WiMAX Silicon and Systems: Ready for Deployment

The arrival of the first silicon-powered systems based on the new WiMAX standard offers a compelling argument to extend broadband wireless access.|By George Wu

Glossary of acronyms
16-QAM — 16-Phase Quadrature Amplitude Modulation
64-QAM — 64-Phase Quadrature Amplitude Modulation
ADC — Analog-to-Digital Converter
AES — Advanced Encryption Standard
AHB — Advanced High-performance Bus
APB — Advanced Peripheral Bus
ARM-CPU — A Central Processing Unit based on Intellectual Property Licensed from ARM
ATM — Asynchronous Transfer Mode
BPSK — Binary Phase-Shift Keying
BWA — Broadband Wireless Access
CPE — Customer Premises Equipment
CRC — Cyclic Redundancy Code
DAC — Digital-to-Analog Converter
DES — Data Encryption Standard
DMA — Direct Memory Access
DSL — Digital Subscriber Line
E1 — a dedicated phone connection supporting data rates of 2 Mb/s
ECC — Error Correction Code
FDD — Frequency Division Duplexing
FFT — Fast Fourier Transform
IEEE — Institute of Electrical and Electronics Engineers
IP — Internet Protocol
LOS — Line-of-Sight
MAC — Media Access Control
MMDS — Multichannel Multipoint Distribution Service
NLOS — Non-Line-of-Sight
OFDM — Orthogonal Frequency Division Multiplexing
PDA — Personal Digital Assistant
PHY — Physical Layer
PMP — Point-to-Multipoint
QPSK — Quadrature Phase-Shift Keying
RF — Radio Frequency
RISC — Reduced Instruction Set Computer
RX — Receiver
SoC — System on Chip
T1 — a dedicated phone connection supporting data rates of 1.544 Mb/s
TDD — Time Division Duplexing
TX — Transmitter
U-NII — Unlicensed National Information Infrastructure (bandwidth for wireless LAN networks by FCC 5.15 to 5.35 GHz and 5.75 to 5.825 GHz)

Access to broadband wireless connectivity has been range-bound, limited by bandwidth constraints and expensive network installation costs that have kept access out of reach for many businesses, communities and travellers outside of metropolitan areas. That will change with the arrival of the first silicon-powered systems based on the new WiMAX standard with potential to extend broadband wireless access.

WiMAX covers wide area, metropolitan and rural networks with data rates as fast as 75 Mb/s and typical cell sizes ranging from 2 to 10 km. Each basestation will have sufficient bandwidth to support at least several dozen businesses with T1/E1 connectivity, and hundreds of homes with DSL or similar connectivity. WiMAX-certified products are intended to be affordable, easy to install and interoperable, and will simplify the job when carriers install WiMAX-compliant systems in remote locations or as replacements for DSL or cable.

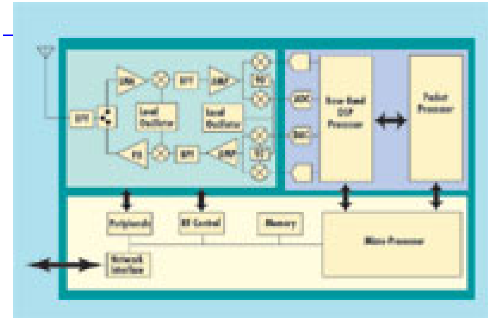
Rev 0
The WiMAX standards are critical because they assure service providers and users that WiMAX-certified equipment will interoperate correctly, and with the quality of service required for dependability. The original version, IEEE 802.16, supports point-to-point architecture in the 10 to 66 GHz range, transmitting at data rates as fast as 120 Mb/s using frequencies that require line-of-sight propagation and ideal mounting locations for base- and subscriber stations. The basestation connects to a wired backbone and can transmit wirelessly as far as 30 miles to a large number of stationary subscriber stations.

Rev 1
By early 2003, a revised version, IEEE 802.16a, was approved. It is focused on fixed broadband access to accommodate non-line-of-sight access over lower frequencies.

IEEE 802.16a was published in early 2003 with support for mesh architectures. It operates in the licensed and unlicensed frequencies between 2 GHz and 11 GHz using OFDM. IEEE 802.16-2004 — which provides support for indoor CPE — followed last year.

Rev 1+

Further enhancements are coming. Now in development is the "802.16e" version, which will add mobility and portability to the 802.16 technology. The most significant market expansion will take place in the future versions, bringing BWA directly to the end user. This "last-mile" market is by nature a PMP architecture using NLOS RF propagation. WiMAX-certified networks will emerge worldwide in both licensed and unlicensed bands within this spectrum, with the ability to replace existing proprietary pre-802.16 services.



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The WiMAX standards define and suggest key profiles for the MAC layer, which packs and unpacks raw data based on standard protocols to accommodate data, voice and video, and for the PHY, which handles the air interface and modulation schemes based on subscriber needs and RF link quality.

The standard generates profiles and also allows for vendor customization to meet specific or localized market needs, or to allow the vendor to differentiate products with value-added features.

Early WiMAX implementations will begin in basestation configurations designed for single standalone units and for much more complex rack-mounted systems and blade servers that work alongside wireline network systems. Devices also will be deployed in WiMAX-certified subscriber stations that are expected to cost much less than the custom stations currently used in the relatively small number of broadband wireless deployments in the United States. A typical implementation of system components is shown in Figure 1.

Over the longer term, WiMAX-certified broadband access will enable high-bandwidth metro area networks for home and small business users, along with backhaul networks for cellular basestations and Internet connections. This access will be available in either LOS or NLOS wireless service, both supported by WiMAX.

LOS

LOS service points a fixed antenna on the roof of a home or business at a WiMAX-enabled tower with a strong and stable connection capable of sending high amounts of data with little loss or errors. LOS transmissions use WiMAX frequencies as high as 60 GHz that feature low interference and a lot of bandwidth. NLOS service is similar to the proven and popular Wi-Fi, by which a small computer-based antenna links with a tower using a frequency range from 2 to 11 GHz. Longer-wavelength transmissions are not as easily disrupted by physical obstructions and can bend around obstacles.

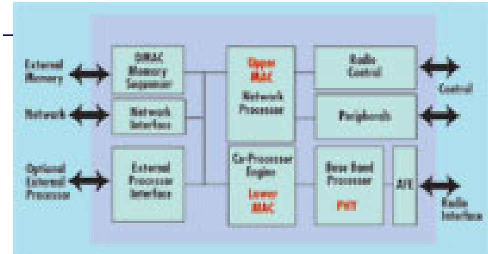

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Figure 2. SoC implementation: integrated silicon solutions will make WiMAX subscriber stations highly cost-effective and help drive the adoption of WiMAX networks.

Currently, the focus is on frequency bands in the 2 to 6 GHz portion of the spectrum, where the allocated bandwidths are relatively narrow compared with available bandwidths in the 10 to 66 GHz range. Microwave frequencies below 10 GHz are referred to as *centimeter bands*, and those above 10 GHz are *millimeter bands*. The much wider allocated channel bandwidths in the millimeter bands can accommodate large data capacities; therefore, millimeter bands are generally more suitable for high data-rate LOS sight backhauling applications (major pipelines), while centimeter bands are better suited for multipoint, NLOS, tributary and last-mile distribution.

The centimeter spectrum contains a significant tributary known worldwide as the *last-mile market*. IEEE 802.16-2004 supporting fixed NLOS BWA to supplant or as a supplement to DSL and cable access for last-mile service is the foundation for the first wave of WiMAX deployment. In the future, IEEE 802.16e, to be ratified in 2005, will add mobility and portability to applications such as notebooks and PDAs for spectrums below 6 GHz range.

WiFi-style access will be limited to a four to six mile radius (perhaps 25 square miles or 65 square km of coverage, which is similar in range to a cell phone zone). On the other hand, the WiMAX transmitting station sends data to WiMAX-enabled computers or routers in the transmitter's 30-mile radius (perhaps 3,600 square miles or 9,300 square km of coverage).

Initial Deployments

Implementing WiMAX-certified equipment begins with an Internet service provider, which installs WiMAX basestations according to user demand. The basestation transmits data to a subscriber station at speeds comparable to or better than cable modems. Users pay the provider a monthly fee. The monthly service charges may generally be lower than the current landline service fees because infrastructure build-up cost is lower for WiMAX.

In a residential network application, the WiMAX basestation sends data to a WiMAX-enabled router, which then sends it to the computers on a network. The WiMAX protocol accommodates different methods of data transmission, including VoIP, which allows users to make phone calls anywhere using broadband Internet connections. As WiMAX-compatible computers become common, the use of VoIP will increase significantly.

Because of the potential for high growth and use, the WiMAX Forum is focusing its initial profiling and certification efforts on the MMDS, the 3.5 GHz licensed bands and the unlicensed upper U-NII 5 GHz band, where there is less interference, sufficient power levels and adequate bandwidth. Power levels and power control for both transmit and receive are important for system efficiency in any WiMAX network. Levels must be actively managed to ensure solid communications and to mitigate potential interference.

In addition, power levels are dynamically adjusted on a per-subscriber basis, depending on the subscriber's profile and distance from the basestation. Overall data throughput starts with adequate power levels.

Receive Requirements

As specified by the WiMAX standard, receive level specifications are the same across the centimeter bands. The Rx must be able to accurately decode an on-channel signal of –30 dBm (at 1 µW) maximum and must be able to tolerate a signal as strong as 0 dBm (at 1 mW) at the receiver input without causing damage to the front end. In addition, the Rx should be able to provide a minimum image rejection of 60 dB. The WiMAX standard specifies that "the image rejection requirement be inclusive of all image terms originating at the receiver RF and subsequent intermediate frequencies." Adherence to these requirements will ensure reliable near and far operation.

Transmit Requirements

Subscriber stations that do not use subchannels (single carrier) must exhibit a minimum of 30 dB range of monotonic power control. For stations that do use subchannels (OFDM), a category that will include all WiMAX-certified subscriber stations in the 2 to 11 GHz range, the transmitter must have a dynamic power control range of at least 50 dB in no less than 1 dB steps. The power control accuracy must be within ±1.5 dB over a 30 dB range or ±3 dB over any range greater than 30 dB.

For the basestation transmitter, the output power level control must have at least a 10 dB range. The actual transmitted power will depend on the subscriber distance, propagation characteristics, channel bandwidth and modulation scheme (BPSK, QPSK, 16-QAM, 64-QAM). BPSK is the least data-efficient method and is used where the subscriber station is furthest from the basestation, thus requiring additional transmit power. 64-QAM, on the other hand, offers high data efficiency, or bits per symbol. It is used when the subscriber is relatively close to the basestation, thus requiring less transmit power.

New SoC Chips

A newly developed, highly integrated SoC design (see Figure 2) delivers a broad range of options for optimal WiMAX capability. It is compliant with and supports the IEEE802.16-2004 WiMAX standard.

The SoC includes PHY and MAC capabilities, with the MAC partitioned into upper and lower layers running on two different RISC engines to enhance the performance and provide flexible architecture for upgrading PHY parameters. The lower layer MAC processor is tightly coupled with the PHY and is responsible for processing all the computationally intensive tasks. All the security modules for DES and AES as indicated by IEEE802.16-2004 are fully supported. The SoC supports a baseband interface with integrated DAC and ADC converter functionality, TX/RX power measurement, automatic frequency correction, dynamic frequency selection and RF attenuator control options.

The PHY features 256 FFT OFDM waveforms to support both LOS and NLOS environments, along with adaptive modulation and variable ECC encoding per RF burst. It also incorporates TDD and FDD to address regulations worldwide, with channels from 1.75 to 20 MHz for all the modulation schemes as defined by the standard. The Fujitsu chip is designed to support both subscriber station and basestation applications.

MAC Partitioning Reduces Complexity

The original WiMAX MAC was enhanced to accommodate different PHYs and services, which address the needs of different environments. The standard accommodates TDD or FDD deployments, allowing for both full and half-duplex terminals in the FDD deployment.

The MAC supports point-multipoint wireless access, with support for higher layer or transport protocols such as ATM, Ethernet and IP. Its complex software design resolves the challenges of using the RF spectrum efficiently, supporting hundreds of connections and users over high bit rates with optimal quality of service, and handling routine tasks such as data encryption/decryption and CRC checking. The MAC software also must ensure security and privacy, and include convergence layers for the different protocols.

This particular SoC's MAC is divided into two lower-complexity main parts. The upper MAC is implemented in either an internal network processor or external host processor, and the lower MAC, also known as the PHY service access point, which bridges the upper MAC and OFDM PHY together and isolates the two from each other.

The ARM CPU supports the MAC layer, scheduler, drivers, protocol stacks and user application software. The ARM subsystem includes an AHB bus for high-performance transactions, with a multi-channel DMA controller to take care of the transactions. It also includes an APB bus for slower peripherals.

System implementers also will have access to comprehensive, WiMAX-compliant reference designs that provide all the required software and hardware for RF and baseband interface requirements, along with all the components needed for a CPE solution.

Challenges in implementing WiMAX begin with the service providers, who must integrate new equipment with existing networks. To achieve this integration, it is important to work as closely as possible with silicon and system vendors who have worked together to develop and test the initial WiMAX capabilities, have significant experience with it and have committed their development programs to the testing and patent application demands required for emerging technology.

Ready for Deployment

As the initial WiMAX silicon reaches the market, WiMAX's potential to accelerate the introduction of wireless broadband equipment and speed up the "last-mile" broadband deployment worldwide will become clear. By enabling service providers to increase system performance and reliability while reducing costs and risks, this new standard will provide a quantum leap forward in broadband wireless access and use. The latest highly integrated single-chip WiMAX-compliant SoC supports both basestation and subscriber station applications and OFDM 256 point FFT for broadband transmission meets the deployment requirements of this new and exciting BWA technology.

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