White paper

Leveraging 802.16e WiMAX™ Technology in License-Exempt Bands

Wireless operators, public agencies, and enterprises can now adopt the latest WiMAX technology without securing licensed spectrum

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License-exempt spectrum bands make it possible for operators who do not have access to licensed spectrum to deploy wireless broadband networks. Traditionally vendors have developed specific solutions for license-exempt operators, often based on proprietary technology that limits the flexibility and upgradability of their networks.

With Institute of Electrical and Electronics Engineers (IEEE) 802.16e WiMAX, license-exempt operators have access to the most advanced wireless broadband technology on the market today and can take advantage of the same performance, ecosystem, and volume of scale that incumbent, nationwide wireless operators with licensed-spectrum can.

While often positioned as a mobile broadband technology that operates in licensed bands, 802.16e WiMAX can also support fixed and nomadic services, and vertical applications in a range of frequencies up to 6 GHz, including license-exempt bands such as the 5.x GHz band and, in the US, the lightly licensed 3.65 GHz band.

As 802.16e WiMAX products for license-exempt bands are introduced in the market, operators need to know what the value proposition of using 802.16e WiMAX compared to alternative solutions is. How do they stand to gain from a technology that was developed to support mobility? Do they need the extra features that 802.16e WiMAX offers? This paper addresses these questions by looking at operators' requirements and how 802.16e WiMAX meets them.

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802.16d, 802.16e WiMAX and beyond

There are two flavors of WiMAX (Table 1). The 802.16d WiMAX, based on the IEEE 802.16d-2004 amendment, is the first version of WiMAX that supports fixed and nomadic access. The initial WiMAX Forum Certified™ products were based on 802.16d WiMAX and operated in licensed bands only. The second version of WiMAX is referred to as Mobile WiMAX™ or as 802.16e WiMAX, as it is based on the IEEE 802.16e-2005 amendment. It also operates in licensed bands and supports full mobility, including handoffs.

The 802.16e WiMAX technology is also available in products operating in license-exempt bands. However, license-exempt equipment does not yet carry the WiMAX Forum® certification stamp. The WiMAX Forum certification program is currently limited to licensed bands (2.3 GHz, 2.5 GHz, and 3.5 GHz). This is because mobile services predominantly use licensed bands, and certification establishes a required base for plug-and-play interoperability that enables any device to work on any network worldwide.

In both the license and license-exempt cases, the equipment is standards-based and compliant with the same IEEE 802.16e standard, and it supports the same performance and features. The lack of certification for license-exempt equipment does not preclude interoperability: interoperability can (and increasingly is) established among vendors that benefit from offering a flexible end-to-end solution to their customers.

The 802.16e WiMAX platform has become the dominating WiMAX standard, with wider equipment and chipset vendor support, a rapidly growing number of terminal devices and of base station form factors (from femtocells, to single-sector compact picocells, to multi-sector macro base stations). As the 802.16e WiMAX market reaches the economies of scale, 802.16d TDD WiMAX, while still supported by vendors, is quickly becoming a legacy technology, mostly targeted at niche markets.

Perhaps more importantly, 802.16d TDD WiMAX lacks a clear upgrade roadmap, mostly due to the limited interest from vendors and operators alike. The move from 802.16e WiMAX towards IEEE 802.16m is under way and it will provide improved performance, and support for voice services and wider channels

	802.16d TDD WiMAX	802.16e WiMAX
Access	Fixed and nomadic	Fixed, nomadic, and mobile
Certified products	36 products (19 subscriber stations and 17 base stations) (Source: WiMAX Forum)	80 products (49 subscriber stations and 31 base stations) (Source: WiMAX Forum)
Certification	3.5 GHz band. Time Division Duplex (TDD) multiplexing. No plans for extension to other bands	2.3, 2.5 GHz, and 3.5 GHz, plus additional bands to be added in the future. TDD multiplexing, with FDD expected in the future
Channels	3.5 MHz	5 MHz, 7 MHz, 8.75 MHz, 10 MHz; 20 MHz in the future
Radio interface	MIMO A (optional)	MIMO A, MIMO B, maximum receive ratio combined (MRRC), and hybrid automatic repeat request (HARQ) for improved capacity and coverage
Focus	Becoming a legacy, niche technology	Primary focus of WiMAX Forum, vendors, and operators
Devices	External or desktop customer premises equipment (CPE) and data cards	External or desktop CPEs, data cards, embedded laptops, handheld devices, and phones
Standards roadmap	No backwards compatibility with IEEE 802.16e or IEEE 802.16m	Backwards compatibility with IEEE 802.16m
Market	Limited vendor choice, few chipset vendors	Economies of scale, many chipset vendors

Table 1. Two WiMAX flavors: comparing 802.16d WiMAX and 802.16e WiMAX certified products

Performance requirements

Wireless broadband operators are under intense pressure to achieve profitability rapidly and to provide data and voice services that can successfully compete with wireline services. To achieve these goals, operators need to clearly define their requirements and carefully select the technology that is best suited to meet them.

While some requirements depend on specific applications and services, there are a few common requirements that are independent of the applications and services supported and are crucial to all operators in license-exempt bands. They include:

- **High capacity.** The technology used has to support high data rates, which effectively bring down the bit-based cost for the overall network. High data rates allow the operator to support a higher number of subscribers within the same sector, or to provide higher data allowances to subscribers.
- **Robust coverage.** Operators that deploy equipment in rural or low-density areas or support services requiring only limited bandwidth typically have coverage-driven networks. Establishing good coverage can be especially challenging in license-exempt bands because they typically have lower power allowances and higher frequencies than licensed bands.
- **Interference management.** While levels of interference vary by area and band used, wireless operators using license-exempt bands need tools to manage existing interference or to defend their investment from interference that may emerge in the future.
- **Traffic management.** Wireless broadband networks are increasingly used to support voice alongside data services, to serve customers with different service plans, access priority or allowances, and to support multiple types of vertical applications. A brute-force approach of providing more bandwidth than needed to avoid managing traffic is no longer cost effective or, increasingly, sufficient, because traffic from individual users keeps growing at a fast pace. Quality of service (QoS) and traffic prioritization and management are needed to provide fair access to all subscribers, to support voice and video data, and, more generally, to provide priority access to those applications or services that require it, on the basis of the service level agreement (SLA) in place.
- **Mobility support** has not yet become a requirement, but it is a feature that many operators are interested in, even if they do not yet plan to roll out services or vertical applications that require mobile access at launch.

Wireless operators that serve **residential subscribers** are the ones that often face the toughest competition from wireline operators, unless they operate in rural areas where wireline connectivity is limited. Their requirement focus is often on the subscriber end: their business case rests on the availability of low-cost CPEs with a variety of form factors.

To serve **business subscribers,** wireless operators have to provide a high-availability, secure, and dedicated high-capacity link; entry level is a 1.5 Mbps T1-equivalent link. QoS is also crucial, to provide carrier-grade voice services and to prioritize traffic from different applications.

For **vertical applications,** requirements vary greatly. Some applications (e.g., remote metering, vehicle and asset tracking) require wide-area coverage, but limited bandwidth. At the other end of the spectrum, surveillance closed-circuit television (CCTV) cameras require high throughput and low latency and jitter, but coverage requirements are often concentrated in selected areas (e.g., along a freeway to remotely control traffic or track traffic violations, or at ATM locations to secure the assets and protect customers). Vertical applications that support the mobile workforce (e.g., utilities engineers maintaining infrastructure, police cars, and public agency staff) also require support for mobility and, in some cases, QoS-based traffic prioritization. For applications like meter reading, parking meters, or remote sensors with a large number of devices that generate little traffic (and low average revenue per user [ARPU]), the availability of low cost

modules is crucial to the business case. For mobile applications, cost sensitivity for the subscriber terminal is usually lower, but the requirements are more stringent (e.g., screen size, rugged design, weight, keyboard type, or form factor), and custom-made devices may be needed in some cases.

Why choose 802.16e WiMAX-based equipment?

The appeal of 802.16e WiMAX-based equipment to wireless operators either serving residential and business subscribers or hosting vertical applications is driven by the ability of the technology to meet operators' requirements, both from a business model perspective and from a performance one.

The strongest pull towards 802.16e WiMAX is that it is a technology with a well established evolution roadmap, with strong industry backing and a rapidly expanding ecosystem. The 802.16e WiMAX has a path toward the next WiMAX version, 802.16m, which 802.16d TDD WiMAX lacks. Operators with 802.16e WiMAX-based networks will be able to upgrade their infrastructure to 802.16m WiMAX when the equipment becomes available. Operators with 802.16d TDD WiMAX do not have this opportunity, unless they are ready to build an overlay network or entirely replace the old equipment with the new 802.16e one.

With the introduction of 802.16e WiMAX-based equipment for use in license-exempt bands, 802.16d TDD WiMAX is rapidly becoming a legacy technology, as it already is in licensed bands. Wireless operators that do not have a clear migration path to 802.16e WiMAX are concerned that their vendors might cease their development of new 802.16d TDD WiMAX-based products in favor of the newer standard.

The availability, selection, and cost of subscriber devices present even bigger constraints as they depend on overall market size. Operators using 802.16e WiMAX-based equipment in license-exempt bands can take advantage of the economies of scale achieved in licensed bands because vendors can modify the existing network equipment and devices to operate in license-exempt bands. Furthermore, having launched commercial products in the licensed WiMAX bands (i.e., 2.3 GHz, 2.5 GHz, and 3.5 GHz), some vendors are expected to extend their produce line to license-exempt bands rapidly.

Support for mobility is another major appeal of 802.16e WiMAX, even though most operators do not yet have specific plans on how to leverage it within the fixed services they currently offer. The prevailing attitude among operators is that mobility is a nice-to-have feature that gives them additional flexibility in how they market their services. From a business model perspective, operators in license-exempt bands have so far been focused on fixed services and applications. From a technology perspective, full mobility in high-frequency license-exempt bands is very challenging.

The interest from wireless operators and vertical market players is mostly tied to the potential to offer nomadic access or limited mobility, which can be easily tied to the service currently available as an add-on service. The ability to support mobile devices, for instance, may be valuable to subscribers who just want to access the network from different locations, but not necessarily within a fully mobile scenario. A student with a laptop needing to access a college WiMAX network will prefer a data card or built-in module over a desktop modem. As these types of applications do not require blanket coverage of an entire region or country, they can be supported within license-exempt bands within carefully chosen hot zones.

Mobility will also enable operators to expand the range of services they offer their vertical customers within their coverage area, and to include applications that require, for instance, support for the mobile workforce or in-vehicle connectivity (e.g., for safety and security, government, utilities, and transportation applications).

Finally, 802.16e WiMAX-based equipment supports advanced functionality that is conducive to improved performance compared to 802.16d WiMAX and other

wireless broadband technologies. The spectral efficiency of the air interface in the two versions of WiMAX in their basic configurations is comparable, but several features that are available or required in 802.16e WiMAX are not implemented in 802.16d TDD WiMAX equipment. For instance, QoS is available in both versions of WiMAX, but 802.16e WiMAX can provide better support for voice services though an additional QoS level that makes it possible to dynamically allocate capacity to voice traffic only when needed. Furthermore, 802.16m WiMAX is expected to provide enhanced voice support.

Similarly, 802.16d WiMAX supports only multiple input multiple output (MIMO Matrix) A as an option. In 802.16e WiMAX, support for MIMO A—to provide more robust coverage—and for MIMO B—to increase capacity—are part of the standard. MIMO A is especially attractive to rural operators because it allows them to deploy fewer base stations to cover the same area. MIMO A also uses a diversity transmission scheme that helps operators to manage interference. MIMO B is better suited to operators in metropolitan areas, where multipath environments, including indoor locations, dominate.

The use of subchannelization with orthogonal frequency division multiple access (OFDMA) in 802.16e WiMAX also enhances coverage as terminal devices can receive and transmit more efficiently than with other wireless interfaces. Hybrid automatic repeat request (ARQ) and convolutional turbo code (CTC) also provide improved coverage, but they are not supported in 802.16d WiMAX.

Finally, 802.16d WiMAX equipment today only supports channel widths up to 7 MHz, while 802.16e WiMAX supports up to 10 MHz, and it is expected to reach 20 MHz with 802.16m WiMAX. The increase in channel size effectively lowers the cost per bit to the operator, because each base station can transport more traffic.

IEEE 802.11-based mesh and 802.16e WiMAX

For wireless operators in license-exempt bands, IEEE 802.11-based mesh networks are an alternative that is well suited to some applications. However, the 802.11 standard was initially designed for local area networks (LANs), so establishing wide-area coverage can be difficult because the range of each access point is limited.

Even though the cost of individual access points may be low, the cost of installing, protecting, and maintaining a dense network of access points escalates quickly and may become higher than installing a WiMAX network.

In addition, 802.11-based networks have limited QoS functionality, and the mesh architecture may trigger high latency. These factors may limit the suitability of 802.11-based mesh solutions for enterprise and vertical applications, such as surveillance, that require guaranteed performance and low latency.

Conclusions

802.16e WiMAX is rapidly becoming the technology of choice for wireless operators, and not only for operating in licensed bands and with a strong focus on mobility. As they plan to expand their residential or business service, or to grow their vertical market applications, wireless operators looking for a future-proof technology find 802.16e WiMAX equally compelling for license-exempt bands. Equipment based on 802.16e WiMAX supports full mobile access, but it also supports high-performance fixed networks.

Thanks to the wide industry support for the 802.16e version of the standard, operators using 802.16e WiMAX-based equipment will be able to rely on a stronger ecosystem than available to 802.16d TDD WiMAX operators, which in turn will translate into more robust interoperability and the availability of a wider range of affordable subscriber devices.

The service provider view: AzulStar

Leveraging 802.16e WiMAX for market expansion

AzulStar is a US-based wireless Internet service provider (WISP) providing residential and business customers with data and voice services ranging from basic connectivity to high-bandwidth dedicated links (Table 2), using the lightly licensed 3.65 GHz band and the licensed 2.5 GHz band. It operates in selected US markets in New Mexico (Albuquerque, Bernalillo, Corrales, Rio Rancho, and Placitas; a Santa Fe launch is planned) and Michigan (Ferrysburg, Grand Haven, Grand Rapids, Grandville, Jenison, Kentwood, Norton Shores, Spring Lake, Walker, Wyoming; service is planned for Ann Arbor and Lansing in the near future). Although AzulStar is satisfied with the performance of its 3.65 GHz deployments that use 802.16d WiMAX technology, the company feels ready to transition to 802.16e. The ability to support the mobility and enhanced indoor coverage that 802.16e WiMAX brings are certainly advantages, but the decisive factor for AzulStar is the ability to take advantage of a future-proof technology with a strong ecosystem.

AzulStar	Features	Price/month
Residential		
Max1.5	1–1.5 Mbps Unlimited	Data: $20/VoIP: $37
Max3	2–3 Mbps Unlimited	Data: $28/VoIP: $44
Max6	4–6 Mbps Unlimited	Data: $37/VoIP: $53
Business		
Full T1	1.5 Mbps symmetric	$300
T3 10M	10 Mbps symmetric	$1,100
T3 100M	100 Mbps symmetric	$5,000

Table 2. AzulStar residential and business service plans in USD

In the markets where it operates, AzulStar competes directly against DSL and cable operators. "The high cost of 802.16d subscriber units dramatically limits our growth," Tyler van Houwelingen, founder and CEO of AzulStar, says. "With 802.16e WiMAX technology, we expect to be able to source subscriber units from multiple vendors at a lower price point that will enable us to offer a wider choice to our customers and to successfully compete with wireline operators."

The cost of the CPE is crucial to AzulStar and other operators. The company estimates that the overall subscriber units cost two times as much as base stations. As a result, profitability and the ability to gain market share are predicated on AzulStar's ability to source inexpensive subscriber units from a wide set of suppliers that develop different form factors, while retaining interoperability. Low-cost subscriber units give AzulStar the ability to address the entire market and not only those households with poor or no wireline coverage or that are unsatisfied with their current wireline provider.

Interestingly, AzulStar also provides system integration services to transit operators and agencies. AzulStar has been involved in the buildout of trackside railway infrastructure (e.g., with 3.65 GHz base stations along the tracks and on trains), in the provision of broadband connectivity to buses, and in roadside networks with CCTV cameras to provide information to riders and field workers. The transportation network and the WISP wireless broadband network are in some markets jointly operated by AzulStar, which leads to leaner, more cost-effective network management and operations, which in turn translates into a faster path to profitability for AzulStar and better financial terms for its customers.

The wider selection of interoperable devices will also put AzulStar in a better position to address vertical markets such as transportation. Vertical applications tend to have strict requirements on subscriber units, and it is crucial that neither the network operator nor the vertical player be locked into the base station vendor when choosing machine-to-machine modules or subscriber devices, so that they are free to pick the best-of-breed solution in their specific market segment.



The service provider view: Towerstream

"Why use 802.16d WiMAX when 802.16e WiMAX is available?"

Towerstream has been providing symmetric dedicated connections to businesses in major metropolitan areas in the US since 2001, accumulating deep experience in many pre-WiMAX wireless broadband technologies. Arthur Giftakis, VP of Engineering, acknowledges that "there is no right or wrong wireless technology" and that coexistence of multiple technologies will be necessary, but he is confident that 802.16e WiMAX is the "perfect storm" technology for Towerstream.

Towerstream has initially deployed Alvarion 802.16e WiMAX-based 3.65 GHz equipment in downtown Chicago and in the Boston metro area, where WiMAX offers "a great fit for the T1 market," Giftakis said. In the future, Towerstream will extend the coverage in the 3.65 GHz band to other markets, and will gradually start the transition from pre-WiMAX technologies to 802.16e WiMAX-based equipment in the 5.x GHz band.

An early supporter of WiMAX, Towerstream has been conducting trials of WiMAX solutions for the last three to four years, but it was only when 802.16e WiMAX-based equipment became available that the operator decided to make the transition. Any 802.16d WiMAX-based solution would have been a temporary one, eventually requiring a forklift upgrade—most likely before the initial investment could be recouped.

Although strictly a fixed operator today, Towerstream is intrigued by the support for mobility that 802.16e WiMAX provides. While fixed services are at the core of the Towerstream service proposition (Table 3), nomadic and mobile access may become a valuable addition to service plans in the future. Towerstream is exploring this opportunity, even though it deems it to be too early to make any commitment.

Towerstream	Features	Price/month
Two-year contract required; symmetric and dedicated links		
T1	1.5 Mbps, 99.99% uptime	$300
5 Mbps	5 Mbps, 99.99% uptime	$500
8 Mbps	8 Mbps, 99.99% uptime	$900
20 Mbps	20 Mbps, 99.999% uptime	$2,500
DS3	45 Mbps, 99.999% uptime	$3,000
100 Mbps	100 Mbps, 99.999% uptime	$4,000
OC3	150 Mbps, 99.999% uptime	$5,000
Redundancy	Variable throughput	From $256

Table 3. Towerstream service plans in USD

The improved single-wall penetration and non-line-of-sight capabilities that 802.16e WiMAX technology delivers are also crucial to enable subscribers to connect from indoor locations using desktop CPEs, embedded laptops or phones, or data cards. Furthermore, the availability of a wide range of interoperable, affordable (below $100–150) devices that Towerstream expects to see in the market soon will reduce customer acquisition costs and strengthen customer retention. Giftakis does not see the absence of a WiMAX Forum certification program for license-exempt equipment as an obstacle to interoperability. "Vendors will work to establish interoperability, and when available it will be crucial to keep equipment prices low," Giftakis said.

Business considerations were the major drivers to select 802.16e WiMAX-based technology, but performance was also carefully assessed. QoS, for instance, is crucial to provide robust voice services. Advanced antenna technologies including MIMO A and MIMO B bring a substantial improvement in the signal strength in challenging environments.

The service provider view: Adam Internet

Bringing broadband to underserved areas in Metropolitan Adelaide, South Australia with 802.16e WiMAX

Even in developed countries there are still households and businesses without broadband—in both rural and urban areas. In the city of Adelaide, South Australia, an estimated 8% to 10% of the greater metropolitan population lives in broadband blackspots. As part of its commitment to provide all households and small businesses with broadband by 2012, the Australian Government is partnering with ISPs to expand the availability of broadband to underserved areas.

Adam Internet, based in South Australia, is the first ISP to deploy a wireless network in partnership with the South Australian Government, which is providing partial funding for the infrastructure development costs. Qualifying subscribers in areas where wireline broadband is not available can receive a subsidy from the Commonwealth Government to offset installation costs.

Adam Internet provides both broadband connectivity and VoIP services to its WiMAX subscribers at fees comparable to those for metropolitan ADSL services, which are still the core of the Adam Internet product offering. As customary in the Australian market, plans are capped and defined by a traffic allowance, as well as by downlink and uplink bandwith.

"The choice of 802.16e WiMAX was the obvious choice for us," says Scott Hicks, Adam Internet's Managing Director. The initial plan was to deploy 802.16d TDD WiMAX. "But we soon realized that few vendors were still developing 802.16d WiMAX products, and with 802.16e WiMAX we could achieve 50% cost savings in subscriber devices," says Hicks.

Adam Internet WiMAX service plans			
AdamMax Open plans	**Downlink, uplink speed**	**Monthly data (peak, off-peak)**	**Monthly fees**
Starter	Up to 12 Mbps, 1 Mbps	1 GB (0.5 GB, 0.5 GB)	$44.95
Light		10 GB (5 GB, 5 GB)	$54.95
Medium		20 GB (10 GB, 10 GB)	$59.95
Average		50 GB (25 GB, 25 GB)	$69.95
Super		80 GB (40 GB, 40 GB)	$84.95
Premium		120 GB (60 GB, 60 GB)	$104.95
Ultra		160 GB (80 GB, 80 GB)	$124.95

Table 4. Adam Internet WiMAX service plans in AUD (1AUD = 0.9 US$)

With no access to licensed spectrum at this time, Adam Internet has chosen to use license-exempt spectrum equipment. When 802.16e WiMAX-based products operating in the 5 GHz band became available, Adam Internet was eager to trial them, and has become one of the first operators to deploy a 5 GHz 802.16e WiMAX-based network, launching in Adelaide in November 2009. The network rollout is done in close collaboration between Adam Internet network engineers, who have experience in point-to-point links used to connect business users, and Alvarion engineers. A combination of wireless links and fiber provide the backhaul to the Adam Internet network.

Adam Internet's goal was to provide 12 Mbps in the downlink to 75% of eligible customers. To achieve this goal, it found that a base station radius of 3 to 3.5 km was the sweet spot to reliably meet the bandwidth target and provide a good customer experience, even though coverage may extend beyond the 3.5 km in many environments.

About Alvarion

Alvarion (NASDAQ: ALVR) is the largest WiMAX pure-player with the most extensive WiMAX customer base and over 250 commercial deployments around the globe. Committed to growing the WiMAX market, the company offers solutions for a wide range of frequency bands supporting a variety of business cases. Through its OPEN WiMAX strategy, superior IP and OFDMA know-how, and proven ability to deploy end-to-end turnkey WiMAX projects, Alvarion is shaping the new wireless broadband experience.

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Senza Fili Consulting provides advisory support on wireless data technologies and services. At Senza Fili we have in-depth expertise in financial modeling, market forecasts and research, white paper preparation, business plan support, RFP preparation and management, due diligence, and training. Our client base is international and spans the entire value chain: clients include wireline, fixed wireless and mobile operators, enterprises and other vertical players, vendors, system integrators, investors, regulators, and industry associations.

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