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Advances of Radio Interface in WCDMA Systems

Ju Wang
Virginia Commonwealth University, USA

Jonathan C.L. Liu
University of Florida, USA

WCDMA AND MULTIMEDIA SUPPORT

Recent years have witnessed the rapid progress in handheld devices. This has resulted in a growing number of mobile phones or PDAs that have a built-in camera to record still pictures or live videos. Encouraged by the success of second generation cellular wireless networks, researchers are now pushing the 3G standard to support a seamless integration of multimedia data services. One of the main products is WCDMA (Holma & Toskala, 2001), short for wideband code division multiple access. WCDMA networks have 80 million subscribers in 46 countries at the time of this writing.

WCDMA can be viewed as a successor of the 2G CDMA system. In fact, many WCDMA technologies can be traced back to the 2G CDMA system. However, WCDMA air interface is specifically designed with envision to support real time multimedia services. To name some highlights, WCDMA:

- Supports both packet-switched and circuit-switched data services. Mobile best-effort data services, such as Web surfing and file downloads, are available through packet service.
- Has more bandwidth allocated for downlink and uplink than the 2G systems. It uses a 5 MHz wide radio signal and a chip rate of 3.84 mcps, which is about three times higher than CDMA2000.
- Support a downlink data rate of 384 kbps for wide area coverage and up to 2 Mbps for hot-spot areas, which is sufficient for most existing packet-data applications. WCDMA Release 5 (Erricson, 2004) adopts HSDPA (High-speed downlink packet access), which increases peak data rates to 14 Mbps in the downlink.

To achieve high data rate, WCDMA uses several new radio interface technologies, including (1) shared channel transmission, (2) higher-order modulation, (3) fast link adaptation, (4) fast scheduling, and (5) hybrid automatic-repeat-request (HARQ). These technologies have been successfully used in the downlink HSDPA, and will be used in upcoming improved uplink radio interface in the future. The rest of this article will explain the key components of the radio interface in WCDMA.

BACKGROUND

The first CDMA cellular standard is IS-95 by the U.S. Telecommunication Industry Association (TIA). In CDMA system, mobile users use the same radio channel within a cell when talking to the base station. Data from different users is separated because each bit is direct-sequence spread by a unique access code in the time domain. This even allows adjacent cells to use the same radio frequency with acceptable transmission error rate, which results in perhaps the most important advantages CDMA-based cellular network has over TDMA and FDMA: high cell capacity. CDMA network is able to support more users and higher data rates than TDMA/FDMA based cellular networks for the same frequency bandwidth (Gilhousen, Jacobs, Padovani, Viterbi, Weaver, & Wheatley, 1991).

On the CDMA downlink, the base station simultaneously transmits the user data for all mobiles. On the uplink, mobile transmissions are in an asynchronous fashion and their transmission power is controlled by the base station. Due to the asynchronous nature in the uplink, Signal-Interference-Ratio (SIR) in uplink is much lower than downlink. Thus, the capacity of a CDMA network is typically limited by its uplink. Improving uplink performance has been one of the most active research topics in the CDMA community.

Three main competing CDMA-based 3G systems are CDMA2000 (Esteves, 2002), WCDMA (Holma & Toskala, 2001), and TD-SCDMA, all based on direct-sequence CDMA (DS-CDMA). Commonalities among these systems are: close-loop power control, high data rate in downlink, link-level adaption, TDM fashion transmission, fair queue scheduling, and so forth. Main differences reside in the frequency bandwidth of carrier, link-adaption methods, and different implementation of signaling protocol. TD-SCDMA use TDD separation between uplink and downlink.

Aside from these industry standards, hybrid systems integrating WCDMA and WLAN have attracted a great deal of attention recently. One such system is described by Wang and Liu (2005). Such systems might offer the final solution toward true multimedia experiences in wireless.

WCDMA DOWNLINK

WCDMA downlink provides Forward traffic CHannels (FCH) for voice connections and Downlink Shared CHannel (DSCH) for high-speed data services. The DSCH is a common channel shared by several users based on time or code multiplexing. For example, the DSCH can be allocated to a high data rate user, or assigned to several concurrent lower bit rate users with code multiplexing. The base station uses a downlink control channel for sending out fast power control command and accessing parameters (spreading factor, channelization codes, etc).

The recently released High-Speed downlink Packet Data Access (HSPDA) (Erricson, 2004) provides enhanced support for interactive data services and multimedia streaming services. The key features of HSDPA are rapid adaptation to changes in the radio environment and fast retransmission of erroneous data. The spreading factor in the DSCH can vary from 4 to 256 for different data rates. Together with adaptive modulation, hybrid-ARQ, power allocation and other link adaptation techniques, this feature allows the WCDMA downlink to offer high-speed data services.

With HSPDA, the channel usage can be regulated by a fast-scheduling (Bharghavan, Lu, & Nandagopal, 1999) algorithm. Instead of round-robin scheduling, the radio resources can be allocated to mobile users with favorable channel condition. The probability that the base station will find a "good" mobile station is quite high especially when the cell is crowded. The overall downlink capacity can be increased significantly. Such a channel-dependent scheduling is known as multiuser diversity. The main drawback of this method is that mobile users with bad channel condition might receive little or no service. The WCDMA standard allows individual vendors to implement their own scheduling algorithms with different emphasis in access fairness and overall throughput.

WCDMA UPLINK

WCDMA uplink supports two different transmission modes. The voice mode is compatible to IS-95, which provides the connection-oriented service in asynchronous fashion. The data rate in the voice mode is low (about 10 kbps), but the delay and BER is guaranteed in this type of service. The other uplink transmission mode in WCDMA is the shared data access mode. Essentially a best effort service, this mode allows mobile stations to be polled by the base station for transmission. Still without QoS guarantee, the base-controlled data mode allows a much higher throughput than the voice channels.

The peak uploading speed is usually cited as an important performance metric for uplinks. However, this term is often misleading because it does not tell the true uplink performance of the network. Peak uploading speed is usually observed in a clean environment, where in-cell/out-cell interference is minimized. In reality, the achievable data rate is highly dependant on the nearby radio activity in the same frequency band. To achieve high data rate, uplink power control and scheduling algorithms must be carefully designed (Akyildiz, Levine, & Joe,1999).

Uplink data mode can be implemented in different ways. In one approach, the uplink is accessed through data frame, which is further divided to equal-size time slots. Each 10 ms frame is split into 15 slots. Each slot is of length 2,560 chips. The base station will broadcast the allocation of different time slots for the mobile stations in the cell. For a given time slot, only the assigned mobile station will transmit. This approach requires mobile stations to be able to synchronize with the uplink time slots to avoid transmission conflict. Within each time slot, adaptive modulation is used for