APPLICATION BRIEF

Services and Applications Perspective

Timing and Synchronization in WiMAX Networks

Overview

The emerging Worldwide Interoperability for Microwave Access (WiMAX) standard promises to be the core enabling technology for next-generation broadband mobile wireless applications including last mile broadband, hotspots, cellular backhaul and full mobile high speed broadband access. Architected to ensure low latency and low jitter to support real-time services, WiMAX provides a wide range of QoS levels appropriate for a variety of applications and subscriber requirements including internet access, streaming services, interactive gaming, video-on-demand, and voice-over-IP (VoIP) services. With its basis in robust Orthogonal Frequency Division Multiplexing (OFDM) modulation, shared data rates up to 70 Mbps, and an outstanding range of 3 to 5 miles, WiMAX leverages an internet protocol (IP) core that creates an open architecture for mobile data networks while significantly reducing network cost and complexity for delivery of high bandwidth personal broadband services (see Figure 1).

WiMAX has already begun making important inroads through real-world deployments. Small niche players, creating commercial hot spots for example, have proven out the technology as large players are beginning to position WiMAX in their wireless platforms. The drive behind WiMAX is so strong that many in the industry see WiMAX as the foundation of 4G networks, if not very real competition for today's 3G networks.

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WiMAX Network Architecture

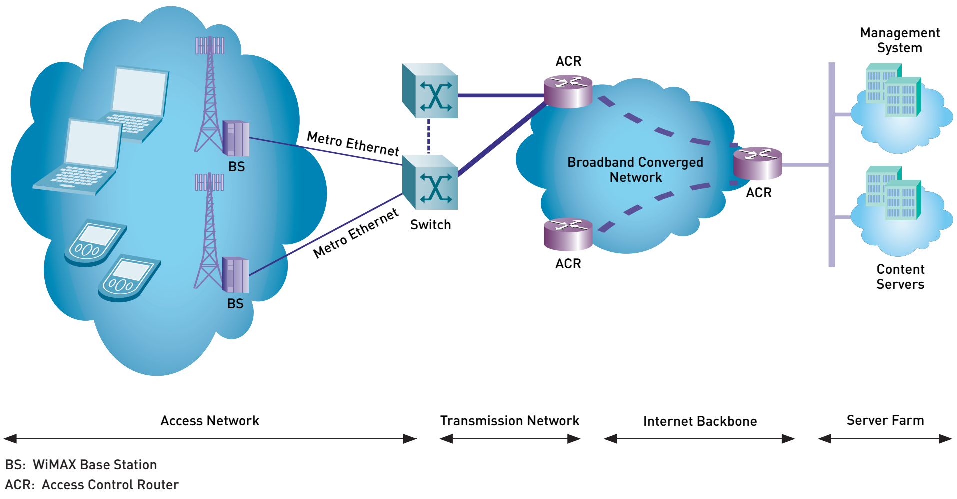

FIG. 1 WiMAX network topology: leveraging core IP network for simplicity & lower capital and operating costs.

It's All in the Timing

Synchronization paces the flow of information and ensures that networks perform at peak efficiency. Since carriers cannot control the mix of voice, video and data traffic, networks must be designed to meet the most stringent requirements to ensure that customers consistently are provided the best service quality.

All wireless systems require precise synchronization to assure high QoS.

For synchronization, it is important to have both a precise and accurate clock. When a base station clock is not accurate, it measures, for example, a second just a little shorter than a second actually is. This clock will lose accuracy the longer it runs, and as a result the base station will begin transmitting before it is the base station's time slot. The greater the error, the earlier the base station will transmit until it overruns another base station's time slot.

Accurate timing is as important as precise timing since a clock that is accurate but not precise will lead to similar contentions between channels. With accuracy and precise timing, base stations can coordinate their transmissions to maximize effective bandwidth, reduce dropped calls/connections, and increase operating revenue.

Synchronization Requirements for Major Wireless Systems

System	Frequency Accuracy	Time Accuracy
CDMA	5 x 10-8	1 μs GPS (10 μs holdover)
GSM	5 x 10-8	N/A
UMTS (FDD mode)	5 x 10-8	N/A
UMTS (TDD mode)	5 x 10-8	2.5 μs
WiMAX (FDD mode)	8 x 10-6	N/A
WiMAX (TDD mode)	8 x 10-6	1 μs GPS (25 μs holdover)

FDD: Frequency Division Duplex **TDD:** Time Division Duplex

TABLE 1 Summary of Synchronization requirements for major wireless systems.

Synchronization Requirements Within WiMAX Networks

The introduction of WiMAX is having a profound impact on today's networks, even those not immediately deploying WiMAX. Table 1 shows the synchronization requirements for the major wireless technologies. WiMAX needs a timing infrastructure to implement both time and frequency synchronization. Today's CDMA networks already require both time and frequency synchronization. However, GSM networks require only frequency synchronization. As WiMAX continues to enter the mainstream, GSM carriers will need to upgrade their networks to support time synchronization as well.

Timing plays a critical role in WiMAX base station efficiency. In Frequency Division Duplex (FDD) mode, the available spectrum is split into uplink and downlink frequency channels. In Time Division Duplex (TDD) mode, however, the full spectrum is divided into timeslots dedicated to uplink and downlink traffic. Guardband gaps, established between uplink and downlink transmission bursts, allow base stations and subscriber stations to "turnaround" from transmit to receive modes of operation (see Figure 2) without interference.

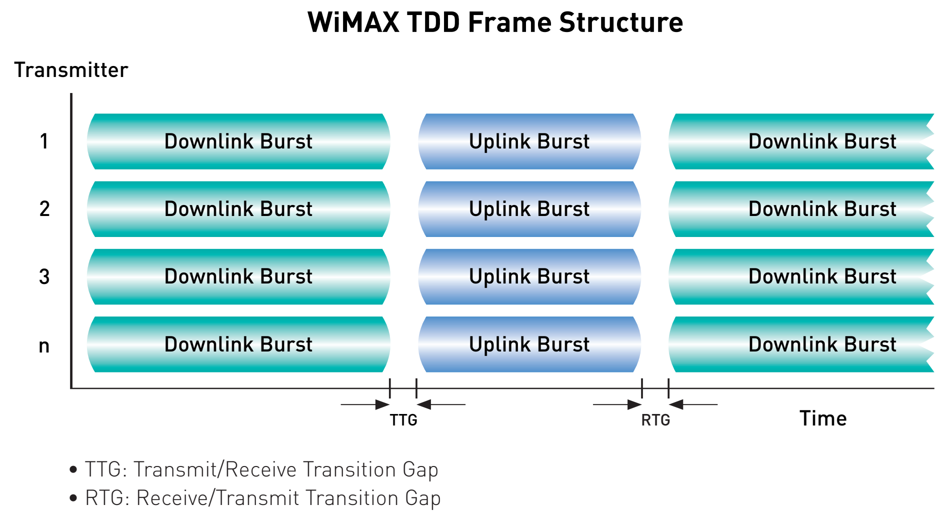

FIG 2 TDD mode requires tight time synchronization to prevent interference.

The IEEE 802.16 standard defines these guardband gaps as the receive/transmit transition gap (RTG) and the transmit/receive transition gap (TTG). However, as a base station clock loses synchronization accuracy (also known as drift), it's TDD framing will drift outside the guardbands and interfere with adjacent sites. The less accurate the clock source, the wider the guardband necessary to ensure that TDD framing disruptions do not occur.

To maximize capacity, the standard allows for RTG and TTG as small as 5 μs but requires very precise synchronization. If a base station has poor synchronization, it will require a wider guardband, wasting precious frequency spectrum. Tighter synchronization minimizes the guardband, substantially increasing the effective bandwidth. The IEEE 802.16 standard calls for the use of global positioning system (GPS) receivers to provide the precise time reference for synchronization of WiMAX networks.

WiMAX Time Division Duplex mode requires precise time synchronization.

Distributing Timing Over the Network Backhaul

GSM and UMTS base stations have long recovered their frequency synchronization over TDM T1/E1 backhaul feeds. To avoid degradation of timing references, TDM networks implement timing mechanisms within the physical network itself, creating a reliable end-to-end synchronization chain. Running traditional TDM backhaul to a base station, however, can account for 30 to 50% of operating expenses. For this reason, many carriers are looking to move to IP/Ethernet for both a wider data pipe and lower operating costs.

The primary drawback of moving to IP is that it breaks the synchronization chain, effectively leaving remote base stations without reliable access to an accurate and precise timing reference. Carriers have discovered that such breaks in the synchronization distribution chain are a primary cause of dropped calls and, as a consequence, of customer dissatisfaction and lost revenue.

For remote base stations, the most reliable alternative to backhaul timing references has been to employ GPS-based receivers. GPS provides a highly accurate and precise Stratum 1 Primary Reference Source (PRS) on the order of 1EE-12. GPS, while highly reliable, presents deployment considerations. Installation and antenna placement to assure a view of the sky can be challenging, such as when a base station is located in the basement of a skyscraper.

IEEE 1588: Precision Timing Protocol (PTP)

IEEE 1588 Precision Timing Protocol (PTP) offers a compelling alternative to GPS in WiMAX and other wireless applications by providing a cost-effective way to pass very accurate timing references between nodes while meeting the synchronization needs of WiMAX for both FDD and TDD modes of operation. IEEE 1588 PTP technology is entering trial stage now for many telecommunication applications. While GPS is highly accurate and precise, it can be more costly and complex to implement and manage than IEEE 1588 PTP (see Table 2). GPS requires that a receiver be placed at each base station as well as assurance of line-of-sight satellite access. IEEE 1588 PTP, in comparison, uses Ethernet backhaul to transport timing signals. The actual cost differential depends upon the particular application/installation.

IEEE 1588 Precision Timing Protocol (PTP) is an emerging alternative to GPS timing.

WiMAX Synchronization Options

WiMAX Sync Technology Options	Strengths	Weaknesses
GPS	• Stratum 1 traceable • Provides time and location data • Well accepted for synchronization of wireless base stations (all CDMA base stations use GPS)	• Higher Opex to install and maintain GPS antenna runs • Reliant on GPS system • Requires a holdover oscillator if GPS signal is lost
IEEE 1588 Precision Timing Protocol	• Timing over IP/Ethernet backhaul • Low cost client in each WiMAX base station • Sync is distributed from IEEE 1588 master clocks in the network • Standalone solution, or back-up to GPS for extended holdover	• Standard not finalized - Version 2 standard will benefit telecom applications and is expected to go to final draft by March 2007 • Less accurate than GPS • Emerging technology with little field history

TABLE 2 WiMAX synchronization options.

Many providers are considering using IEEE 1588 PTP in new base station deployments to reduce equipment and installation costs. PTP clocks are configured in a point-to-multipoint (master/slave) configuration. IEEE 1588 PTP master clocks can be installed into existing Building Integrated Timing Supply (BITS) or Synchronization Supply Unit (SSU) systems located in central office aggregation points, and simple slave devices are installed in the remote base stations. The master clocks establish a two-way communication path over Ethernet with the remote slaves to pass very accurate time and frequency synchronization (see Figure 3).

IEEE 1588 PTP can also provide a reliable backup timing reference in base stations deployed with a GPS receiver. If the GPS signal becomes unavailable, the base station can still hold synchronization using IEEE 1588 PTP until the GPS reference can be restored. In this way, synchronization is never compromised nor is network availability adversely affected.

The master/slave mechanism of IEEE 1588 PTP makes it convenient to deploy in existing networks, enabling carriers to efficiently prove out PTP and gain confidence in its capabilities. It requires no changes in the existing network, other than that a master clock must be sourced.

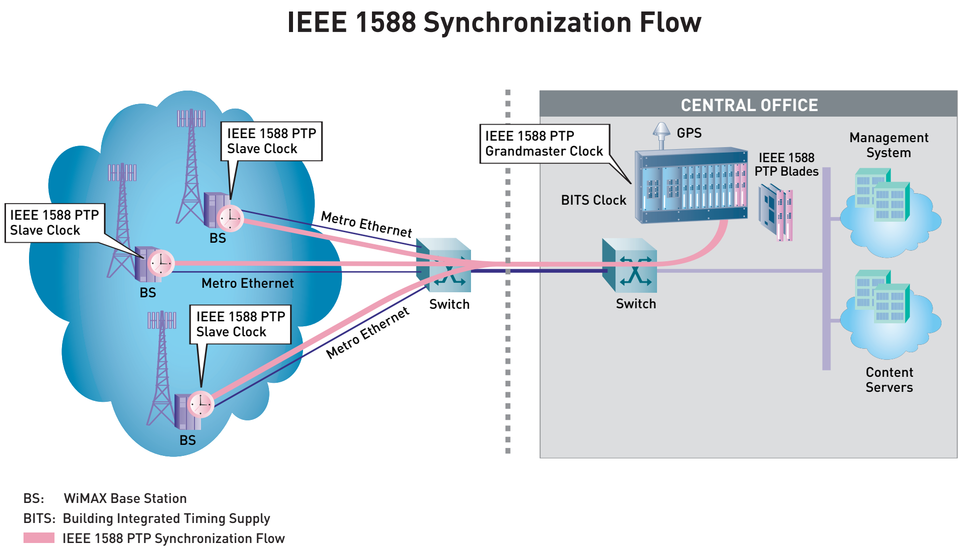

FIG. 3 Utilizing IEEE 1588 PTP, carriers can reduce the number of GPS-based receivers required in a WiMAX network, significantly reducing deployment cost as well as simplifying network maintenance.

WiMAX In the Real World

The mobile version of WiMAX, 802.16e, was ratified in December of 2005 and supports full mobility of clients. While it is not mandated by the standard, TDD is most likely the mode of choice for mobile applications because it divides the entire frequency spectrum into upstream and downstream time slots compared to FDD's separate upstream and downstream frequency channels, yielding more efficient utilization of the limited frequency spectrum available.

It is important to remember that careful consideration regarding timing distribution for WiMAX applications be given from the very start. The WiMAX network is entirely IP and there is no option of recovering timing signals as there is with TDM applications. Engineers must find a cost-effective way to provide a timing reference to WiMAX base stations. The appeal of IEEE 1588 PTP for WiMAX networks is that it is complementary to GPS based primary reference sources deployed in master clock locations. Deploying an IEEE 1588 PTP slave in a base station can be significantly less expensive and easier to maintain than a GPS-based receiver.

Existing BITS/SSU infrastructure can be leveraged to provide IEEE 1588 PTP timing for NGN networks.

Whether WiMAX is destined to be the fiercest competitor against 3G or serve as the foundation of 4G has yet to be seen. It is clear, however, that WiMAX will play a major role in shaping wireless networks by challenging carriers to preserve the synchronization chain with precise and accurate timing references. With a combination of Cesium- and GPS-based primary reference signals distributed using GPS and IEEE 1588 PTP, carriers will be able to deploy innovative and advanced WiMAX services in a reliable and cost-effective manner.

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