UNIVERSITI PUTRA MALAYSIA

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By

ABDUL HALIM ALI

Thesis Submitted in Partial Fulfilment of Requirements for the Degree of Master of Science in the Faculty of Engineering,
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To my wife Zahrah,

my sons Izzat, Idham, Irwan, Ahkmal

and

my daughter Fatayah

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LIST OF ABBREVIATIONS AND TERMINOLOGY

It is useful to define certain terminologies that will be used throughout this literature.

Call Blocking Probability	-	A new originating call made by the user to get access to the systems but blocked due to no availability of the traffic channel in the service area.
Calling Probability	-	The ratio of expected successful selective calls relative to the total numbers of attempts.
Force Termination Probability	-	An ongoing call been dropped due to the weak signal strength or unsuccessfully handoff due to no traffic channel available in the target service area.
Service Area	-	The area within which a radio system provides a satisfactory service.
Cell Size	-	The size of the service area where mobile can request for a service if there is any available traffic channel.
Microcell	-	The cell service area of the lower tier of the multitier network.
Macrocell	-	The cell service area of the higher tier of the multitier network.
Speed Sensitive	-	The class of mobile's mobility in the service area.
Carried Traffic	-	The amount of traffic request for service as compared to the offered traffic.
Delay	-	A queuing system before a handoff is granted.
GoS	-	Grade of Service
QoS	-	Quality of Service
C/I	-	Carrier to Interference Ratio

DCA	-	Dynamic Channel Allocation
LOS	-	Line of Sight
BS	-	Base Station
pdf	-	probability density function
SOS	-	Static Offset
DOS	-	Dynamic Offset

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

TELETRAFFIC PERFORMANCE OF HIERARCHICAL CELLULAR NETWORK IN DIFFERENT POPULATIONS OF SLOW MOBILE GENERATED TRAFFICS

By

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August 1999

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Faculty: Engineering

Ever since the first analogue mobile cellular was launched 15 years ago, the growth of and demand for the cellular communications have never reached its saturation stage. The technological change from analogue to digital and now the merging of cellular mobile and personal communications system (PCS) have already taken place. All of these changes will tremendously increase in the number of mobile communication users which leads to serious Quality of Service (QoS) problems. The objective of layered network architecture comprising a hierarchical layer of different cell sizes is to provide increased capacity and alternate routes for calls that may be otherwise blocked when parts of the network are congested. Thus, this configuration results in higher traffic capacity and improves the quality of service (QoS) of the network.

Today, teletraffic problems present a much greater challenge than when the first analogue mobile cellular was launched. The coming of hierarchical network makes it even more challenging to the network designers to design the hierarchical network structure that is able to cope with the huge growth of traffic and provide acceptable QoS to the customers at the same time. In this study two types of cell sizes were used whereby the upper layers are of large cell radius known as macrocells and the lower layers are of small cells radius size known as microcells. The hierarchical structure of cells serves two purposes. Firstly, the cells of small and large radius provide a more economically efficient system for higher and lower traffic densities, respectively, and secondly the subscribers of lower and higher mobility can efficiently be served in small and large cell radius, respectively.

Two types of users' mobility patterns within the layers were included in the model. They were fast mobile low traffic density users travelling at the speed of 9 m/s and slow mobile high traffic density moving at the speed of 1.5 m/s. These basically represent the vehicular and pedestrian traffic respectively. Three models for two different categories of slow mobile high traffic densities known as independent model, semi-interactive and fully-interactive model were simulated. They were analysed for 50% and 70% slow mobile high traffic densities.

Two main parameters have been chosen to measure the accuracy of the system via the probability of call blocking and forced termination that basically determine the QoS of a network. From this study, it was found that hierarchical networks should be considered when the slow mobile generated traffics population reaches 50% of the entire mobile populations in the service area.

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

PENCAPAIAN TELETRAFIK RANGKAIAN SELULAR BERTINGKAT DALAM POPULASI YANG BERBEZA BAGI PENJANAAN PERGERAKAN TRAFIK TAHAP RENDAH

Oleh

ABDUL HALIM BIN ALI

Ogos 1999

Pengerusi: **Profesor Madya Borhanuddin Mohd Ali, Ph.D**

Fakulti: **Kejuruteraan**

Pertumbuhan dan permintaan bagi komunikasi sel tidak pernah sampai tahap tepu sejak komunikasi sel yang ulung berteknologi analog dilancarkan 15 tahun yang lepas. Teknologinya sentiasa berubah dari analog ke digital dan dewasa ini penyatuan sel bergerak bersama sistem komunikasi peribadi telah pun bermula. Perubahan ini akan meningkatkan jumlah pengguna komunikasi bergerak yang akan menjadi punca utama masalah perkhidmatan yang berkualiti (QoS). Matlamat rekabentuk rangkaian bertingkat yang mengandungi pelbagai saiz sel di setiap tingkat untuk menambah keupayaan dan menyediakan laluan pilihan kepada panggilan-panggilan yang mungkin terhalang disebabkan oleh rangkaian sesak. Oleh itu rangkaian konfigurasi bentuk ini akan menghasilkan keupayaan trafik yang tinggi dan seterusnya meningkatkan perkhidmatan.

Kini permasalahan teletrafik amat mencabar berbanding dengan sel bergerak analog yang pertama dahulu. Kedatangan rangkaian bertingkat akan memberi lebih cabaran kepada pereka rangkaian bagi merekabentuk struktur rangkaian bertingkat yang boleh mengendalikan pertumbuhan pesat pengguna dan menyediakan perkhidmatan yang berkualiti (QoS) kepada pengguna. Dalam kajian ini dua jenis saiz sel digunakan di mana lapisan atas adalah sel berjejari besar yang dikenali sebagai sel makro dan lapisan bawah adalah sel berjejari kecil yang dikenali sebagai sel mikro. Sel struktur bertingkat digunakan dengan dua sebab, pertamanya sel berjejari kecil dan besar dapat menyediakan sistem penjimatan yang cekap bagi trafik yang tinggi dan rendah ketumpatannya. Kedua, pengguna yang bergerak pada kelajuan tinggi dan rendah boleh dilayan masing-masing oleh kedua-dua sel berjejari kecil and besar.

Dua jenis bentuk pergerakan pengguna dimasukkan ke dalam model tersebut iaitu pergerakan pengguna pada tahap tinggi ketumpatan trafik rendah yang kelajuannya pada 9 m/s dan pergerakan pengguna pada tahap rendah ketumpatan trafik tinggi yang kelajuannya pada 1.5 m/s. Kedua-dua pergerakan ini mewakili trafik berkenderaan dan pejalan kaki. Tiga jenis model dalam dua keadaan kebolegerakan pengguna pada kelajuan rendah ketumpatan trafik tinggi yang berbeza telah disimulasi. Model ini dikenali sebagai model bersendiri (jenis I), model separa-saling tindak (jenis II) dan model saling tindak penuh (jenis III). Ketiga-tiga model ini dianalisa bagi peratusan 50 dan 70 peratus pada kebolegerakan pengguna pada kelajuan rendah ketumpatan trafik tinggi.

Dua parameter utama telah dipilih untuk menyukat ketepatan sistem, kebarangkalian panggilan sekat dan penamatan paksaan, yang secara asasnya menentukan kualiti perkhidmatan. Daripada kajian tersebut didapati rangkaian bertingkat boleh digunakan bila populasi trafik pergerakan kelajuan rendah mencapai 50% daripada keseluruhan populasi trafik di dalam kawasan perkhidmatan.

CHAPTER I

INTRODUCTION

Background

Unlike fixed network, a wireless network must support customers on the move. User mobility, the increasing demand on channel traffic and the evolution of wireless networks toward personal communication systems (PCS) are the major challenges to system designers.

A layered network architecture comprises a hierarchical layer of cells to provide increased traffic capacity and alternate routes for calls that may be otherwise blocked when network are congested when a single cell is used. The two-tier PCS system integrates the high tier PCS system and the low tier PCS systems into a single system to provide advantages for both tiers. Such systems are expected to provide better grade of service (GoS), increase in channel traffic and more cost effectiveness to both the operators and users at the expense of the extra tier switching management.

The introduction of low tier into high tier makes efficient use of frequency spectrum by means of frequency re-use. Frequency planning is another important factor to avoid any co-channel interference. In hierarchical networks, a low tier having small cell sizes is known as microcell and a high tier having larger cell sizes is known as macrocell. Each macrocell overlay a number of microcells. The smaller the size of microcells the larger the number of the microcells overlaid under macrocells. As the cell size becomes smaller the number of handoffs increases. To maintain the user's radio link when the mobile moves from one cell to another is the main service features to determine the grade of service. The mobility of users from one cell to another in maintaining the radio link is a process known as handoffs.

Handoffs

Effective handoff strategies are essential for the proper functioning of a cellular mobile network. A satisfactory handoff scheme needs consideration in three key areas; propagation, traffic and switching and processing. This means that a neighbouring base station (BS) should have free traffic channel and sufficient signal quality for transmission and that the handoff calls should be executed before any significant deterioration to the existing signal occurs. Jabbari and Fuhrmann (1997), Hong and Rappaport (1986), Fitzpatrick et.al. (1997) and Rappaport (1993), agreed that the probability of forced termination is an important feature to determine the GoS of a system. Various handoff models have been proposed to minimise the probability of forced terminations. These models provide better understanding of handoff performances. The followings are the general view of four handoff model schemes: -

1. The non-prioritised scheme (NPS)
2. The prioritised scheme (PS)
3. The first in first out (FIFO)
4. The measurement based priority scheme (MBPS)

The Non-Prioritised Scheme (NPS)

The cell handles a handoff calls exactly the same as new originating calls. The handoff will immediately forced terminate when there is no channel available.

The Prioritised Scheme (PS)

The cells have reserved a number of channel traffics for the purpose of handoffs. This increases the new calls blocking but improve the probability of forced terminations.

First-In-First -Out Scheme (FIFO)

The scheme is based on the adjacent cells in a network overlapping each other. The area of overlapping is known as handoff areas. The period when the mobile enters the handoff area is referred to as the degradation interval and the priority will be given to the mobile in this area for handoff rather than a new originating call.

Measured-Based Priority Scheme (MBPS)

The scheme is similar to the FIFO model except for the queuing policy. The priorities are defined by the power strength received by the mobile. The handoff area is the region marked by different ranges of the power ratio. The handoff calls receive higher priority if the power ratio is closer to expiration and determined by the network.

Overview

Many approaches have been used to analyze a hierarchically layered cellular network. Rappaport and Hu (1994) used Poisson traffic stream model while Cimini and

Foschini (1993) used Interrupted Poisson process and the Hayward approximation is used by Baiocchiz et.al. (1995).

Hong and Rappaport (1986) proposed an analytical model assuming exponentially distributed degradation intervals. The traffic model was based on a special mobile movement pattern by a Poisson process. Lin et.al. (1994) proposed traffic model based on arbitrary mobile patterns and employed the proposed residual times by Wong (1993) to derive the exact values of the force termination probability.

Tekinay and Jabbari (1992) proposed a similar analytic model assuming normal distribution degradation intervals. The system was modelled by a Markov chain. They considered the handoff traffic as an independent input parameter. In reality the handoff is affected by the mobile mobility, the call holding time distribution and the originating call traffic.

All the proposed model above are based on interarrival rate of new originating call, handoffs, mobility and call holding time. Propagation, traffic, switching and processing are all important factors determining the teletraffic performances. Most research works focused only one factor at a time. The interdependent studies of combined parameters that simulate the real environment is an interesting area of study. None of these authors studied on the combined issues on the teletraffic performances except for Senarath and Everitt (1996). They proposed a model based on Poisson arrivals with negative exponential on a combined platform on a single layer microcell size network architecture rather than a multi-layer architecture network. The teletraffic performances based on interdependency parameters have been extensively studied.

Method of Study

The coming of the third generation mobile and the merging of cellular and PCS requires high traffic channels capacity. An alternative method to increase the traffic capacity is by using multitier architecture network. Not many literatures have been published which are related to multi-layer architecture.

The primary emphasis of this study was to analyse the teletraffic performance of a multi-layer architecture network. Two layered network architecture was assumed. The overflow and handoff calls between layers in both directions were included. From the simulations the optimum value between GoS and the microcellular cell size could be chosen. Which provide optimum utilisation of a system, better probabilities of new calls blocking and forced termination. The model proposed by Jabbari and Fuhrmann (1997) was used extensively in this study.

Chapter II gives the overview of the multi-layer cellular systems and call and handoff admission strategies. It analysed the sharing of available resources between the layers. The cell size, frequency planning and channel assignments were among the main factors considered in designing the multitier cellular systems. In this chapter, a brief discussion on reversible and non-reversible traffic in multi-layer systems was presented.

In Chapter III, using a fluid flow mobility model, a simulation model that is applicable to predict the teletraffic performance of a multitier cellular network was developed. This chapter describes the basic analytical model developed by Jabbari and Fuhrmann (1997) and presented the flow diagram of how simulation takes place.

Chapter IV presented the graphical results of the teletraffic performance. Two percentage users of slow mobility pattern were presented; 50% and 70% slow mobile.

Using realistic values it was found that high percentage slow mobile user experienced large increases in handoff rates. Chapter V summarised the numerical results of the simulation model and presented the conclusions and recommendations of the optimum value of the multitier cellular network.

CHAPTER II

MULTI-LAYER CELLULAR SYSTEMS

Introduction

There are over 80 million mobile subscribers world-wide, ever since the first analogue mobile system was launched 15 years ago (Lagrange, 1997). With an average annual growth of 40 percent world-wide, the forecasts of mobile subscribers by year 2001 will be more than 590 million (Madfors, 1997). As the mobile users grow rapidly in a short period of time, demands of high quality of services (QoS) and the need of large service area coverage are important agendas to the cellular operators.

There are several methods that have been proposed to meet the tremendous growth of cellular subscribers. They are cell splitting, frequency hopping and reuse partitioning, respectively. However, the above methods rely entirely on the concept of macrocell and a single layer cellular network. To further increase the traffic channel capacity and to improve the GoS, a multi-layer network has been a subject of study of Chih et.al, (1993), Cimini and Foschini (1993), Rappaport and Hu, (1994), Fitzpatrick et.al., (1997) and Jabbari and Fuhrmann, (1997). A multi-layer network is a network with different layers of cell sizes integrated into a single system. For example, the network may consist of macrocells at the upper layer, microcells at the lower layer and picocells at indoor layer. Extension of layers could be made later when the need arises or a new system is introduced. In the case of Iridium networks, an additional layer by satellites may provide world-wide global services. The integration of these layers provides better GoS. The microcell coverage is used to overcome hot spot and high density cellular subscribers area. It is well known that as the cell becomes smaller the handoff rates increase proportionately and this would lead to poor teletraffic performance. It is important to determine the functions of each layer of the systems. The high-traffic density are basically generated by the low mobility users (e.g. pedestrian); they are dedicated for microcells, whereas low-traffic density are generated by high-mobility users (e.g. vehicular traffic) catered by macrocells. This algorithm is important to avoid excessive handoff rates. The higher the handoff rates are, the worst the GoS is. To reduce forced termination, handoff calls are given priority to access the traffic channel in both macrocell and microcell layers.

Multi-layer network architecture is shown in Figure 1. The use of microcells improves the transmission quality, provides flexibility in teletraffic and significantly increases system capacity without generating too much interference due to their low transmitting power, low antenna height and small coverage area. Above all, the overlaying macrocells enhance spectrum coverage at low costs demonstrating the advantages of resource sharing between layers.