UNIVERSITI PUTRA MALAYSIA

PERFORMANCE STUDIES OF MULTIMEDIA TRAFFIC IN CDMA CELLULAR NET\VORK

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FSKTM 1999 14

PERFORMANCE STUDIES OF MULTIMEDIA TRAFFIC IN CDMA CELLULAR NETWORK

By

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Thesis Submitted in Fulfilment of the Requirements for the Degree of Masters of Science in the Faculty of Computer Science and Information Technology, Universiti Putra Malaysia

February 1999

This thesis is dedicated to,

Accha and Amma ………………

ACKNOWLEDGEMENTS

I would like to sincerely thank my supervisors especially Associate Professor Dr. Ashwani Kumar Ramani for giving his undivided attention in showering me with wisdom and ideas for my work. Special thanks are due to Dr. Veeraraghawan Prakash from the Faculty of Engineering for the numerous discussions and suggestions. He has wilfully shared his knowledge and time in guiding my work. My immense debt is due to Ms. Shyamala Doraisamy who has been very patient and supportive with my work. My regards to Dr. Abdul Azim Abd. Ghani, Dean of the Faculty of Computer Science and Information Technology, Encik Azizol HJ. Abdullah, Head, Department of Networking and Communication technology and all the staff members of the faculty for their support.

I'm grateful to Elok Robert Tee for his generosity in letting me share his office and resources in doing my work. Thank you to all my friends who have directly or indirectly given me the encouragement to complete this work.

Finally, I would like to thank my parents who provided me with continual encouragement and support during this study.

February, 1999 *Madhavan*

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LIST OF ABBREVIATIONS

AMPS	Advance Mobile Phone System
ATM	Asynchronous Transfer Mode
BER	Bit Error Rate
BS	Base Station
CDMA	Code Division Multiple Access
D-AMPS	Digital Advance Mobile Phone System
DS-CDMA	Direct Sequence Code Division Multiple Access
FCFS	First Come First Serve
FDM	Frequency Division Modulation
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
GSM	Global Service for Mobile
IC	Integrated Circuit
IDWAN	Integrated Digital Wireless Access Network
MAC	Media Access Control
MHz	Megahertz
MS	Mobile Station
MSC	Mobile Switching Center
TDMA	Time Division Multiple Access
NA-TDMA	North American Time Division Multiple Access
NMT	Nordic Mobile Telephone
PN	Pseudonoise
PRMA	Packet Reservation Multiple Access
PSTN	Public Switched Telephone Network
RF	Radio Frequency
SNR	Signal to Noise Ratio
TACS	Total Access Communication Systems

Abstract of thesis presented to the Senate of the Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science.

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February 1999

Chairman: Associate Professor Ashwani Kumar Ramani, Ph.D.

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The current generation of wireless cellular network is mostly used for voice communication. Although data services such as short message services (SMS) are available, voice communication still takes precedence. However, in the near future, it is anticipated that wireless communication is expected to handle multimedia traffic that is currently available on land networks. Multimedia traffic includes video services such as real time video and audio, voice services and data services similar to the ones available in the Internet. The cellular network carrying multimedia traffic is analysed in a single cell where Code Division Multiple Access (CDMA) protocol is used for users to access the network simultaneously. The study is analysed for the reverse link communication, i.e., communication between the user and the base station. CDMA is used because of its merits in minimising the effect of interference, increasing cell capacity and high security features compared to other access technologies. The model inputs include co-channel interference, signal to noise ratio, bit error rate requirements, number of users, the channel access priority and threshold. Suitable assumptions to enable simulation are made. The model is simulated to see the impact of complementing data traffic along with voice and video traffic. The model is also simulated for synchronous transmission and asynchronous transmission of packets. The results shows that data traffic can be successfully complemented along with voice and video traffic without significantly degrading voice and video delay. Data traffic can tolerate delay but is loss sensitive. Data traffic delay can be used without suffering any loss, even by reducing the data access priority. The model also compared the effects of synchronous and asynchronous transmission. Synchronous transmission indicated an overhead in packet delay compared to asynchronous transmission. It is concluded from the work that voice, video and data traffic can be served in a cell simultaneously with asynchronous transmission. A higher bandwidth can assure a higher number of multimedia users in a asynchronous CDMA cellular network. The model will serve as a useful design tool.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

ANALISA RANGKAIAN CELLULAR CDMA MEMBAWA TRAFIK MULTIMEDIA

Oleh

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Februari 1999

Pengerusi: **Profesor Madya Ashwani Kumar Ramani, Ph.D.**

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Rangkaian komunikasi selular (bimbit) tanpa wayar masa kini, lazimnya digunakan untuk komunikasi suara. Walaupun perkhidmatan data seperti perkhidmatan mesej singkat wujud, komunikasi suara diberi keutamaan. Walau bagaimanapun, dijangka pada masa akan datang, komunikasi melalui udara mampu memberi perkhidmatan multimedia yang kini didapati pada rangkaian daratan. Perkhidmatan multimedia merangkumi video dan audio langsung, perkhidmatan suara dan juga perkhidmatan yang boleh diperolehi melalui internet. Analisis rangkaian multimedia yang menampung perkhidmatan multimedia dibuat dalam suasana sebuah sel di mana protokol "Code Division Multiple Access (CDMA)" digunakan untuk membolehkan pengguna memasuki rankaian tersebut secara serentak. Analisis ini dilakukan untuk komunikasi antara peggguna dan stesen tapak rangkaian. CDMA digunakan kerana kelebihannya mengurangkan kesan gangguan, meningkatkan kebolehan sel dan mempunyai ciri-ciri keselamatan yang ketat berbanding dengan teknologi laluan yang lain. Input untuk

model ini ialah ganguan antara pengguna, nisbah isyarat kepada bunyi, bilangan pengguna, keutamaan laluan dan saiz laluan serentak. Andaian yang sesuai dibuat untuk membolehkan simulasi dijalankan. Model ini disimulasi untuk memerhati kesan menyesuaikan perhidmatan data bersama perkhidmatan suara dan video. Ia juga disimulasikan untuk penghantaran berkala dan tak berkala. Keputusan menunjukkan bahawa perkhidmatan data boleh diselitkan bersama–sama perkhidmatan video dan suara tanpa mengganggu kelambatan dalam perkhidmatan video dan suara. Perkhidmatan data boleh menerima penangguhan tetapi sensitif terhadap kehilangan. Perkhidmatan data boleh digunakan tanpa menanggung sebarang kehilangan meskipun keutamaan data dikurangkan. Model ini juga membezakan transmisi berkala dan transmisi tidak berkala. Transmisi berkala menunjukan penambahan dalam kelambatan perkhidmatan video berbanding dengan transmisi tak berkala. Kesimpulannya ialah, perkhidmatan data, video dan suara dapat diberikan secara serentak dalam suasana sebuah sel secara tak berkala. "Bandwidth" yang lebih tinggi membolehkan lebih ramai pengguna menggunakan rangkaian selular tak berkala CDMA. Model in boleh digunakan sebagai satu alat rekabentuk yang berguna.

CHAPTER I

INTRODUCTION

The electronic wireless communication can be traced back since the time of Thomas Edison and Guglielmo Marconi about 100 years back. Early research on portable communication was carried out over 40 years ago by AT&T bell labs. In the 1960's, Motorola continued the task and came out with the first mobile cellular telephone service in the early 1980's (William W.E, 1993). With the advancement in semiconductor and IC packaging technology, a dramatic reduction in cost and size of communication equipment have boosted the wireless industry.

The first generation systems were cellular phones with wide area coverage. The others were residential cordless phones. Analogue FM voice signal was used. In the second generation, cellular phones with small cell (area) coverage were implemented. Each cell would communicate to the nearest base station. Cordless phones with expanded area coverage were introduced. Digital voice signal is used rather than the conventional analogue FM. In the third generation, a convergence of cellular, cordless and paging will be introduced which will develop the Integrated Digital wireless Access Network (IDWAN) (Alphna Doshi, 1997).

This generation of wireless communications will be strongly dominated by multimedia traffic. One of the most serious challenges is the design of an efficient and robust medium access control (MAC) protocol that can integrate heterogeneous traffic types and meet their requirement of quality of service. In the following section, we explain the currently available access protocols that are used in wireless communication.

Wireless Multiple Access Technologies

In wireless communication, there are several multiple access technologies such as FDMA, TDMA and CDMA.

Frequency Division Multiple Access (FDMA) is an access technology where every user needs a different frequency bands to access the network. It only needs a distinctive radio frequency for each user and the receiver has to only tune to that particular frequency. Since an analogue radio frequency (RF) is sent, this technology does not need a digitised speech decoder. This is a narrow-band technology.

The advantage of this technology is that it is simple and inexpensive as RF is used to propagate the signals. Terminal power amplifiers only needs to accommodate actual transmit power. The limitations of these technology is, it needs a radio transceiver unit in the base station for each voice channel. The allowable tolerance on the frequency source is less due to the narrow channel width. Because of this limitation, the bandwidth for this technology is limited and thus cannot support a large number of users.

Time Division Multiple Access (TDMA) is similar to FDMA except that each RF frequency is partitioned into time slots. With this technology, a single RF channel can carry multiple users where each user is assigned to their own time slots. The bandwidth per channel is now proportional to the number of time slots. Because a single RF may carry multiple users with different time slots, a digital speech coding is required.

Opposed to FDMA, TDMA requires less numbers of RF frequencies for a given voice circuit capacity. It also gives flexibility in providing capacity to individual users as slots are allocated to each user. Because time is slotted, an additional delay in the speech path is seen compared to FDMA. Bandwidth is also limited in this technology as interference is the main limitation.

Code Division Multiple Access (CDMA) is a spread spectrum technology where multiple users operate on the same band simultaneously but their signals are distinguished by being encoded with different high rate spreading sequences. In spread spectrum technology, signals are spread over a much wider frequency band than would ordinarily required by their information content.

The original information-bearing signal is combined with a pseudo-random signal. The end product of this resembles a white noise. This signal will appear to be background noise to conventional receivers. Only a receiver with the correct pseudo-random spreading code can recover the original user information.

Because of spread spectrum technology, the capacity of users is said to be unlimited (Shuzo Kato, 1997). The only limitation is not the technology but the electronic device and cost itself. The need for cell site frequency is eliminated, as no spectrum would be the same. The speech activity is said to be smoother compared to TDMA and FDMA architecture (Viterbi, 1995). Because it is still a new technology in the cellular (wireless) market, the performance is still very uncertain. Spread spectrum is a complex technology requiring sophisticated base-band digital processing.

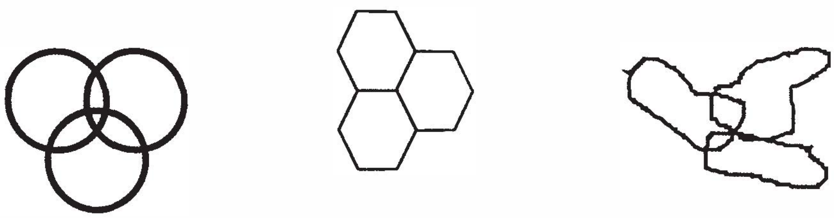
A summary of the comparison between these three access technologies is shown in Table 1.1.

Table 1.1: Comparisons of Access Technologies

	FDMA	**TDMA**	**CDMA**
Circuits per RF carrier	single	Multiple	Unlimited
Transmission	Continuous	Burst	Either
RF Bandwidth	Narrow	Medium/wide	very wide
Mobile Complexity	Low	High	High
Shared system cost	High	Low	Low

Cellular Technology

The cellular technology has provided a breakthrough in wireless communication by providing access to a large number of users. This is possible by reusing the same frequency in different geographical areas known as cells. The shape of a cell must be such that, the cells interlocking obtain the total coverage. Theoretically, the shape of the cell is hexagonal and this shape is assumed for planning and representation of cells on paper in order to simplify the situation when covering a specific area. But the actual cell shape is dependent on the topology of the geographical area itself and the radiation pattern of the transmitter's antenna (Yacoub, 1993). The different cell structures are shown in Figure 1.1. Each site services subscriber stations within a limited geographical area. When a subscriber moves between cells, over the air messaging is used to transfer control from the old cell to the new cell. This transfer of control is termed hand-off or hand-over.



IDEAL Hexagonal ACTUAL

Figure 1.1: Different Cell Structures

The original cellular system was called the Advanced Mobile Phone System, or AMPS. It is this system that was used throughout North America. Similar systems, with slight variations, are Nordic Mobile Telephone (NMT) in Scandinavia, and Total Access Communications System (TACS) used in the United Kingdom, China, and other countries. Spectral allocations are in the 800-900 MHz region.

Traditionally radio communication systems have separated users either by frequency channels, time slots, or both. These concepts dated back from the earliest days of radio. Even spark transmitters used resonant circuits to narrow the spectrum of their radiation. Scheduled net operation was probably the first manifestation of time slotting (John Escher, 1997). Modern cellular systems began with the use of channelised analogue FM. More recently several hybrid FDM-TDM digital systems have been developed extensively, to enhance service quality and capacity. In all these systems, each user is assigned a particular time-frequency slot. In large systems the assignments to the time-frequency slots cannot be unique. Slots must be reused in multiple cells in order to cover large service areas. Satisfactory performance in these systems depends critically on control of the mutual interference arising from the reuse. The reuse concept is familiar even in television broadcasting, where channels are not reused in adjacent cities.

CDMA offers an answer to the capacity problem. The key to its high capacity is the use of noise-like carrier waves, as was first suggested decades ago by Claude Shannon (Shannon C.E, 1949). Instead of partitioning either spectrum or time into disjoint "slots" each user is assigned a different instance of the noise carrier. While those waveforms are not rigorously orthogonal, they are nearly so. Practical application of this principle has always used digitally generated pseudo-noise, rather than true thermal noise. The basic benefits are preserved, and the transmitters and receivers are simplified because large portions can be implemented using high-density digital devices (Lathi B.P, 1998).

The major benefit of noise-like carriers is that the system sensitivity to interference is fundamentally altered. Traditional time or frequency slotted systems must be designed with a reuse ratio that satisfies the worst-case interference scenario, but only a small fraction of the users actually experience that worst-case. Use of noise-like carriers, with all users occupying the same spectrum makes the effective noise, the sum of all other-user signals. The receiver correlates its input with the desired noise carrier, enhancing the signal to noise ratio at the detector. The enhancement overcomes the summed noise enough to provide an adequate SNR (signal to noise ratio) at the detector. Because the interference is summed, the system is no longer sensitive to worst-case interference, but rather to average interference.

CDMA was initially used in American Army and not exposed to the public because of its high security features. Because this technology uses digital coded random signal for transmission, it was impossible for intruders to detect information transmitted in this form. This clearly indicates the advance security features of CDMA compared to other access schemes.

The demand for mobile communication has increased tremendously over the years. Although initially, voice communication was the only demand catered in wireless, now new services such as, video on demand, multimedia traffic is needed because of the mobility of wireless communication. This brings new challenges such as increased bandwidth allocation for mobile, servicing more users in constrained environment and catering for various traffic types.

Although there are several types of MAC protocol designed for CDMA system, they are typically not intended for a cellular structure. For example, the packet CDMA in (A. Sheikh, 1994) is intended for a mesh network of quasi-static users. On the other hand, those that are designed to take advantage of the cellular structure, such as, C-PRMA (G. Bianchi, 1994), R-ISMA (G. Wu, 1994) or PRAP (C.C. Lu, 1994), do not take advantage of the DS/CDMA scheme. In addition, protocols of the type DS/CDMA ALOHA (Z. Liu, 1994) were not designed and evaluated for the case of heterogeneous traffic. Thus, a suitable scheme has to be implemented to accommodate these various types of traffics. New challenges and the future direction of wireless data can be found in (Alphna Doshi, 1997).

Cellular Traffic

In a cellular network, data is transmitted in the form of frames. The duration (size) of a frame is dependent on the type of multiple access scheme used. Global Service for Mobile (GSM) and NA-TDMA uses a TDMA frame format. In GSM, the size of a frame is 4.615 ms. Each frame is further divided into 8 time slots. Each slot is 156 bits (0.577 ms). The frame structure is shown in Figure 1.2. There are also multiple frame structures such as multiframe (120ms), superframe (6.12 s) and hyperframe (3.48 h). A larger frame allows maximum throughput on the system but under noisy condition, a larger frame is prone to higher error rate. A suitable frame size has to be selected. Frames are usually divided into smaller blocks before being transmitted. This reduces the error rate due to large frame size.

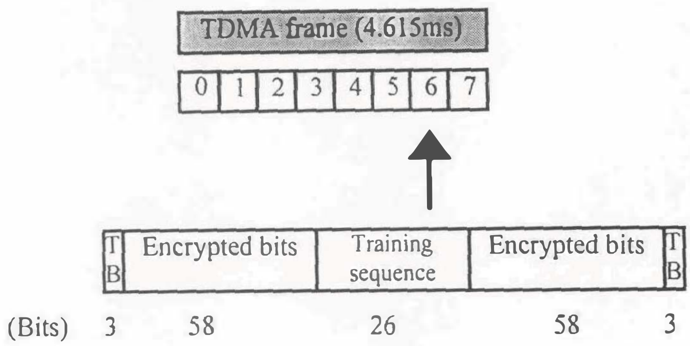


Figure 1.2: TDMA Frame Structure for GSM

For a reverse link CDMA channel, a variable data rate of 9600, 4800, 2400 or 1200 bps are available. All of these frame sizes are 20 ms. The size of information bits that can be carried by each frame is dependent on the data rate. The higher the data rate, the more information bits can be carried in a frame. A data rate of 9600 bps can carry 172 bits while a data rate of 1200 bps can carry 16 bits of information in a frame. The actual burst transmission rate is fixed at 28800 code symbols per second. With a higher transmission rate, more bits can be sent such as video streams.

The frame structure is shown in Figure 1.3. The contents of each frame are information bits (size dependent on bit rate), the corresponding forward CDMA channel (frame quality indicator) and tail bits (8 bits). Two different frame types were explained above but there are also other frame structures for different access protocols. TDMA frames are the most commonly used and they are divided into slots. Each frame has a fixed size. In CDMA however, although frame duration is constant (20 ms) but the information bits in each frame can vary depending on the available bit rate. Both protocols are able to handle high bit rate traffic such as video by expending their frame structure accordingly. Frame size in the form of ATM packets is also discussed in (A.J. Mueller, 1994).

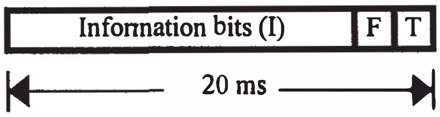


Figure 1.3: Frame Format for Reverse Link CDMA

In a mobile cellular network, traffic can be classified as transmission with high traffic rates and transmission with lower traffic rates. High rate traffic has a lower burst rate (such as video) and lower traffic rates has high burst rates (such as text). But video traffic is more tolerant to delay compared to voice traffic which is less tolerant. On the other hand, data traffic is highly loss sensitive and loss of data packet must be avoided. A buffer can mitigate the burstyness of video packet and a large buffer size can prevent the lost of data packet. A suitable scheme has to be adapted to these different traffic types, where different traffics have its own characteristics.

In this work, a cellular DS/CDMA network carrying multimedia traffic types is evaluated. An important feature of this MAC protocol is its simplicity. An outline of this protocol can be found in (Roman Pichna, 1995) for the case of two traffic types. The following section outlines the objectives of this work.

Research Objectives

The environment in a single cell with multiple users is studied. The CDMA protocol that can handle simultaneous users are assumed for this study. Transmission from the user to the base station is (reverse link) taken for this study. The primary goal of this research is to:

- Study the behaviour of the network with different traffic types such as data, voice and video. Although traffic can be categorised in different hybrids, these three traffic are most common.

- Study the different schemes in handling the multimedia traffic in terms of packet delay and blocking at the lowest level.

- Study the suitability of the service schemes by investigating the performance measures, obtained from the simulation.

- Study the effect of complementing data traffic along with voice and video traffic in the cell.

Organisation of Thesis

Chapter II presents the related literature reviewed in the concerned area. In this chapter the architecture of a basic cellular network is introduced. The