REVIEW AND IMPLICATIONS OF TIME DIVISION MULTIPLE ACCESS TECHNIQUES FOR WIRELESS ENVIRONMENT SERVICES AND APPLICATIONS

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ABSTRACT

Time division multiple access (TDMA) is a channel access method for shared medium (usually radio) networks. It allows several users to share the same frequency channel by dividing the signal into different timeslots. The users transmit in rapid succession, one after the other, each using his own timeslot. This allows multiple stations to share the same transmission medium (e.g. radio frequency channel) while using only the part of its bandwidth they require. TDMA is used in the digital 2G cellular systems such as Global System for Mobile Communications (GSM), IS-136, Personal Digital Cellular (PDC) and iDEN, and in the Digital Enhanced Cordless Telecommunications (DECT) standard for portable phones. It is also used extensively in satellite systems, and combat-net radio systems. 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.

Key words: *Personal Digital Cellular (PDC), Global System for Mobile Communications (GSM), Digital Enhanced Cordless Telecommunications (DECT), Hierarchical Cell Structures (HCSs), Cellular Telecommunications Industry Association (CTIA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), Time Division Duplexing (TDD), North American Digital Cellular (NADC), Extended Time Division Multiple Access (ETDMA)*

1.INTRODUCTION

TDMA is a type of Time-division multiplexing, with the special point that instead of having one transmitter connected to one receiver, there are multiple transmitters. In the case of the *uplink* from a mobile phone to a base station this becomes particularly difficult because the mobile phone can move around and vary the *timing advance* required to make its transmission match the gap in transmission from its peers.

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[1][5][9].

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[11]-[17].

2.TDMA IN 3G SYSTEMS

Although most major 3G systems are primarily based upon CDMA, Time Division Duplexing (TDD), packet scheduling (dynamic TDMA) and packet oriented multiple access schemes are available in 3G form, combined with CDMA to take advantage of the benefits of both technologies.

While the most popular form of the UMTS 3G GSM system uses CDMA instead of TDMA, TDMA is combined with CDMA and Time Division Duplexing in two standard UMTS UTRA modes, UTRA TDD-HCR (better known as TD-CDMA), and UTRA TDD-LCR (better known as TD-SCDMA). In each mode, more than one handset may share a single time slot. UTRA TDD-HCR is used most commonly by UMTS-TDD to provide Internet access, whereas UTRA TDD-LCR provides some interoperability with the forthcoming Chinese 3G standard[5]-[6].

3. 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 1*.

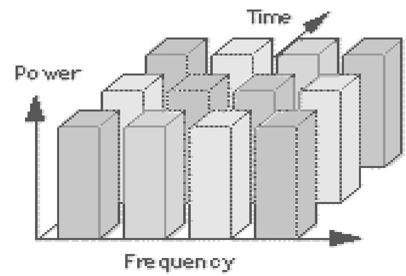

Figure 1. TDMA

Source: International engineering consortium

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 2* shows four different, simultaneous conversations occurring.

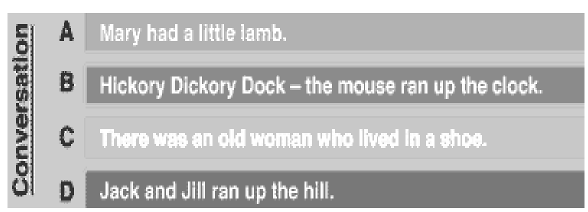

Figure 2. Four Conversations—Four Channels

Source: International engineering consortium

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 3*. After the conversation in time-slot four is transmitted, the process is repeated.

Figure 3. Four Conversations—One Channel

Source: International engineering consortium

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.

TDMA systems still rely on the switch to determine when to perform a handoff. Unlike the old analog system however, the switch does not do this in a vacuum. The TDMA handset constantly monitors the signals coming from other sites, and it reports this information to the switch without the caller being aware of it. The switch then uses this information to make better handoff choices at more appropriate times[20]-[24].

4. 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.

5. 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[12]-[19].

6.TDMA FEATURES

TDMA 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.

7. 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 which can cause interference.

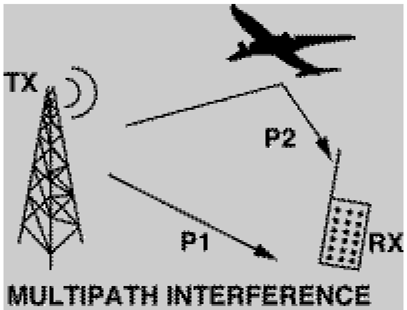

Figure 4. Multipath Interference

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[4][16][24].

8.COMPARISON WITH OTHER MULTIPLE-ACCESS SCHEMES

In radio systems, TDMA is usually used alongside Frequency-division multiple access (FDMA) and Frequency division duplex (FDD); the combination is referred to as FDMA/TDMA/FDD. This is the case in both GSM and IS-136 for example. Exceptions to this include the DECT and PHS micro-cellular systems, UMTS-TDD UMTS variant, and China's TD-SCDMA, which use Time Division duplexing, where different time slots are allocated for the base station and handsets on the same frequency.

A major advantage of TDMA is that the radio part of the mobile only needs to listen and broadcast for its own time slot. For the rest of the time, the mobile can carry out measurements on the network, detecting surrounding transmitters on different frequencies. This allows safe inter frequency handovers, something which is difficult in CDMA systems, not supported at all in IS-95 and supported through complex system additions in Universal Mobile Telecommunications System (UMTS). This in turn allows for co-existence of microcell layers with macrocell layers.

CDMA, by comparison, supports "soft hand-off" which allows a mobile phone to be in communication with up to 6 base stations simultaneously, a type of "same-frequency handover". The incoming packets are compared for quality, and the best one is selected. CDMA's "cell breathing" characteristic, where a terminal on the boundary of two congested cells will be unable to receive a clear signal, can often negate this advantage during peak periods[5]-[20]

9. DYNAMIC TDMA

In Dynamic Time Division Multiple Access, a scheduling algorithm dynamically reserves a variable number of time slots in each frame to variable bit-rate data streams, based on the traffic demand of each data stream. Dynamic TDMA is used in

- IEEE 802.16a WiMax
- Bluetooth
- The Packet radio multiple access (PRMA) method for combined circuit switched voice communication and packet data.

10. CONCLUSION

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.

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