Time Division Multiple Access (TDMA)

Definition

Time division multiple access (TDMA) is digital transmission technology that allows a number of users to access a single radio-frequency (RF) channel without interference by allocating unique time slots to each user within each channel. The TDMA digital transmission scheme multiplexes three signals over a single channel. The current TDMA standard for cellular divides a single channel into six time slots, with each signal using two slots, providing a 3 to 1 gain in capacity over advanced mobile-phone service (AMPS). Each caller is assigned a specific time slot for transmission.

Overview

The wireless industry began to explore converting the existing analog network to digital as a means of improving capacity back in the late 1980s. In 1989, the Cellular Telecommunications Industry Association (CTIA) chose TDMA over Motorola's frequency division multiple access (FDMA) (today known as narrowband analog mobile-phone service [NAMPS]) narrowband standard as the technology of choice for existing 800-MHz cellular markets and for emerging 1.9-GHz markets. With the growing technology competition applied by Qualcomm in favor of code division multiple access (CDMA) and the realities of the European global system for mobile communications (GSM) standard, the CTIA decided to let carriers make their own technology selection.

The two major (competing) systems that split the RF are TDMA and CDMA. CDMA is a spread-spectrum technology that allows multiple frequencies to be used simultaneously. CDMA codes every digital packet it sends with a unique key. A CDMA receiver responds only to that key and can pick out and demodulate the associated signal.

Because of its adoption by the European standard GSM, the Japanese Digital Cellular (JDC), and North American Digital Cellular (NADC), TDMA and its variants are currently the technology of choice throughout the world. However, over the last few years, a debate has convulsed the wireless community over the respective merits of TDMA and CDMA.

The TDMA system is designed for use in a range of environments and situations, from hand portable use in a downtown office to a mobile user traveling at high speed on the freeway. The system also supports a variety of services for the end user, such as voice, data, fax, short message services, and broadcast messages. TDMA offers a flexible air interface, providing high performance with respect to capacity, coverage, and unlimited support of mobility and capability to handle different types of user needs.

Topics

1. The Digital Advantage

All multiple access techniques depend on the adoption of digital technology. Digital technology is now the standard for the public telephone system where all analog calls are converted to digital form for transmission over the backbone.

Digital has a number of advantages over analog transmission:

- It economizes on bandwidth.
- It allows easy integration with personal communication systems (PCS) devices.
- It maintains superior quality of voice transmission over long distances.
- It is difficult to decode.
- It can use lower average transmitter power.

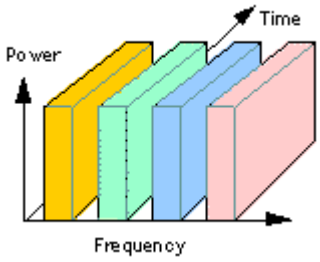
- It enables smaller and less expensive individual receivers and transmitters.

- It offers voice privacy.

Frequency Division Multiple Access (FDMA)

TDMA is basically analog's FDMA with a time-sharing component built into the system. FDMA allocates a single channel to one user at a time (see *Figure 1*). If the transmission path deteriorates, the controller switches the system to another channel. Although technically simple to implement, FDMA is wasteful of bandwidth: the channel is assigned to a single conversation whether or not somebody is speaking. Moreover, it cannot handle alternate forms of data, only voice transmissions.

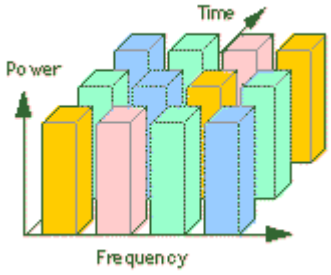
Figure 1. FDMA



2. How TDMA Works

TDMA relies upon the fact that the audio signal has been digitized; that is, divided into a number of milliseconds-long packets. It allocates a single frequency channel for a short time and then moves to another channel. The digital samples from a single transmitter occupy different time slots in several bands at the same time as shown in *Figure 2*.

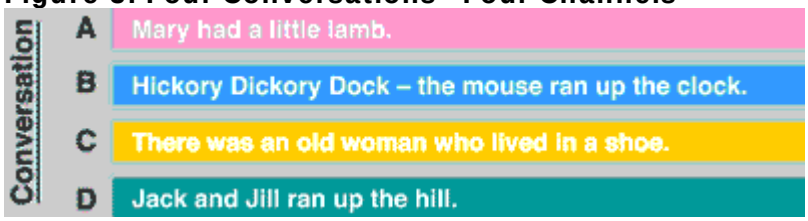
Figure 2. TDMA



The access technique used in TDMA has three users sharing a 30-kHz carrier frequency. TDMA is also the access technique used in the European digital standard, GSM, and the Japanese digital standard, personal digital cellular (PDC). The reason for choosing TDMA for all these standards was that it enables some vital features for system operation in an advanced cellular or PCS environment. Today, TDMA is an available, well-proven technique in commercial operation in many systems.

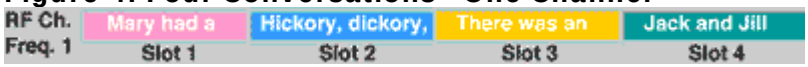
To illustrate the process, consider the following situation. *Figure 3* shows four different, simultaneous conversations occurring.

Figure 3. Four Conversations—Four Channels



A single channel can carry all four conversations if each conversation is divided into relatively short fragments, is assigned a time slot, and is transmitted in synchronized timed bursts as in *Figure 4*. After the conversation in time-slot four is transmitted, the process is repeated.

Figure 4. Four Conversations—One Channel



Effectively, the IS–54 and IS–136 implementations of TDMA immediately tripled the capacity of cellular frequencies by dividing a 30-kHz channel into three time slots, enabling three different users to occupy it at the same time. Currently, systems are in place that allow six times capacity. In the future, with the utilization of hierarchical cells, intelligent antennas, and adaptive channel allocation, the capacity should approach 40 times analog capacity.

3. Advanced TDMA

TDMA substantially improved upon the efficiency of analog cellular. However, like FDMA, it had the weakness that it wasted bandwidth: the time slot was allocated to a specific conversation whether or not anyone was speaking at that moment. Hughes' enhanced version of TDMA extended time division multiple access (ETDMA) attempts to correct this problem. Instead of waiting to determine whether a subscriber is transmitting, ETDMA assigns subscribers dynamically. ETDMA sends data through those pauses which normal speech contains. When subscribers have something to transmit, they put one bit in the buffer queue. The system scans the buffer, notices that the user has something to

transmit, and allocates bandwidth accordingly. If a subscriber has nothing to transmit, the queue simply goes to the next subscriber. So, instead of being arbitrarily assigned, time is allocated according to need. If partners in a phone conversation do not speak over one another, this technique can almost double the spectral efficiency of TDMA, making it almost 10 times as efficient as analog transmission.

4. The Advantages of TDMA

In addition to increasing the efficiency of transmission, TDMA offers a number of other advantages over standard cellular technologies. First and foremost, it can be easily adapted to the transmission of data as well as voice communication. TDMA offers the ability to carry data rates of 64 kbps to 120 Mbps (expandable in multiples of 64 kbps). This enables operators to offer personal communication-like services including fax, voiceband data, and short message services (SMSs) as well as bandwidth-intensive applications such as multimedia and videoconferencing.

Unlike spread-spectrum techniques which can suffer from interference among the users all of whom are on the same frequency band and transmitting at the same time, TDMA's technology, which separates users in time, ensures that they will not experience interference from other simultaneous transmissions.

TDMA also provides the user with extended battery life and talk time since the mobile is only transmitting a portion of the time (from 1/3 to 1/10) of the time during conversations.

TDMA installations offer substantial savings in base-station equipment, space, and maintenance, an important factor as cell sizes grow ever smaller.

TDMA is the most cost-effective technology for upgrading a current analog system to digital.

TDMA is the only technology that offers an efficient utilization of hierarchical cell structures (HCSs) offering pico, micro, and macrocells. HCSs allow coverage for the system to be tailored to support specific traffic and service needs. By using this approach, system capacities of more than 40-times AMPS can be achieved in a cost-efficient way.

Because of its inherent compatibility with FDMA analog systems, TDMA allows service compatibility with the use of dual-mode handsets.

Dual band 800/1900 MHz offers the following competitive advantages:

- Identical applications and services are provided to subscribers operating in both bands.

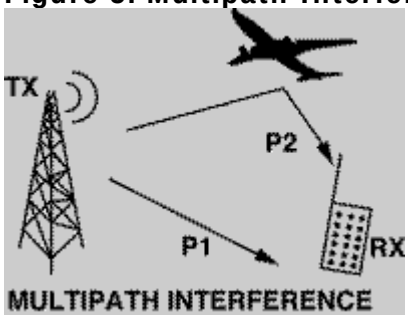
- Carriers can use the same switch for 800- and 1900-MHz services.
- Seamless interworking between 800- and 1900-MHz networks through dual-band/dual-mode phones.
- Using dual-mode, dual-band phones, subscribers on a TDMA 1,900 channel can hand off both to/from a TDMA channel on 800 MHz as well as to/from an analog AMPS channel

5. The Disadvantages of TDMA

One of the disadvantages of TDMA is that each user has a predefined time slot. However, users roaming from one cell to another are not allotted a time slot. Thus, if all the time slots in the next cell are already occupied, a call might well be disconnected. Likewise, if all the time slots in the cell in which a user happens to be in are already occupied, a user will not receive a dial tone.

Another problem with TDMA is that it is subjected to multipath distortion. A signal coming from a tower to a handset might come from any one of several directions. It might have bounced off several different buildings before arriving (see *Figure 5*) which can cause interference.

Figure 5. Multipath Interference



One way of getting around this interference is to put a time limit on the system. The system will be designed to receive, treat, and process a signal within a certain time limit. After the time limit has expired, the system ignores signals. The sensitivity of the system depends on how far it processes the multipath frequencies. Even at thousandths of seconds, these multipath signals cause problems.

All cellular architectures, whether microcell- or macrocell-based, have a unique set of propagation problems. Macrocells are particularly affected by multipath signal loss—a phenomenon usually occurring at the cell fringes where reflection and refraction may weaken or cancel a signal.

6. TDMA Versus CDMA

Since the introduction of CDMA in 1989, the wireless world has been occupied by a debate over the relative merits of TDMA and CDMA—a debate whose fervor makes it reminiscent, at times, of a religious debate.

The proponents of CDMA have claimed bandwidth efficiency of up to 13 times that of TDMA and between 20 to 40 times that of analog transmission. Moreover, they note that its spread-spectrum technology is both more secure and offers higher transmission quality than TDMA because of its increased resistance to multipath distortion.

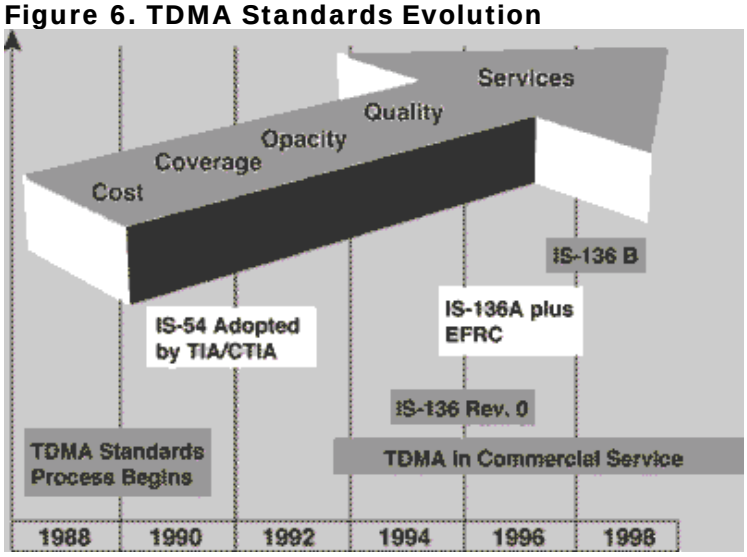
The defenders of TDMA, on the other hand, point out that to date there has been no successful major trial of CDMA technology that support the capacity claims. Moreover, they point out that the theoretical improvements in bandwidth efficiency claimed for CDMA are now being approached by enhancements to TDMA technology. The evolution of TDMA will allow capacity increases of 20 to 40 fold over analog in the near future. This combined with the vastly more expensive technology needed for CDMA ($300,000 per base station compared with $80,000 for TDMA) calls into question what real savings CDMA technology can offer. So far, IS–136 TDMA is the proven leader as the most economical digital migration path for an existing AMPS network.

We still lack the final word in this debate. However, it seems clear that for the near future at least, TDMA will remain the dominant technology in the wireless market.

7. The IS–136 Digital-Control Channel (DCCH): Features And Capabilities

The original TDMA standard was IS–54, introduced in 1988–89 by the Telecommunications Industry Association (TIA)/CTIA (see *Figure 6*). It inaugurated a feature set including authentication, calling-number ID, a message-waiting indicator (MWI), and voice privacy.

Figure 6. TDMA Standards Evolution



IS–54B was superseded in 1994 with the introduction IS–136 followed closely by revisions A and B.

IS–136 was backward compatible to IS–54B and included a DCCH and advanced features.

IS–136A upbanded IS–136 for seamless cellular service between the 800-MHz and 1,900-MHz frequency bands. In addition, it introduced over-the-air activation and programming services.

IS–136B includes a new range of services including broadcast SMS, packet data, etc.

Self-Test

1. The earliest versions of TDMA effectively _____ analog wireless carrying capacity.

    a. doubled

    b. tripled

    c. quadrupled

2. FDMA allocated ____ users per channel.

    a. 1

    b. 3

c. 6

d. 10

3. The basic cost for a TDMA base station is _____.

   a. $300,000

   b. $150,000

   c. $100,000

   d. $80,000

4. _____ allows handoff to/from an analog AMPS channel.

   a. CDMA

   b. TDMA

5. What technology has the longer handset battery life?

   a. TDMA

   b. CDMA

6. _____ enable users access to PCS–like services

   a. TDMA

   b. CDMA

   c. both

   d. neither

7. _____ technology depends on sending a unique key to a receiver.

   a. TDMA

   b. CDMA

8. Greater security is offered by _____.

   a. spread spectrum

   b. narrow spectrum

9. The most widely deployed digital technology at the present time is _____.

    a. TDMA

    b. CDMA

    c. FDMA

10. ETDMA allocates bandwidth _____.

    a. statically

    b. dynamically

Correct Answers

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Glossary

AMPS
advanced mobile-phone system

CDMA
code division multiple access

CTIA
Cellular Telecommunications Industry Association

DCCH
digital-control channel

ETMDA
extended time division multiple access

FDMA
frequency division multiple access

GSM
global system for mobile communications

HCS
hierarchical cell structure

JDC
Japanese digital cellular

MWI
message-waiting indicator

NADC
North American digital cellular

NAMPS
narrowband analog mobile-phone system

PCS
personal communications service

PDC
personal digital cellular

RF
radio frequency

SMS
short message service

TDMA
time division multiple access

TIA
Telecommunications Industry Association

VMAC
voice mobile attenuation code