor (NLOS) | 1 km (5/8 miles) | 21 Mbit/s w. 10 MHz channel |
| Suburban indoor (NLOS) | 2.5 km (1.5 miles) | 22 Mbit/s w. 10 MHz channel |
| Suburban outdoor (LOS) | 7 km (4 miles) | 22 Mbit/s w. 10 MHz channel |
| Rural indoor (NLOS) | 5 km (3 miles) | 4.5 Mbit/s w. 3.5 MHz channel |
| Rural outdoor (LOS) | 15 km (9 miles) | 4.5 Mbit/s w. 3.5 MHz channel |

## WiMAX Spectrum and Regulation Issues

WiMAX-compliant equipment will be allowed to operate in both licensed and unlicensed bands. The minimum channel bandwidth for WiMAX usage is 1.75 MHz per channel, while 10 MHz is considered as an optimum.

Although 2.4 GHz and 5 GHz non-licensed bands are largely available, their usage could be limited to trials because of the risks of interference preventing QoS commitments.

The 2.5 and 3.5 GHz licensed bands will be the most common bands for WiMAX applications. It should be noted that the 5 GHz band is also partially licensed in some countries.

Most countries have already allocated licensed spectrum, generally to alternate operators. Nevertheless large quantities of spectrum are still in

process of allocation, and some countries have not even defined any WiMAX licensed bands yet.

WiMAX is designed to accommodate either Frequency Division Duplexing (FDD), which is more suited to enterprise traffic, or Time Division Duplexing (TDD), which is more adapted to asymmetrical traffic. Cohabitation of FDD and TDD techniques is possible within the same bands, provided guard bands are implemented.

## Conclusion

The latest developments in the IEEE 802.16 group are driving a broadband wireless access (r)evolution thanks to a standard with unique technical characteristics. In parallel, the WiMAX forum, backed by industry leaders, helps the widespread adoption of broadband wireless access by establishing a brand for the technology.

Initially, WiMAX will bridge the digital divide and thanks to competitive equipment prices, the scope of WiMAX deployment will broaden to cover markets where the low POTS penetration, high DSL unbundling costs, or poor copper quality have acted as a brake on extensive high-speed Internet and voice over broadband.

WiMAX will reach its peak by making Portable Internet a reality. When WiMAX chipsets are integrated into laptops and other portable devices, it will provide high-speed data services on the move, extending today's limited coverage of public WLAN to metropolitan areas. Integrated into new generation networks with seamless roaming between various accesses, it will enable end-users to enjoy an "Always Best Connected" experience.

The combination of these capabilities makes WiMAX attractive for a wide diversity of people: fixed operators, mobile operators and wireless ISPs, but also for many vertical markets and local authorities.

Alcatel, the worldwide broadband market leader with a market share in excess of **37%**, is committed to offer complete support across the entire investment and operational cycle required for successful deployment of WiMAX services.

## Glossary

**CPE** Customer Premise Equipment
**DSL** Digital Subscriber Line
**FDD** Frequency Division Duplex
**MAC** Media Access Control
**MIMO** Multiple-Input-Multiple-Output
**NLOS** Non-Line-Of-Sight
**OFDMA** Orthogonal Frequency Division Multiplex Access
**PLC** Power Line Communications
**POTS** Plain Ordinary Telephone System
**STC** Space Time Coding
**TDD** Time Division Duplex
**WLAN** Wireless Local Area Network
**WLL** Wireless Local Loop

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**LAINE Philippe**
Network Strategy Manager, Chief Technology Officer organization.
After his university studies in Electrical Engineering, Philippe started his career in 1985 as a software engineer, working on various projects in telecommunications and satellite image processing. In 1989, Philippe joined Alcatel, at first working on a cable TV project, then as project manager in charge of the development of network management systems.
From 1995 to 2001, as marketing manager in the Mobile Networks Division, he handled the promotion of GSM, GPRS, and 3G mobile systems. Based on this experience, he joined the Network Strategy Group to define and promote the corporate vision for the evolution of wireless networks.

**BOETTLE Dietrich**
Project Leader, Wireless Access, CTO/Research & Innovation.
After his studies at the University of Stuttgart, Dietrich joined Standard Elektrik Lorenz (SEL), now Alcatel, in Stuttgart, Germany. His main activities in the past included managing projects and leading research teams in the areas of optical transmission and broadband switching.
He is currently head of the Access Network department in Stuttgart and project leader for the Alcatel project Wireless DSL in Research and Innovation.

**BOSCHER Christophe**
Networking Strategy, Chief Technology Officer organization within the Mobile Communications Group.
Christophe is a member of the CTO organization within the Mobile Communication group. He focuses on networking strategy for ubiquitous broadband access delivery.
Christophe obtained an engineer's degree in electrical engineering from the Ecole Polytechnique de l'Université de Nantes in 1988.
Prior to his current position, he held a variety of positions within several Alcatel business units in charge of data networking. He worked ten years in R&D as a software developer and system engineer on several data systems, beginning with X.25 and evolving to Frame Relay, ATM, and IP/MPLS. He has also been product manager in charge of Voice-over-DSL solutions.

**FEIJT Laurence**
Broadband Access, Solution Marketing, Solution Marketing Management within the Fixed Communication Group.
Laurence graduated in business studies at the Institut Catholique des Hautes Etudes Commerciales (ICHEC) in Brussels (Belgium). She took a postgraduate course in Telecommunications at the Université Libre de Bruxelles (ULB) and earned her MBA in Telecommunications Marketing at INSEAD.
Laurence joined Alcatel in 1998 in the product management team for NGN. Today, she works in the Broadband Access Solution team, responsible for the development of end-to-end solutions in the Broadband Access Space including xDSL, WLAN, and other fixed wireless technologies. She is also involved as consultant in the Alcatel Consultancy Program for xDSL customers.
Laurence has written and contributed to several papers on topics related to broadband access.