Designing Wireless Base Stations with APEX CAM

Introduction

Content addressable memory (CAM) can be used to run fast searches within a system. When a system supplies the initial data to be searched, CAM searches its memory space and returns with the location of the data. By using this method, CAM is able to implement fast searches and use contents of the memory to find the address, rather than using the address to find the content.

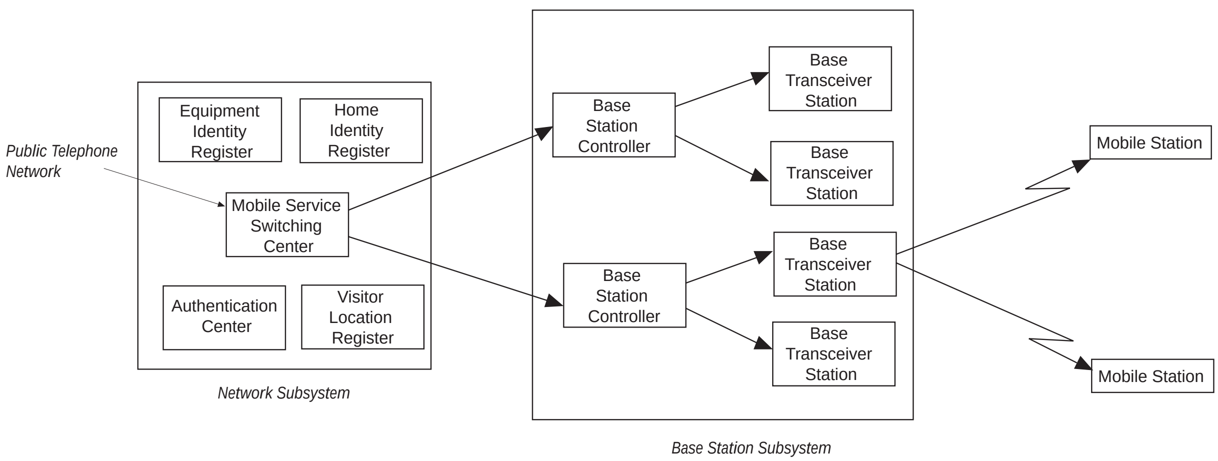
An application where CAM can be used is in a wireless base station, where the speed of data transmission is crucial. This white paper describes the application of CAM in popular mobile communication standards, including code division multiple access (CDMA) IS-95, wideband code division multiple access (W-CDMA), and global system mobile (GSM) standards.

Cellular System Network

A plain old telephone system (POTS) converts sound waves of a user's voice into electrical signals, which are then transmitted over a physical network through wires. A cellular phone system, on the other hand, converts the sound waves of a user's voice into radio waves that are transmitted through the air using radio frequency transmission.

Figure 1 shows the basic elements required when processing a call in a cellular system network, including the positions of the mobile stations, base station subsystems, and the mobile service switching center.

Figure 1. General Architecture of a Cellular System Network



The mobile service switching center is the central part of the network subsystem, which switches calls between mobile subscriber units and functions as a switching node for the public telephone network. Other responsibilities include registration, authentication, location updates, handovers, and call routing to roaming subscribers.

Because the mobile service switching center can service multiple base station subsystems, all calls to and from a public network or between mobile subscribers, pass through this system. The home location register and visitor location register also provide call routing and roaming capability and use the equipment identity register and the authentication center for security and authentication.

M-WP-APEXCAM-01

Base Station SubSystem

The base station subsystem is composed of two parts: the base station controller and the base transceiver station.

The base station controller controls the base transceiver station and all the control functions and physical links to and from the mobile station. Other responsibilities include handovers, configuration of cell data, control of radio frequency power levels within the base transceiver station, and supervising the functionality and control of multiple base transceiver units.

The base transceiver station, which consists of all the radio transmission and reception equipment, handles the radio-link protocols to the mobile station in order to provide coverage to a geographical location.

Mobile Station

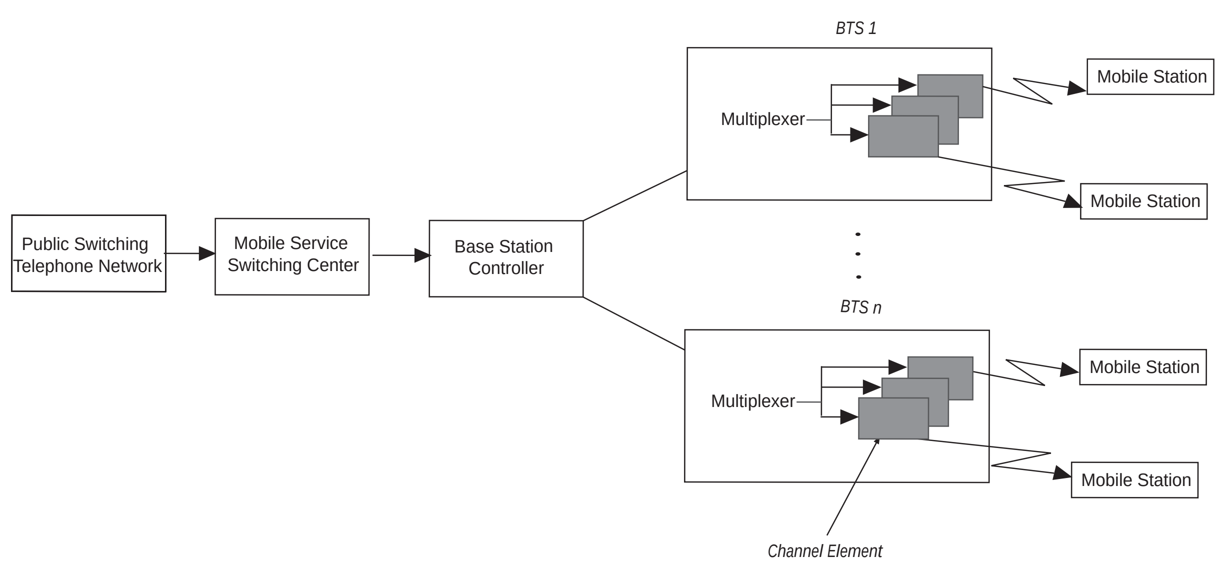
A mobile station is a device that can be either hand-held or physically mounted onto a vehicle. This device contains mobile equipment.

Optimizing CDMA Systems with CAM

CDMA is a form of spread-spectrum transmission, where the transmitter spreads the information contained in a particular signal over a much larger bandwidth than the original signal. Traditionally, CDMA has been used in military applications because its noise-like waveform is hard to detect. The main principle of spread-spectrum transmission is the use of noise-like carrier waves and wider bandwidth requirements for simple point-to-point communication at the same data rate.

A CDMA (IS-95) network consists of a public switching telephone network (PSTN), mobile switching service center, base station controller, base transceiver station, and the mobile cell. Each base transceiver station contains multiple channel elements, and each channel element services one user.

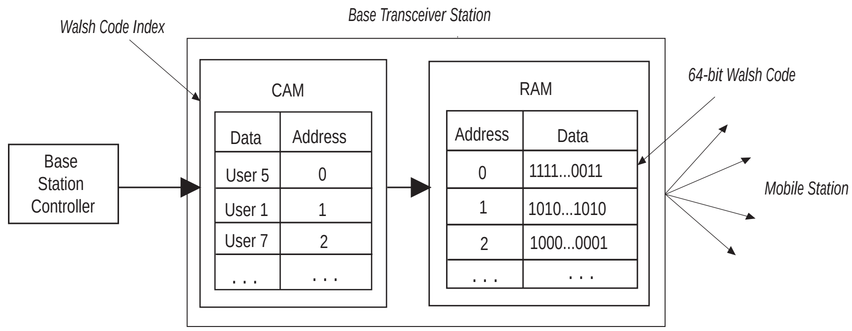
Figure 2. CDMA Network Architecture



The CDMA system uses a 64×64 Walsh matrix; each Walsh code is 64 bits in length. Each user is assigned a unique Walsh code for channelization. The system is responsible for keeping track of which of the 64 Walsh codes is assigned to each channel element. This can be done efficiently by using a combination of CAM and RAM, where

CAM provides the Walsh index member for a user, and RAM provides the corresponding 64-bit long Walsh Code, shown in figure 3. A Walsh Code is the spreading code, by which the user's data is spread. By using this combination, the system can efficiently track the Walsh Codes used for different users in the system.

Figure 3. CAM and RAM Combination to Implement Walsh Code in a CDMA System



Optimizing W-CDMA Systems with CAM

Wideband code division multiple access (W-CDMA) uses an air interface based on direct sequence code division multiple access. W-CDMA operates on a wide bandwidth compared to I5-95, in order to fulfill the requirements of the IMT 2000. Key features include performance improvements over the second generation data rate requirement and service flexibility.

Performance Improvement

Using techniques such as power control, variable spreading code, turbo coding, etc., W_CDMA techniques provide higher capacity, low bit error rate, and higher coverage area compared to older generation technology.

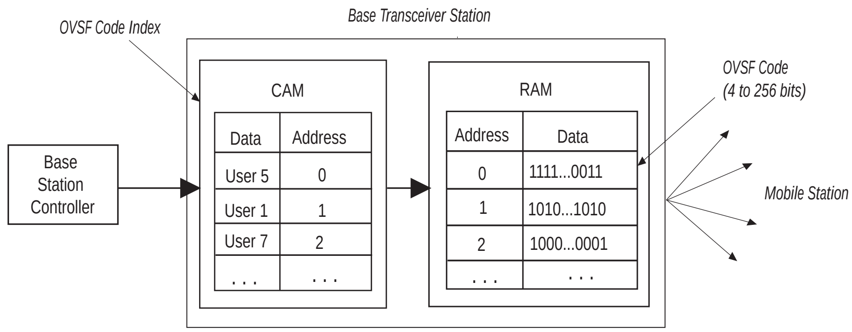
Service Flexibility

W-CDMA has the flexibility to handle mixed services and services with variable bit rates because power is the shared resource between users. In the downlink, the total carrier transmitter power is shared between the users transmitting from the base transmission station. In the uplink, there is a maximum level of interface power that is shared between the transmitting mobile stations.

The flexibility of W-CDMA is supported by orthogonal variable spreading factor (OVSF) codes for channelization of different users. OVSF is the spreading code with which a user's data is spread in the base transceiver station used in both handset and BTS. OVSF codes maintain downlink transmission orthogonally between users even when they are using different bit rates. One physical resource carries multiple services with different bit rates. As the bit rate changes, the power allocation to the physical resource changes to maintain the quality of service at any instant of connection.

Several physical channels can be transmitted in parallel on one connection using different OVSF channelization codes in order to gain higher channel bit rate. Because the system needs to keep track of which OVSF code is assigned to each channel element in the base transceiver station, a combination of CAM and RAM can be used to implement OVSF. CAM provides the OVSF index for a user and RAM provides the corresponding OVSF code, which can be from 4 to 256 bits in length, shown in Figure 4. By using an OVSF code, the system can keep track of the OVSF codes used for various users.

Figure 4. CAM & RAM Combination of OVSF Code in W-CDMA System



Optimizing GSM Design with CAM

GSM, a leading standard for digital mobile telephones, was originally developed to create a common European mobile telephone network. Since its creation, it has rapidly been adopted by numerous countries throughout the world.

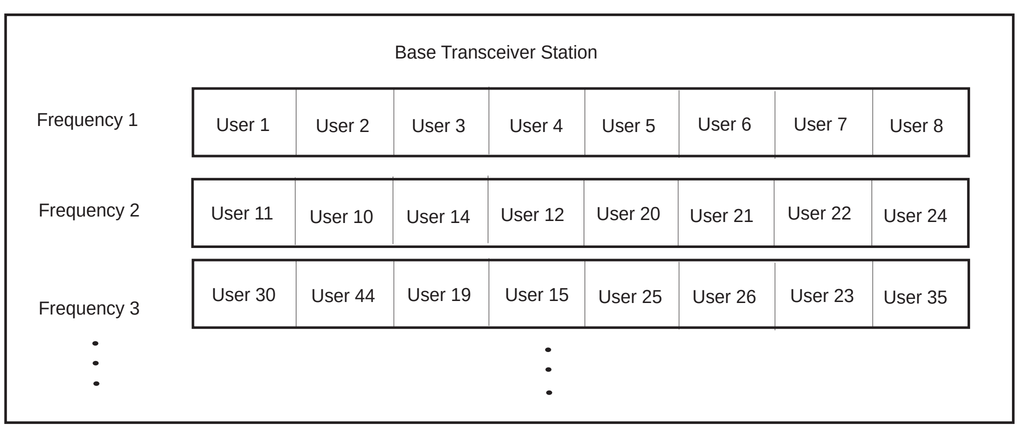
Using CAM embedded APEX 20KE devices in the base transceiver station can significantly increase a GSM network’s performance by reducing the time required to look up a packet destination.

GSM uses channel elements to control communication between the mobile stations and the base transceiver station. Channel elements are defined by frequency and time, using frequency-division multiple access (FDMA) and time-division multiple access (TDMA). GSM systems communicate over a 25 MHz frequency range. The range is divided into 124 carrier frequencies spaced 200 KHz apart. Each base station can use one or more carrier frequencies.

The frequencies are divided by time using a TDMA scheme. The unit of time in TDMA is called a burst period. Eight burst periods are grouped into a TDMA frame.

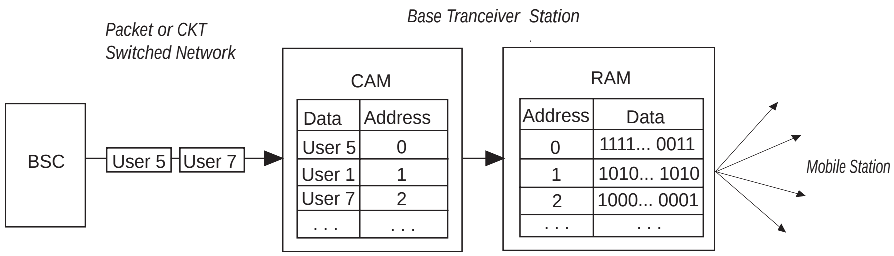
Each mobile station uses a channel, so eight mobile stations or users can gain access to the network on the same TDMA frame. Figure 5 shows how eight users can access a base transceiver station at one specific frequency.

Figure 5. Eight Channel Elements per Frequency



CAM is used in the base transceiver station to accelerate the routing. Figure 6 shows how a CAM and RAM combination is used to determine the correct frequency and time slot for a particular mobile station.

Figure 6. CAM and RAM Combination Determine Packet Destination in a Base Transceiver Station



Using CAM embedded in APEX 20KE devices rather than a discrete CAM device speeds the GSM network's routing process. Because CAM is embedded in the APEX 20KE devices, on and off chip delays associated with discrete CAM are eliminated. The embedded CAM device also cuts design time and reduces the board size by eliminating the need for a second device on the board.

A typical base transceiver station manager calls for up to 128 mobile stations; therefore, a 128-word CAM is required. Such CAM requires only four APEX ESB's, enabling the system to be easily integrated into an APEX device.

Conclusion

CAM can provide a solution for any application that requires a fast memory search. CAM can be used to accelerate a number of communication applications, including cellular phone base stations. A base station transceiver can use CAM to route packets to their appropriate destinations. Since a base transceiver station typically supports up to 128 cell phones simultaneously, CAM in APEX devices provides an ideal solution: one 128×32 CAM requires only four ESBs.

By integrating the CAM into the APEX device, a designer can reduce the board area and power consumption of a base transceiver station or base station controller. The reduced size provides a critical advantage for wireless systems and by reducing the component count, the systems reliability is improved.