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Swisscom Innovations' Programmes

On Track to access large Capacity in the MAN: The Broadband Wireless Access Standard 802.16

With the new standard 802.16 for wireless metropolitan networks, users will be able to get wireless broadband that operates over entire cities or large geographic areas. How this rolls out into the marketplace is a huge topic of discussion. While a lot remains to be seen and will be shaped by many complex forces, including the role of merchant chip suppliers similar to those supplying parts for WLAN devices, some movement is already under way that will shape the early going.

The programme "Future Network Services" explores emerging technologies enabling wired and wireless, fix and mobile broadband services. A multitude of access technologies will coexist in the near future. Customers will be able to access the network, including voice services, through end devices supporting several access technologies, as for example DSL, GSM, GPRS, UMTS, WLAN and Bluetooth. With its Innovation Programmes, Swisscom Innovations follows the objective of recognising early on the impact of technological developments, finding new business opportunities, promoting technical synergies and developing concrete innovation proposals. Further, the expertise built up enables active engineering support of business innovation projects.

The broadband, fixed-wireless market has experienced slow growth over the past few years in part because of high-priced proprietary technology. The IEEE developed the 802.16 standard to reduce the cost of base stations and Customer Premises Equipment

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products (CPE), create an interoperable equipment market and promote the widespread adoption of MAN broadband wireless technologies.

The initial IEEE 802.16 standard (WirelessMAN) was developed as a wireless metropolitan area network technology operating between 10 and 66 GHz and it requires line-of-sight. The 802.16 standard was approved by the IEEE in 2002 to provide up to 50 kilometres of wireless range. An amendment, 802.16a, was added in January 2003, designed to include the low-frequency 2–11 GHz spectrum, some of which is unlicensed and includes the spectrum that is being used by 802.11b, a, and g. The 802.16a wireless broadband technology provides ranges up to 50 kilometres in rural areas and 3–5 kilometres in more densely populated urban regions and shared data rates up to 70 Mbit/s, without needing a direct line-of-sight. It is considered the next step beyond wireless LAN because it is optimised for broadband operation, fixed and mobile, in the MAN. 802.16a includes numerous advances that are expected for the 802.11 standard, such as quality of service, enhanced security, higher data rates and mesh and smart antenna technology allowing better utilisation of the spectrum.

In order to ensure interoperability of 802.16-based technology and to help accelerating the introduction of these devices into the marketplace, the WiMAX (World Interoperability for Microwave Access) Forum was formed. The WiMAX Forum is to 802.16 what the Wi-Fi Alliance is to 802.11 wireless LANs, including big players such as Fujitsu, Intel, Nokia and Proxim. The WiMAX will also make sure that 802.16a works with HiperMAN products, a future standard from the European Telecommunications Standards Institute (ETSI) pushed by the OFDM Forum, a WiMAX member. The two standards are being developed in collaboration to get seamless interoperability. The WiMAX 2–11 GHz Technical Working Group (TWG) has the mandate of creating testing and conformance documents as contributions to IEEE and ETSI standards bodies in support of the IEEE 802.16a and ETSI HiperMAN standards.

A proactive approach is needed to impulse the strategic role of broadband wireless access for remote areas, for hotspot locations, for broadband Internet connectivity, as a cheaper alternative to last mile connections or leased lines and finally as an alternative for connecting business offices.

The position of the 802.16a standard today is parallel to that of WLAN technology in the late '90s. In the near future, 802.16a will also achieve low price and high performance. A range of industry players are wishing to accelerate the process, to remove the obstacles and to bring all of this energy together to allow new partnerships to move ahead positively.

The next sections describe the capabilities of the 802.16 standard, particularly its amendment 802.16a and to a lesser extent 802.16e.

Physical Layer

The **802.16** standard was designed for fixed point-to-multipoint broadband wireless access. Furthermore, this first standard was designed for Line-of-Sight (LOS) conditions, which means there must be no element between the Base Station (BS) and the Subscriber Station (SS).

802.16 can operate at frequencies from 10 to 66 GHz; the bandwidth actually used depends on the country's regulation: the IEEE defined a flexible standard which can be adapted to local transmission restrictions. With these conditions, LOS and frequency, the modulation did not have to be very complex and a single-carrier technique was selected as a base for the physical layer (referred to as PHY within the IEEE).

The modulation standardised for 802.16 is also called "WirelessMAN-SC"; it includes several modulation schemes: QPSK, 16-QAM, 64-QAM (optional) which can be used independently for each user and also on a burst-by-burst basis. In fact, if the propagation conditions get worse, the modulation scheme will automatically change to a slower but more robust one.

Both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) modes are supported. The downlink (transmission from the BS to SS) is a

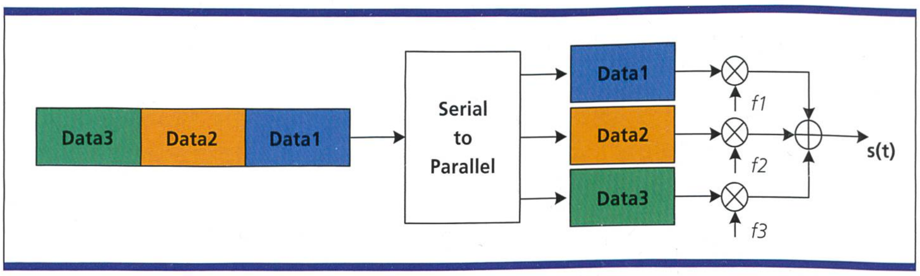

Fig. 1. Simplified view of the process to generate an OFDM signal with 3 subcarriers at frequencies f1, f2 and f3.

Time Division Multiplexing (TDM) signal where all the SS are allocated a time slot serially, whereas the uplink is Time Division Multiple Access-based (TDMA). For the FDD mode, the BS has to support both full-duplex and half-duplex SS. A full-duplex SS can receive and transmit data to the BS at the same time, whereas a half-duplex SS can only emit and receive at different times.
In contrast, 802.16a was designed for fixed point-to-multipoint broadband wireless access in Non-Line-of-Sight (NLOS) conditions and optional mesh architecture support. A mesh network is a network where SSs can directly communicate between each other without being forced to go through the BS.
802.16a defines several possibilities for the physical layer for frequencies from 2 to 11 GHz: a different Single Carrier mode called "WirelessMAN-SCa"; and two more advanced techniques: OFDM (Orthogonal Frequency Division Multiplexing with 256 subcarriers, multiple access is done with TDMA) and OFDMa (another variant with 2048 subcarriers, multiple access is done by addressing a subset of the multiple carriers to individual receivers). FDD and TDD modes are also supported, but it must be noted that the mesh option can only be used in TDD mode and in a licensed frequency band. Several modulation schemes can be used to efficiently send data and at the same time take into account the transmission conditions: BPSK, QPSK, 16-QAM, 64-QAM (optional) and 256-QAM (optional).

Orthogonal Frequency Division Multiplexing (OFDM)

As said in the previous section, 802.16a defines several modulation techniques: WirelessMAN-SCa, OFDM and OFDMa. Manufacturers will concentrate their efforts on OFDM; indeed, this technique offers many advantages for efficiently transmitting data over varying links. It is also used for ADSL, wireless LAN 802.11a and 802.11g, Digital Audio and Video Broadcasting (DAB, DVB-T).
OFDM is a technique which splits the available bandwidth into many narrow-band channels, each having its own subcarrier. So if the available bandwidth for a system is B and there are N subcarriers, each subcarrier occupies $f = B/N$ Hz. All subcarriers are mutually orthogonal within a time interval of length $T_s = 1/f$. That means all the different subcarriers will not interfere with one another. All these subcarriers must be generated in an efficient manner; it would not be realistic to have hundreds of oscillators to generate them. When writing the mathematical expression of an OFDM signal, it appears that it can be generated initially as a discrete-time signal. This is why all the subcarriers can first be generated using an Inverse-Fast-Fourier-Transform (IFFT). This kind of function is well known and has already been implemented in silicon chips for a long time. Figure 1 shows a simplified view of the process to generate an OFDM signal with 3 subcarriers at frequencies *f1, f2* and *f3*.
When a signal is sent at a high rate over a time dispersive channel (which is typically the case for BWA), successive symbols suffer from Inter-Symbol-Interference (ISI). Samuel Morse first noticed this phenomenon, illustrated in figure 2, on the transatlantic telegraph cables transmitting messages using dots and dashes. ISI has the effect that on the receiver side, successive symbols will not be distinct and correctly distinguishable. There are methods for evaluating the transmission channel and eliminating this ISI, but they are quite complicated and thus relatively expensive. OFDM takes the advantage of splitting the total bandwidth available in several subchannels to include a guard interval before and after sending two successive symbols on a subcarrier.
OFDM splits the bandwidth over different subcarriers (e.g. 256 for 802.16a), but not all of these are used for sending data: some of them are used as pilot signals to detect and correct fading.
Table 1 lists all typical problems BWA systems have to face and how they are solved using OFDM. OFDM is a suitable technology for NLOS BWA because of its

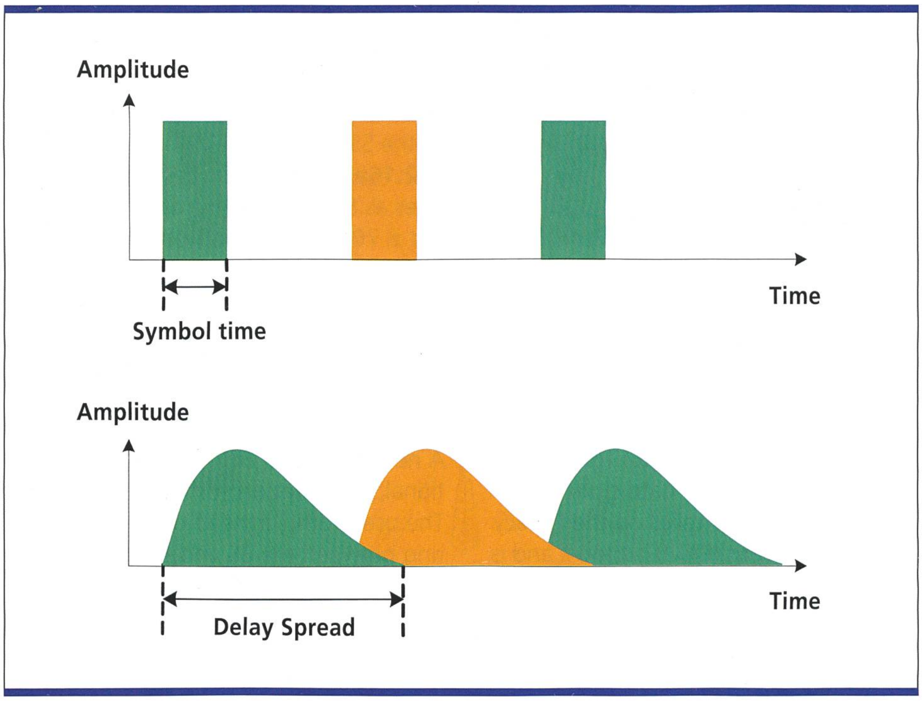

Fig. 2. When a signal is sent at a high rate over a time-dispersive channel (which is typically the case for Broadband Wireless Access), successive symbols suffer from Inter-Symbol-Interference (ISI).

Problems	Solutions
ISI	Guard Interval
Low Bandwidth	Multicarrier Modulation
ICI	Orthogonality
Rapid Fadings	Pilot Carriers
Signal Generation	IFFT
Selective Fadings	Redundancy and Interleaving

Tab. 1. Solving Broadband Wireless transmission problems with OFDM (Orthogonal Frequency Division Multiplexing).

high spectral efficiency; it is highly resistant to radio interference and has many advantages in a multi-path environment (radio waves are reflected against buildings, vehicles). Furthermore, and although 802.16a was not specially designed to enable users' mobility, OFDM supports mobility quite well. Today, making OFDM chips is a very well controlled process which permits low cost per customer, a key factor for a new technology to be successful.

Privacy Sublayer

The privacy sublayer of 802.16 handles SS authentication and data ciphering. The whole sublayer relies on the Privacy Key Management (PKM) protocol and is flexible: it can use new cryptographic methods which are not yet included. Data flows between the BS and the SS have one or more Security Associations (SA) which regroup parameters like the algorithm to use the keys. These SA can be made during connection setup or dynamically.
For SS authentication and authorisation key exchange, cryptographic methods use RSA public key and X.509 certificates which are factory built in but can also be modified by the operator or the end user if permitted. Traffic encryption uses the Data Encryption Standard (DES) in Cipher Block Chaining (CBC) mode and 56 bits keys. The CBC initialisation vector is dependent on the frame counter and differs from frame to frame. PKM protocol messages themselves are authenticated using the Hashed Message Authentication Code (HMAC) protocol with SHA-1. However, management packets are not ciphered but authenticated.

Features

802.16 can provide a maximum throughput of 132 Mbit/s in a cell, which then have to be shared between the different SS. The maximum coverage is 50 km. Bandwidth can be provided on demand to the SS depending on the need and the application. The standard also includes Quality-of-Service (QoS), which means that the traffic can be prioritised depending on the service it targets. Different classes of services are defined to support services like E1/T1, telephony, real-time multimedia applications. Transmission methods can be unicast, multicast or broadcast. On top of them can either be transmitted ATM frames or packet protocols like Ethernet (also Virtual LAN), IP version 4 and IP version 6. The BS and the SS periodically inform each other on the transmit power to use, in order to limit the power consumption of the SS and to limit the interference.
802.16a basically provides the same services as 802.16. The maximum throughput is 70 Mbit/s, which is significantly lower than 802.16, but the latter has the big disadvantage of requiring LOS connectivity. 802.16a also supports advanced antenna systems necessary for coping with NLOS scenarios, such as adaptive antennas.
A new feature of 802.16a, although optional, is its support for mesh networks. The user traffic, instead of always occurring between the BS and the SSs, can also be routed through other SSs and can occur directly between SSs. Depending on the transmission protocol algorithm used, this can be done on the basis of equality using distributed scheduling, or on the basis of superiority of the mesh BS, which effectively results in centralised scheduling, or on a combination of both.
802.16e is still an ongoing job at the IEEE. It is a new amendment to provide mobility support, meaning the possibility for an SS to move from the coverage of one BS to another without losing the active sessions of the different applications. Coverage per BS and throughput are expected to be lower because of the mobility support overhead. Since this is still an ongoing job and its features may be subject to change before its final approval, this article will not speculate further on it.

Applications

Figure 3 shows different scenarios enabled by 802.16a. The first one is the LAN interconnection scenario: it connects the different locations of a company. The second one is a scenario where Internet connectivity to trains would be given using 802.16e. Scenario number three is to use 802.16a to connect Wireless LAN hotspots as a cheaper alternative to leased lines or HDSL. The fourth scenario is an alternative for connecting business offices with E1/T1 and phone lines. Scenario five uses 802.16a as an alternative for ADSL connections at home. The last depicted scenario uses 802.16a as a flexible and quick solution for connecting temporary hotspots (conferences, sportive events press room).
WiMAX should start doing interoperability certifications by the middle of 2004 and first certified products are expected to reach the market by the 4th quarter of 2004.

Following up the Development at Swisscom

In early 2003, the IEEE 802.16 standard was expanded with the adoption of the 802.16a amendment, focused on Broadband Wireless Access with frequencies from 2 to 11 GHz. From that moment on, *Swisscom Innovations* and *Swisscom Mobile* have analysed and kept an eye on this standard and related emerging products. A careful study of the standard has been carried out, and some contacts to leading suppliers like *Intel* and *Alvarion* were made, as well as to leaders in networking research and consulting, such as *The Yankee Group*. We will explore the way ahead and address obstacles such as radio spectrum regulations and access to backhaul.
The WiMAX 2–11GHz TWG is currently defining MAC and PHY System Profiles for IEEE 802.16a and HiperMAN standards. The MAC profiles that are being developed include IP-based versions for both WirelessMAN (Licensed) and WirelessHUMAN (License-exempt). While the IEEE 802.16a amendment has several physical layer profiles, the WiMAX forum through its 2–11 GHz TWG is focusing on the 256 point FFT OFDM PHY mode as its initial and primary interoperability mode. Typical spectrum allocations are being chosen in both licensed and license exempt bands, all supporting the 256-point FFT OFDM PHY mode of operation.

Experiences with Wireless Local Loop (WLL) and Public Wireless LAN (PWLAN)

During the beginning of the broadband wireless hype at the entry to the 21st century there were already trials to offer narrowband and broadband data access services mainly to business customers in larger European cities. Most of these trials were based on Wireless Local Loop (WLL), a wireless access technology. WLL led to a bandwidth on the radio link from approximately X.25 speed (64 kbit/s) up to T1 speed (2 Mbit/s). As often with wireless solutions, the available bandwidth depended largely on the number of wireless connected users, the supplier of the WLL equipment and the settings of the equipment by the WLL operator.

In the 2nd quarter of the year 2000 the Swiss regulatory authority BAKOM (Bundesamt für Kommunikation) organised an Internet auction for two frequency bands to be used for WLL in Switzerland:
- 3.4 GHz Band: 3410–3494 MHz (Up Link) and 3510–3594 MHz (Down Link)
- 26 GHz Band: 24 549–25 053 MHz (Down Link) and 25 557–26 061 MHz (Up Link)

The target was to auction off 48 WLL radio concessions for all regions of Switzerland and led to proceeds of 582 757 580 CHF. Three licences (bought by three potential operators for 120, 134 and 55 million CHF) included the possibility to offer nation-wide coverage. Some radio licences located in fringes (hilly or mountain areas) could not be auctioned off because of a lack of interest. This gave proof to the argument that competitors of the established Public Network Operators (PNOs) are not interested in offering telecom services outside larger cities.
At that time many telecom and IT-networking consultants and regulatory instances in most western countries nevertheless shared the opinion that WLL will be a driving force for the liberalisation of the telecommunications market. It was stated that WLL will form a valuable alternative especially to the access networks of the established PNOs [1]. By following this opinion consistently, Swisscom was excluded from that auction. Meanwhile most of the WLL offerings disappeared from the Swiss market, either because the companies no longer existed or were taken over by larger companies which stopped all WLL offers due to insufficient profitability. Most of the business cases for WLL were based on the assumption that the prices for leased lines will remain high, which was not the case. In addition, new transmission techniques were developed and introduced with a good customer response (e.g. ADSL, cable modems). It is uncertain whether the already auctioned-off frequencies which are not in use for WLL any more may be opened up for use by other mobile transmission techniques such as WirelessMAN.
Today, the broadband hype has been overcome by a more realistic assessment of the market with more profound business models. In addition, cheaper and more sophisticated techniques have been developed by a number of network suppliers for operation in local environments.

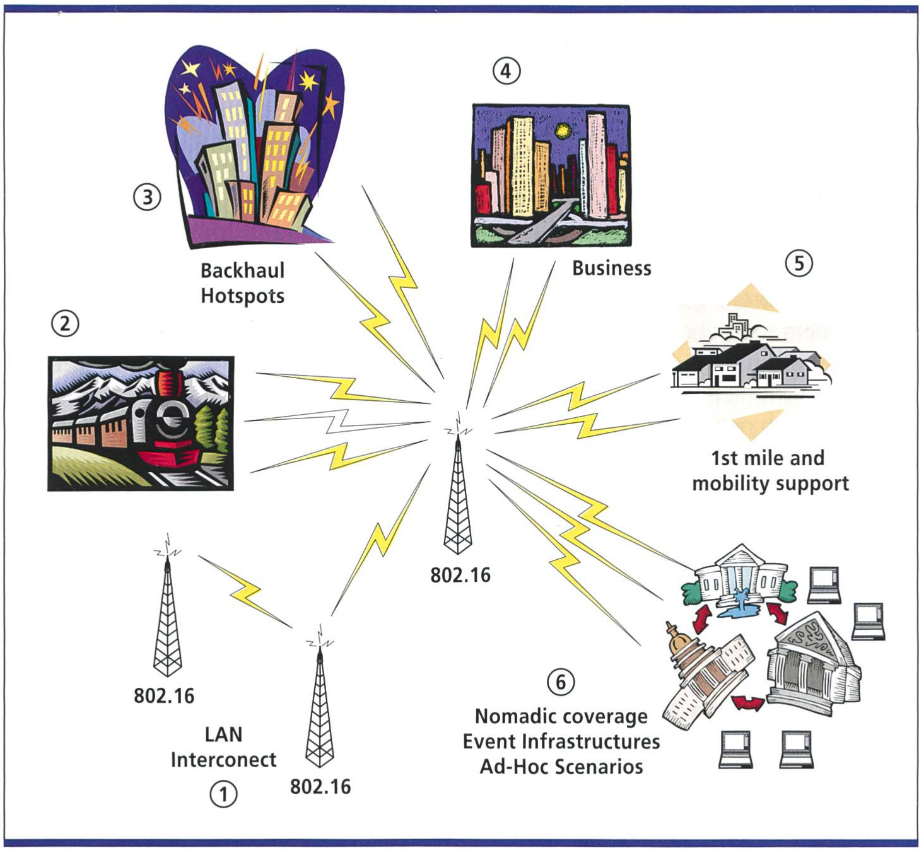

Fig. 3. Different scenarios enabled with 802.16a: ① LAN interconnection (connects the different locations of a company); ② Internet connectivity to trains (using 802.16e); ③ connecting Wireless LAN hotspots, as a cheaper alternative to leased lines or HDSL; ④ an alternative for connecting business offices; ⑤ an alternative for ADSL connections at home; ⑥ a flexible and quick solution for connecting temporary hotspots.

It is self-evident that these developments have had an impact on the mobile communications market as well. One of the latest services of *Swisscom Mobile* called Public Wireless LANs (PWLANs) gives a good example of how wireless broadband access can be offered to business customers at locations where a real demand for broadband Internet access exists (e.g. hotel, congress centres, train stations, airport lounges etc.). *Swisscom Eurospot* extended these PWLAN offerings to many countries in Europe and announced that their PWLAN customers will be able to access around 1000 hotspots in Europe by the end of 2003. So PWLAN roaming is already or will be – within the next few months – nothing unknown to the customers of all Swisscom Eurospot partners.
PWLANs based on the standard IEEE 802.11b offer a bandwidth of max. 11 Mbit/s and are operated in the 2.4-MHz-Band which is licence-free. Some suppliers like *D-Link* even extended this IEEE standard and realise 22 Mbit/s by using a special microchip (note: running their equipment in that particular high-speed modus no longer conforms to IEEE 802.11b). The latest WLAN standard IEEE 802.11a uses frequencies in the 5-MHz Band which is also licence-free but not fully available everywhere. For example in Switzerland, today only the frequencies 5150–5350 GHz can be used by WLANs at a max. EIRP of 200 mW, restricted to indoor use and only in connection with Dynamic Frequency Selection (DFS) and Transmit Power Control Protocol (TPC). This standard leads to a bandwidth of up to 54 Mbit/s. According to BAKOM, by the end of 2003 the frequencies from 5470 to 5725 GHz will be available for PWLANs (for outdoor use only) at an EIRP of 200 mW and again in connection with DFS and TPC only. To avoid interference with other applications, the band 5470 to 5725 GHz can only be operated with an EIRP of 200 mW. The frequency range from 5725 to 5875 GHz is used by military applications (max. EIRP 25 mW). Additional applications like aeronautical

radio navigation, radio location or the so-called rain-fall radar use the range from 5350 to 5470 GHz [2].

New Trial with WirelessMAN

The required spectrum for WirelessMAN (11 to 66 GHz) is quite broad and certainly not entirely available depending on its usage in the countries. In addition, IEEE 802.16a supports a scheme for mesh networks where subscriber stations can communicate with other subscriber stations rather than with the 802.16a base station. This mesh networking capability is a major reason for the current public interest in WirelessMAN technology because it allows the delivery of broadband wireless services in a very flexible way. With mesh networking, only one customer in a given area needs to be connected to a base station. The rest can share the Internet connection amongst themselves. Because the mesh network can be dynamically rearranged according to local conditions, it is said to be more reliable and able to bring high-speed Internet access to urban and suburban customers at lower cost than competitive wireless or wireline alternatives. But it may not be a trivial task to design, develop and produce the appropriate equipment for WirelessMAN because the local conditions regarding the available frequencies may vary. An ideal solution would be the possibility to adapt the WirelessMAN equipment locally to make its installation and operation easier and more flexible and its production cheaper. According to BAKOM, no regulation is planned or underway yet for WirelessMAN.

Positioning WirelessMAN towards Wireless LAN

The new standard 802.16 (WirelessMAN) has often been compared to the 802.11 (Wireless LAN), but the two standards are quite different. On the one hand, 802.11b is a Direct Sequence Spread Spectrum standard originally designed for short range indoor Wireless LAN and only in punctual frequencies, such as 2.4 GHz. On the other hand, 802.16a has an advanced set of protocols for long range outdoor point-to-multipoint WirelessMAN, and it uses Orthogonal Frequency Division Multiplexing (OFDM). It also applies to bands from 2 GHz to 11 GHz.
The 802.11 standard was designed for relatively short distances. Even if 802.11 can be pushed over longer links, it was not designed from the ground up to be used for long distances. It was also not designed to serve a large number of users. In contrast, WirelessMAN was designed specifically to tackle the tough requirements of making wireless broadband work over longer distances and through more difficult environments.
Along with the standard, a compliance testing group has been established called WiMAX, similar to Wi-Fi for 802.11, to make sure that the basic air interface requirements are met between the various equipment suppliers.

Services offered on Top of WirelessMAN

As mentioned above, another WirelessMAN standard is already in the planning process in the form of the proposed standard 802.16e. This variant extends the capability of WirelessMAN to include "mobile broadband wireless access networks ... supporting mobility at vehicular speeds" [3]. Today's 802.16 standard supports quality of service prioritisation that allows it to deliver real-time voice and video at a speed of up to 70 Mbit/s, again at a low cost compared to the wireless and wireline alternatives.
Commercially available services based on 802.16e are not expected for the next four to five years, although field trials have already given proof for two years that this is more than just a beautiful dream. According to The Shosteck Group (Pulse, May 2003), the company "Towerstream" is providing WirelessMAN services to a handful of companies in Manhattan using pre-standard hardware. Another potential WirelessMAN operator named SkyPilot Network is planning to serve California neighbourhoods of up to fifty square miles starting in 2004.
Almost every month other startups are announced, and although it is hard to predict whether these early trials will be successful or not, they will provide useful indications of the conditions under which WirelessMAN may succeed. If the indications are good, the startup WISPs, such as SkyPilot and Towerstream, will be quickly challenged by established landline telecom network operators. As mentioned, those operators will lower prices for equivalent services where they can, and in some cases deploy WirelessMAN themselves. WirelessMAN investors and public network operators are beginning to recognise that 802.16 is a technology tool which is equally available to all com-

Abbreviations

ADSL	Asymmetric Digital Subscriber Line
ATM	Asynchronous Transfer Mode
BPSK	Binary Phase Shift Keying
BWA	Broadband Wireless Access
CBC	Cipher Block Chaining
CPE	Customer Premises Equipment
DAB	Digital Audio Broadcasting
DES	Data Encryption Standard
DFS	Dynamic Frequency Selection
DVB-T	Digital Video Broadcasting-Terrestrial
EIRP	Effective Isotropic Radiated Power
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplexing
FFT	Fast Fourier Transform
HDSL	High bit-rate Digital Subscriber Line
HiperMAN	High PERformance MAN standard
HMAC	Hashed Message Authentication Code
ICI	Inter Carrier Interference
IFFT	Inverse Fast Fourier Transform
ISI	Inter Symbol Interference
LOS	Line of Sight
NLOS	Non Line of Sight
OFDM	Orthogonal Frequency Division Multiplexing
PHY	PHYsical layer
PKM	Privacy Key Management
PNO	Public Network Operator
PWLAN	Public Wireless LAN
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
SA	Security Association
SC	Single Carrier
SS	Subscriber Station
TDD	Time Division Duplexing
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TPC	Transmit Power Control protocol
TWG	Technical Working Group
WirelessMAN	Wireless Metropolitan Area Network (802.16) standard
Wireless HUMAN	Wireless High-Speed Unlicensed Metropolitan Area Network standard
WLL	Wireless Local Loop

petitors and more than just a discrete new business model.

Conclusions

Times in telecommunications never stand still – the next step in wireless broadband communications is already in development at IEEE. The new technique is called WirelessMAN (Wireless Metropolitan Area Network). As its name implies, WirelessMAN links base stations in metropolitan areas at present up to a range of 20 km. WirelessMAN can use either licensed or unlicensed frequencies from 2 to 66 GHz to deliver secure, high-quality digital information at high speeds. The Media Access Control (MAC) layer of the IEEE 802.16 standard allows for latency and quality sufficient to deliver real-time Voice over IP (VoIP) and video services at relatively low costs. In addition, it can carry IPv4, IPv6, ATM, Ethernet and other network protocols which provides a maximum of flexibility for example to Wireless Internet Service Provider (WISP). At IEEE it is said that – in terms of data-carrying capability – WirelessMAN far surpasses 3G wireless networks. Originally, WirelessMAN was envisioned by the IEEE Working Group as an urban broadband wireless access technology, enabling high-speed Internet services at near-fibre speeds to the majority of a country's population. In this original scenario it would be a lower-cost backbone to connect buildings (and not people) to the Internet, competing with cable and DSL technologies. For this reason, the original standard requires a frequency spectrum from 11 to 66 GHz to support purely line-of-sight operation. 3

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Zusammenfassung

Die Zeit steht in der Telekommunikation nie still – schon gar nicht in deren mobilen Ausprägung. Nach dem Boom beim (Public) Wireless LAN steht mit dem WirelessMAN nach IEEE-Standard 802.16 der nächste Evolutionsschritt bereits bevor. Hier geht es unter anderem um einen mobilen Backbone, der Basisstationen in städtischen Gebieten breitbandig untereinander verbindet oder als Alternative zu Mietleitungen und xDSL-Verbindungen angesehen wird (IEEE 802.16a). Diese Anwendung ist sowohl für öffentliche Betreiber von Mobilfunknetzen (etwa für die Anbindung von Basisstationen) als auch für private Firmen zur flexiblen Vernetzung verschiedener Standorte interessant.
Eine zweite Variante des Standards (IEEE 802.16e) bietet aber auch einen flexiblen Breitbandzugang für mobile Endkunden unterwegs. Die grosse Netzflexibilität wird allerdings zu einer höheren Komplexität führen, da Links je nach Netzlast und Bedarf an Verbindungen dynamisch auf- und abgebaut werden. Die Komplexität betrifft sowohl die Netzplanung als auch die Endgeräte, die anfangs wohl kaum zum Discountpreis erhältlich sein werden. Bevor also WirelessMAN denselben Reifegrad erreichen wird wie das heutige Wireless LAN, werden wohl noch vier bis fünf Jahre vergehen. Erste Versuche mit WirelessMAN-Diensten in den USA sind heute jedenfalls weniger aussagekräftig bezüglich ihrer Funktionalität als bezüglich dem Business Case, der potenzielle Kosteneinsparungen gegenüber drahtgebundenen Alternativen verspricht.

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Ludovic Fournier *is a telecommunications engineer from Institut National des Télécommunications (INT), Evry, France and Eurécom, Sophia Antipolis, France. He did his diploma work on secure authentication for WLAN hotspots. In September 2001 he joined Swisscom Innovations, where he has mainly worked on authentication mechanisms for WLAN, mobile VPN, as well as on QoS for GPRS. His current activities range from analysing the 802.16 standard opportunities for Swisscom to WLAN-GPRS integration and mesh networking.*

Ferran Moreno Blanca *is a telecommunications engineer from the Universitat Politècnica de Catalunya (UPC), Barcelona. After working in TV frequency planning, both analog and digital (DVB-T), he did his diploma thesis at Swisscom Innovations in the domain of Secure IP Mobility. Since November 2001 he has been working for Swisscom as a research engineer. He is involved in projects dealing with future wireless technologies (WLAN, Bluetooth, 802.16) and active in techno-economic feasibility analysis.*

Rüdiger Sellin *is a telecommunications engineer from the Fachhochschule Düsseldorf in Germany. After developing Software and Systems for OSI applications, he joined Swisscom (the former Telecom PTT) in 1992. Beneath his intensive standardisation work at ITU-T and ETSI, he helped to build up Swisscom's GSM Network Management Centre and was responsible for functional testing. In addition, he has written many articles for telecom magazines and led telecom seminars in Europe. Since November 2000, he is responsible for Swisscom Mobile's technical communications in telecom magazines as a PR Manager.*