Ultra Mobile Broadband Technology Overview and Competitive Advantages

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Abstract:
To efficiently meet the increasing demands for mobile broadband, Ultra Mobile Broadband (UMB) is designed to complement 3G deployments. It is equipped with all the necessary features for optimal support of real-time and best-effort traffic with seamless mobility. This article overviews the UMB technology, and discusses its competitive advantages, which are fast time to market, flexible deployment options, inherently designed for real-time services and flexible IP-based network architecture. Moreover, the article analyzes key UMB design features, including Orthogonal Frequency Division Multiple Access (OFDMA), advanced antenna techniques, Reverse Link (RL) sector capacity optimization, adaptive interference management mechanisms, efficient RL control design, low-overhead signaling, fast seamless handoffs, multi-carrier support and beacons, enhanced terminal battery life, and flexible IP-based network architecture. UMB is well suited to be at the center of the future that melds broadband applications with faster, more capable mobile multimedia devices. UMB's competitive advantages provide operators with continuous differentiation today and tomorrow.

1 UMB Overview

Ultra Mobile Broadband (UMB) is a leading mobile broadband Orthogonal Frequency Division Multiple Access (OFDMA) solution that utilizes wider bandwidths (up to 20 MHz) to produce an ultra fast user experience. Bringing high-quality mobile broadband access to the mass market, UMB increases network capacity, enhances user experience, and elevates support for a plethora of multimedia applications. Optimized for an ultra mobile broadband experience and designed for efficient support of real-time services such as Voice over Internet Protocol (VoIP), UMB is at the center of the convergence trend for communication, computing, and consumer electronic platforms. UMB leverages a track record of technology leadership and industry partnerships that brought to fruition hundreds of 3G devices, ranging from embedded laptops to very low cost handsets. 3GPP2 standards and vendors have historically driven innovation. With UMB, operators can stay ahead of the competition by differentiating themselves through earlier delivery of advanced and robust solutions.

UMB is designed to provide broadband connectivity to users at speeds comparable to fixed line networks such as Ethernet and Cable/Digital Subscriber Line (DSL) while maintaining high-speed mobility. It supports peak rates up to 288 Mb/s. Furthermore, UMB maximizes system capacity within an operator's limited and valuable spectrum resources. UMB's significant competitive advantages can be summarized as follows:

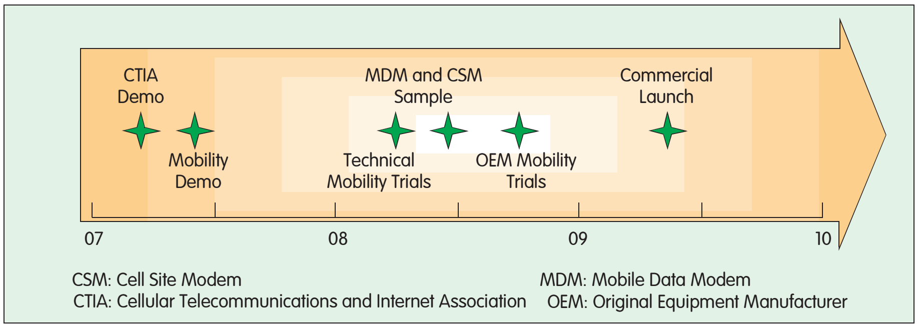
- Designed for high-speed data and VoIP in a mobile environment
- Ultra fast user experience maximizes revenue from all segments: laptops, ultra-mobile PCs, handsets, consumer electronics, desktops
- Lower costs for all services, based on higher data and VoIP capacity
- Continued acceleration of advanced features in the 3GPP2 standards
- 3GPP2 track record of technology leadership, utilizing highly integrated Application-Specific Integrated Circuits (ASICs) and industry partnerships.

3G systems today enable mobile broadband, with applications ranging from high-Speed browsing, fast music downloads, video streaming, VoIP, video telephony to online gaming. With the higher uplink speeds of 3G networks, more and more users can access social networking sites on their mobile devices and upload user generated content.

Looking forward, mobile broadband access will become ever more prevalent. Coupled with the current trend toward IP-based architectures, UMB is attractive to operators that are seeking to future-proof their networks. Using UMB, an operator can efficiently deliver a range of multimedia and VoIP applications across multiple devices, creating exciting revenue opportunities across all market segments.

For existing 3G operators, UMB provides an opportunity to upgrade their networks in a phased manner. A 3G operator can focus on high-demand areas first, falling back to 3G where there is no UMB coverage. Multimode devices supporting both UMB and the existing technologies will enable backward compatibility for UMB users that are not in UMB coverage. The UMB network support for seamless handoffs with 3G technologies is currently being developed in 3GPP2.

Greenfield operators that do not have an existing network can also deploy UMB in available Frequency Division Duplex



▲Figure 1. UMB's rapid development with commercialization by 1H09.

(FDD) or Time Division Duplex (TDD) frequency spectrum to simultaneously support both VoIP and mobile broadband applications.

At Cellular Telecommunications and Internet Association (CTIA) 2007, eight major infrastructure and device Original Equipment Manufacturers (OEMs) joined CDMA Development Group (CDG) to show support for UMB by participating in a half-day UMB seminar. Two full-protocol stack, over-the-air UMB demos were also demonstrated by two major UMB supporters. These demos displayed the impressive data rates and very low latencies that can be achieved by UMB while running simultaneous applications over the air such as high definition video streaming, video conferencing, web browsing, File Transfer Protocol (FTP) uploads and downloads, as well as VoIP. Full mobility demos running such applications in handoff situations on highways are also currently being demonstrated at the Qualcomm San Diego campus.

2 UMB: Competitive Advantages

2.1 Fast Time to Market

Figure 1 shows the timeline for UMB commercialization, outlining its competitive advantage with respect to other OFDMA solutions. UMB standardization (including the network architecture) was completed by the end of 2007 in 3GPP2.

2.2 Unsurpassed Mobile Broadband Performance

There are several important criteria to evaluate the performance of any airlink technology's performance:

(1) Average and Cell-Edge Data Rates

Two important parameters in a field deployment are the average and cell-edge user data rates. UMB's high rates, as shown in Table 1, enable a broadband network to serve its users with consistently high rates regardless of a user's location within the cell.

(2) Peak Data Rates

Peak rates show the user experience close to a cell tower in an unloaded network. Table 2 shows the peak rates for UMB.

(3) Quality of Service

Low latencies, fast connection times, and ability to seamlessly handoff between cells are also important parameters when measuring performance. UMB provides minimum Ping latencies of less than 16 ms, including the Ping request time 1.

(4) Cell Capacity

Higher cell capacity allows more simultaneous users within the network to use applications such as VoIP. UMB's low overhead enables large number of VoIP calls to coexist with high capacity data services. High capacity also enables higher user data rates to be transmitted to users for bursty traffic applications. In addition, increased capacity lowers cost per bit which lowers the cost of all services.

(5) Increased Terminal Battery Life

A long terminal battery life is crucial for an optimal user experience.

2.3 Flexible Deployment Options

UMB offers a great deal of deployment flexibility, allowing an operator to make best use of its spectrum resources. The options include:

(1) FDD/TDD Modes

UMB can be deployed in both FDD and TDD spectrum bands. FDD standardization was completed in April 2007 in 3GPP2.

(2) Flexible Bandwidth Support from 1.25 MHz to 20 MHz

The standard supports spectrum allocations from 1.25 MHz up to 20 MHz. Wider bandwidths increase system throughput and offer higher data rates.

(3) Asynchronous or Synchronous FDD

In asynchronous deployments, each base station may have an independent time reference. The advantage is that it eliminates the need to synchronize base stations to an accurate external timing source. This is a matter of special interest for in-building or underground deployments. Synchronous operation, on the other hand, uses an external global timing source, and permits the network to operate more efficiently. UMB allows for both types of deployments.

(4) Robust Operation with Universal Frequency Reuse

UMB enables robust deployments through its powerful interference management techniques that control other-cell interference. These techniques allow for a deployment without the need for careful frequency planning. Depending on the deployment scenario, fractional frequency reuse schemes may also be used in addition to embedded interference management in order to minimize interference.

(5) Efficient Multi-Carrier Deployment Support

▼Table 1. UMB average and cell-edge data rates for forward-link user (with loaded scenario and by 3GPP2 evaluation methodology)

Single Forward-Link User Data Rates	10 MHz FDD, 1x2 SIMO
Average	8.8 Mb/s
Cell-edge	2.0 Mb/s
FDD: Frequency Division Duplex SIMO: Single-Input Multiple-Output	

▼Table 2. UMB forward-link and reverse-link peak data rates

Bandwidth	10 MHz FDD	20 MHz FDD
Forward Link	135	288
Reverse Link	35	75
FDD: Frequency Division Duplex		

UMB supports phased deployments through its efficient multi-carrier design. With UMB, an operator may start with a 10 MHz deployment, and add more bandwidth as demand increases.

(6) Support for Various Frequency Bands

UMB can be deployed in any new and vacant TDD or FDD frequency band. 1.5, 1.7, 2.3, and 2.5 GHz are some examples of bands that can be available for UMB, in addition to many other bands.

2.4 Inherently Designed for Real-Time Services

UMB is designed from the ground up for efficient delivery of real-time services and can address a mix of real-time VoIP, video and web traffic. For example, UMB supports more than 500 VoIP users per sector in a 10 MHz FDD deployment, while still having additional downlink capacity available for best effort traffic. UMB incorporates many techniques necessary for optimal real-time application support:

(1) Very low-latency seamless handoff mechanisms utilizing fast PHY/Media Access Control (MAC) based handoffs

(2) Advanced Quality of Service (QoS) mechanisms supporting different priority flows simultaneously

(3) Fast and low-overhead signaling to allocate/deallocate resources

(4) Extremely efficient resource request and assignments, virtually eliminating delay and overhead

(5) Low-latency access and fast resource requests by terminals, with minimal overhead

(6) Support for inter-technology handoffs.

2.5 Flexible IP-Based Network Architecture

The flat IP-based UMB network architecture decouples the radio access and the core network, improving scalability and deployment flexibility. The UMB evolved Base Stations (eBSs) integrate many radio access functions such as radio link control, IP packet classification, QoS scheduling, header compression, admission control, user data ciphering and admission control, allowing the all-IP network to support multiple access technologies easily. The UMB architecture supports a simple inter-eBS interface and also reduces the number of network nodes involved in data processing and transport, which leads to improved traffic latency and better support of delay sensitive, interactive and real-time communications. In a UMB network, each eBS can be independently upgraded without impacting handoff performance. Cross-vendor inter-operability is an additional benefit of the UMB architecture.

The UMB network supports seamless handoffs with other technologies such as Evolution-Data Optimized (EV-DO) and CDMA2000 1X. There are mechanisms being specified in 3GPP2 that will facilitate interworking and roaming with current and upcoming cellular technologies.

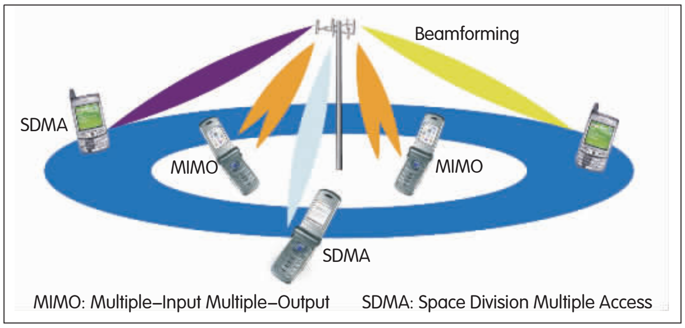


Figure 2. Advanced antenna techniques.

3 Key UMB Design Features

UMB has incorporated many key technologies to enable the industry to meet and exceed its next generation mobile broadband performance objectives:

- OFDMA
- Advanced Antenna Techniques
- Reverse Link (RL) Sector Capacity Optimizations
- Adaptive Interference Management Mechanisms
- Efficient RL Control Design
- Low-Overhead Signaling
- Fast Seamless Handoffs
- Multi-Carrier Support and Beacons
- Enhanced Terminal Battery Life
- Flexible IP-Based Network Architecture.

3.1 OFDMA

UMB utilizes OFDMA for both the downlink and the uplink. OFDMA techniques employ Fast Fourier Transform (FFT) to segment the allocated bandwidth into smaller units which can then be shared amongst the users.

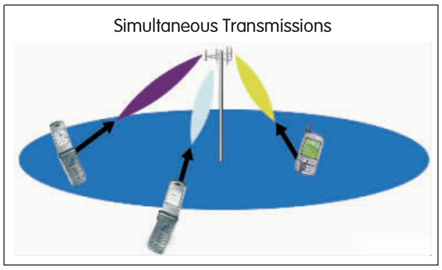
OFDMA and CDMA provide similar spectral efficiencies, with OFDMA having a simpler implementation when used in wider bandwidths. In addition, the ability to use different FFT sizes for OFDM modulation allows implementation across multiple bandwidth allocations. FFT size is scaled accordingly based on the bandwidth of choice.

3.2 Advanced Antenna Techniques

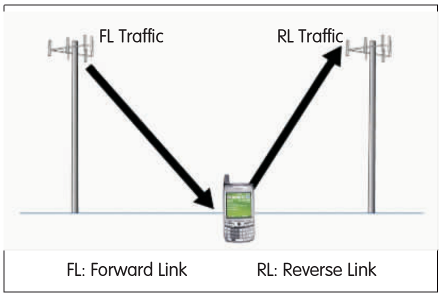
UMB delivers ultra fast user data rates throughout the cell. In addition to utilizing wider bandwidths (up to 20 MHz) for high data rates, UMB incorporates a number of advanced multiple antenna techniques such as Multiple-Input Multiple-Output (MIMO)/spatial multiplexing, Space Division Multiple Access (SDMA) and beamforming to achieve much higher user data rates, as shown in Figure 2. These techniques are complementary to each other, and can be used simultaneously or one at a time.

(1) MIMO/Spatial Multiplexing

An MIMO transmission can significantly increase user's data rates, if the user's mobile environment has a large degree of scattering (multiple signal reflections) and the received signal strength from the base station is strong. MIMO transmission implies transmitting multiple simultaneous data streams (spatial multiplexing) to the user. The benefit of MIMO is that the data rate gains are achieved without allocating any additional power or bandwidth to the user. It should be noted, however, that multiplexing gains are possible only when the user's channel has rich scattering and the user has a strong



▲Figure 3. RL sector capacity optimizations.



▲Figure 4. Disjoint link support.

received Signal to Interference plus Noise Ratio (SINR), which generally implies close proximity to the cell tower. Thus, cell–edge users typically do not benefit from MIMO.

(2) Beamforming

For cell–edge users with lower received signal strengths, UMB utilizes beamforming techniques to increase their data rates by focusing the transmit power from the base station to the direction of the users.

(3) SDMA

SDMA is another powerful antenna technique that allows a base station to transmit simultaneously to multiple users that are spatially separated. Thus, even though the transmissions are simultaneous, the interference caused to the users is minimal. Allowing concurrent transmissions increases the sector capacity accordingly. Note that there is no additional terminal complexity required for SDMA. User feedback is needed in an FDD deployment scenario (user's spatial location) and UMB provides the necessary uplink feedback channels for efficient SDMA operation.

3.3 RL Sector Capacity Optimizations

UMB allows scheduling of users over the same RL subcarriers, and using the multiple antennas at the base station to suppress the intra–sector interference caused by simultaneous transmissions on the same resources, as shown in Figure 3. This technique increases the RL capacity and is named quasi–orthogonal RL in UMB. This operation does not add any complexity to the terminal.

3.4 Adaptive Interference Management Mechanisms

UMB ensures robust and efficient operation even with universal frequency reuse, requiring no frequency planning. There are several interference management techniques UMB uses to minimize interference.

(1) Fast Distributed RL Power Control

This technique tightly manages inter–sector interference to guarantee reliable service to delay–sensitive users, while ensuring high performance. Through RL distributed power control, each user's transmit power is shaped by the interference it is causing to other sectors. UMB also uses a technique where base stations can send frequent busy bits to quickly bring a terminal's interference back to an acceptable level. This is important in situations where bursty traffic might result in a sudden increase of the interference seen by a base station.

(2) Disjoint Link Support

UMB allows a terminal to independently select the strongest Forward Link (FL) and strongest RL sectors, ensuring strongest link performance in both directions, as shown in Figure 4. Since the terminal is power controlled by the strongest RL sector, this also minimizes the interference the terminal is causing to other sectors. Disjoint link support is optional in the standard.

(3) Fractional Frequency Reuse

Fractional Frequency Reuse (FFR) techniques can also be used to improve cell–edge performance. With FFR, users at cell edge are put in reuse with respect to the strongest interfering sectors. Both in RL and FL, the scheduler can dynamically allocate subcarriers to users for efficient interference control. Figure 5 shows an FFR deployment example. FFR favors cell–edge performance with a tradeoff of reduced cell capacity.

(4) Flexband

Flexband is a universal frequency reuse scheme, in which each sector uses an intelligent power tiering among subcarriers. This increases cell–edge data rates without affecting system capacity. Unlike traditional frequency reuse schemes which completely shut off unused subcarriers in one sector, Flexband uses all subcarriers in all sectors. The FL Scheduler schedules users closer to the base station to subcarriers with lower power, while the cell–edge users are scheduled to subcarriers with more power. Figure 6 shows Flexband in a 3–sector deployment. Note that the same technique can be used in multi–carrier UMB deployments as well.

3.5 Efficient RL Control Design

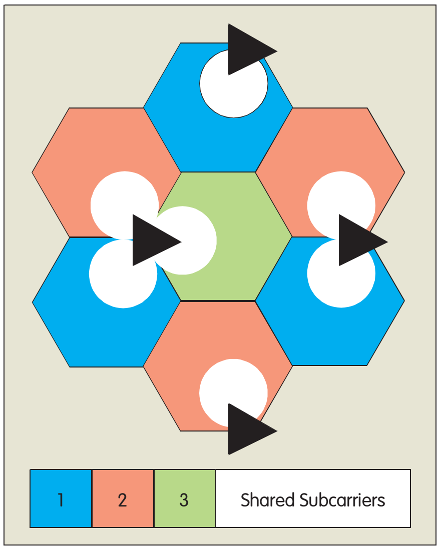
In the uplink, UMB utilizes both OFDMA and CDMA for RL control channel transmission.

(1) CDMA

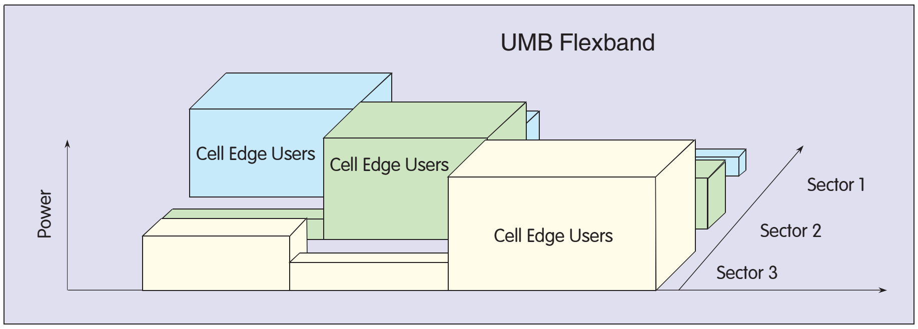
Using CDMA allows for statistical multiplexing which enables very low–latency transmissions with minimal overhead. Transmissions from different terminals in the CDMA control segment are multiplexed in a CDMA fashion, and are not orthogonal with respect to each other. This type of control transmission is best suited for bursty/event–driven and latency–sensitive feedback channels. Hence, Access, BW request and Handoff request channels are sent in the CDMA control segment allowing very fast access and seamless handoffs.

(2) OFDMA

RL OFDMA control segment in UMB is used for periodic and reliable



▲Figure 5. Fractional frequency reuse.



▲Figure 6. Flexband in a 3–sector deployment.

feedback channels such as MIMO and SDMA related feedback. Using OFDMA control segment reduces control overhead in scenarios with multiple periodic and higher rate feedback channels per user.

3.6 Low–Overhead Signaling

Low overhead signaling is essential for high spectral efficiency. UMB has flexible resource and assignment management mechanisms to minimize overhead while maximizing performance.

(1) Control Overhead Adjustment

The period of control channel transmissions in UMB can be changed within a sector. The power of control channels is also adjusted by every PHY frame allowing the system to tailor the overhead required for signaling.

(2) Persistent Assignments

In UMB, the resources can be allocated in a persistent or non–persistent manner. A persistent assignment is valid as long as the assigned resource is in use, but the base station can also de–assign a persistent assignment with minimal delay if necessary. Persistent assignments are important to efficiently support delay–sensitive real–time applications, and to reduce control overhead. They eliminate bandwidth request latency for applications such as VoIP.

(3) Synchronous H–ARQ

Synchronous Hybrid Automatic Repeat Request (H–ARQ) which is used in both the UMB FL and RL also helps reduce assignment signaling overhead, as the resources for successive retransmissions are not independently scheduled.

3.7 Fast Seamless Handoffs

UMB enables seamless handoffs so that the performance of a delay–sensitive application (e.g., VoIP) is not affected by the change of serving sector.

UMB utilizes proven CDMA active set management techniques in the reverse link to enable fast seamless L1/L2 based handoffs. The average delay of a handoff is less than 25ms, with intra–cell handoffs occurring as fast as 10ms.

The handoff decisions in UMB are made by the terminal for both the FL and the RL. The handoff requests are sent directly to the target base station via physical layer signaling, once the terminal decides that the source serving sector is not the strongest sector anymore. Note that in UMB, a terminal can have separate FL and RL serving sectors. To decide on the best RL serving sector, all the base stations in the active set of a terminal send RL pilot strength indications so that the terminal can decide on the strongest RL.

3.8 Multi–Carrier Support and Beacons

UMB allows for phased deployments through its multi–carrier design. For example, an operator can start with a 10 MHz system and then expand to 20 MHz when the demand increases or when vacant spectrum becomes available. UMB can concatenate two channels to support a wider band system, which concurrently supports both the narrowband and the wider band terminals.

The Flexband technique explained in Section 2.4, which allows intelligent power tiering among carriers, can also be used to further optimize performance.

The multi–carrier operation in UMB is seamless to the user due to the use of beacons. Beacons act as out–of–band pilots to enable fast multi–carrier handoffs, eliminating the need for tune–away operation to monitor sectors operating on other carriers. Beacons can also be used in single–carrier systems to perform fast acquisitions, enabling early discovery of candidate Active Set members and reducing the need for neighbor lists. A beacon is an OFDM symbol where all of the power is transmitted on a single tone. Each sector transmits a sequence of beacons on each carrier in a multi–carrier deployment. The interference caused by beacons is minimal.

Figure 7 shows a beacon in time and frequency.

3.9 Enhanced Terminal Battery Life

UMB has several mechanisms to extend the battery life of a terminal:

(1) Quick–Paging

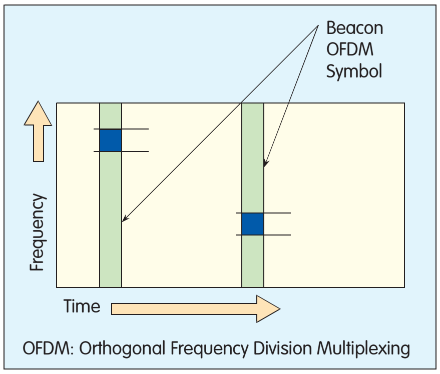
The power consumption of a standby terminal depends on how frequently it needs to wake up to receive the pages, as well as the energy spent during each page period. UMB uses a quick–paging process in which the terminals only need to be awake less than half a millisecond to get their page indicators. This significantly improves standby mode power consumption.

(2) Selected Interlaces

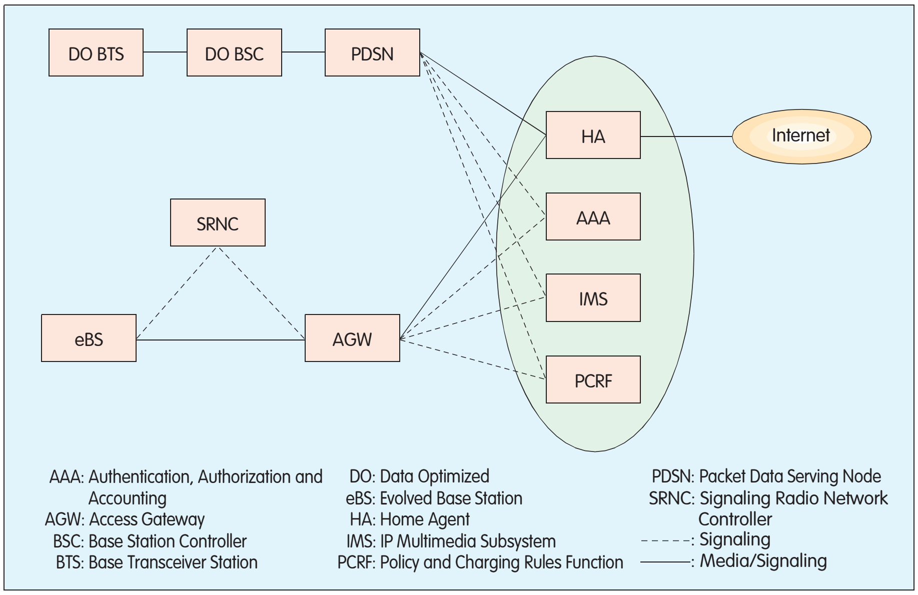
Discontinuous transmissions and receptions allow a terminal to turn off its transmitter and/or receiver on selected traffic periods (interlaces). This reduces its active mode power consumption.

(3) Semi–Connected State

UMB terminals have the ability to maintain their connection ID while powering down between bursts of data transmission. Fast access mechanisms then allow the terminal to return to active state when needed with minimal delay.



▲Figure 7. A beacon is an OFDM symbol with all power transmitted in a single tone.



▲Figure 8. Network nodes in CAN.

Power savings could be substantial, especially during bursty applications such as web browsing.

3.10 Flexible IP–based Network Architecture

UMB supports a flexible IP network architecture where the traditional hierarchical structure has been flattened by distributing the functionality of the Base Station Controller (BSC) to various other nodes. The target date for UMB Converged Access Network (CAN) specification publication is December 2007. Figure 8 shows the network nodes in CAN.

(1) eBS

The UMB eBS functions are similar to the combination of BTS and BSC functions in EV–DO architecture. Namely, in addition to the typical radio link functionality (PHY, MAC, Radio–Link Protocol (RLP), etc), the eBS is also responsible for IP packet classification for over–the–air QoS, Robust Header Compression (RoHC), and user data ciphering. It is also the accounting client which assembles and forwards airlink records.

(2) SRNC

The Session Reference Network Controller (SRNC) performs the signaling functions for the UMB Radio Access Network (RAN). It stores references to ongoing sessions, as well as managing paging and location information. It is also responsible for idle state management, and is the authenticator for EAP–based access authentication. The SRNC can be implemented both in a centralized or a distributed fashion. In the centralized case, there is a single SRNC connected to several eBSs and AGW; whereas in the distributed case, all eBSs act as SRNCs. A terminal has a single SRNC associated with it at a given time.

(3) AGW

The Access Gateway functionalities are similar to that of Packet Data Serving Node (PDSN) in EV–DO networks. AGW tunnels IP packets for user data to the eBS, behaves as the Authentication, Authorization and Accounting (AAA) client for accounting, and also acts as the Foreign Agent if applicable. It is the QoS enforcement and intrusion detection/prevention access point, among other functions it performs.

CAN incorporates efficient tunneling mechanisms for full mobility support enabling fast seamless handoffs. Additional tunneling designs being standardized in 3GPP2 will also support seamless handoffs between UMB and EV–DO and CDMA2000 1X. A single radio solution is being defined through a tune–away procedure for terminals to monitor signals on both radio interfaces, allowing minimal service interruptions during handoffs between UMB and EV–DO/1X. The target date for tunneling requirements for inter–technology handoff support is December 2007.

4 Conclusions

Designed from day one to support mobile broadband, UMB is equipped today with all the necessary features for optimal support of real–time and best–effort traffic with seamless mobility. Very low latency handoffs, tight interference management techniques, and efficient signaling mechanisms are some of the design features that differentiate UMB from other OFDMA based systems. Based on UMB's competitive advantage, operators will enjoy the lead in mobile broadband market with the ability to differentiate themselves through multimedia offerings with a plethora of device platforms.

To efficiently meet the increasing demands for mobile broadband, UMB is designed to complement 3G deployments. Use of multi–mode devices enables seamless mobility between UMB and existing networks. UMB can also be deployed by a greenfield operator to efficiently offer both VoIP and mobile broadband access. UMB delivers higher capacity, increased user data rates and lower latencies along with an IP–based network architecture for flexible deployments. UMB is well suited to be at the center of the future that melds broadband applications with faster, more capable mobile multimedia devices. UMB's competitive advantages provide operators with continuous differentiation today and tomorrow.

Biography

Pinar Ormeci

Pinar Ormeci is a senior manager of technical marketing in Qualcomm. Before this, she worked as system engineer at several R&D facilities including Qualcomm. She has BS and MS degrees in Electrical Engineering focused on wireless communications theory.