



UNIVERSITI PUTRA MALAYSIA

**PERFORMANCE MODELLING FOR MOBILE
CELLULAR NETWORK USING QUEUEING SYSTEM**

HUSSEIN MUZAHIM AZIZ BASI

FSKTM 1999 13

**PERFORMANCE MODELLING FOR MOBILE
CELLULAR NETWORK USING QUEUEING SYSTEM**

HUSSEIN MUZAHIM AZIZ BASI

**MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA**

1999



**PERFORMANCE MODELLING FOR MOBILE CELLULAR
NETWORK USING QUEUEING SYSTEM**

By

HUSSEIN MUZAHIM AZIZ BASI

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

March 1999



In the name of Allah, Most Gracious, Most Merciful

Proclaim! (or read) in the name of thy Lord and Cherisher, who
created (1), Created man, out of a (mere) clot of congealed blood (2)
Proclaim! And thy Lord Most Bountiful (3), He Who taught (the use of)
the pen (4), Taught man that which he knew not.

Surat Al-Alaq (The Clot)

To my Family



ACKNOWLEDGEMENTS

In the Name of Allah, Most Gracious, Most Merciful

It is my pleasure to take this opportunity to convey my sincere thanks and sincere gratitude to my supervisor Associate Professor Dr. A. K. Ramani who introduce me to the field of computer networks. I am also grateful to my co-supervisors Dr. Md. Yazid Mohd. and Ms. Shyamala Doraisamy for their kind support, help and guidance. I am really touched by Dr. Ramani and indeed grateful to him for having taken so much of his valuable time for studying, correcting and restructuring my work.

I would like to convey my sincere appreciation to the staff members of Faculty of Computer Science and Information Technology, the University Library, the Graduate School Office, and the Laboratories Technicians.

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 express my most sincere and warmest gratitude to my father Professor Dr. Muzahim A. Basi, mother Md. Basi, brothers; Firas, Azwer, and my sister Hala. For their prayers, love, generous moral and financial support during my study.

Date: February 1999

Hussein Basi



TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF ABBREVIATIONS	xiv
ABSTRACT	xvi
ABSTRAK	xviii
 CHAPTER	
I INTRODUCTION	1
Personal Communications System	1
Cellular System	3
Mobile Wireless Network	5
Mobile cellular Concept	8
The Theory of Cellular Pattern	10
Co-Channel Interference	12
Cell Splitting	15
The Basic Components of A Cellular Mobile System	17
Mobile Station	17
Base Station	17
Mobile Switching Centre	19
Public Switched Telephone Network	19
Objective of the Research	20
Organisation of the Thesis	21



II	LITERATURE REVIEW	23
	Channel Assignment	24
	Fixed Channel Allocation (FCA)	25
	Dynamic Channel Allocation (DCA)	26
	Hybrid Channel Assignment (HCA)	26
	Channel Sharing	27
	Channel Borrowing	27
	Multiplexing Methods	28
	Frequency Division Multiple Access	28
	Time Division Multiple Access	30
	Air Interface Functionality	33
	Frequency Planning	33
	Numbering the Channels	36
	Voice transmission	37
	Signaling Channels	39
	System Overhead Message Channel	39
	Set-up Channels	40
	Access Channel	41
	Paging Channel	42
	Mobility Management in Cellular Systems	43
	System Access	47
	Registration	51
	Location Areas	54
	Handoff	55
	Roaming	59
	Traffic Intensity and Grade of Service	61
	Outage Channels	63
	Summary	66



III	METHODOLOGY	67
	The Models Description	70
	Discussion of Results	76
	Summary	76
IV	MODEL DEVELOPMENT	78
	The Large Cellular Systems with Queueing	78
	Queueing System	80
	The Outage with Queueing	82
	The Proposed System Analysis	84
	Fixed Outage Rate (Model-1)	85
	Traffic Dependent Outage (Model-2)	91
	Summary	94
V	RESULTS AND DISCUSSIONS	95
	Fixed Outage Rate (Model-1)	97
	Traffic Dependent Outage (Model-2)	111
	Small Cellular System	124
	The Comparison for Large Models	136
	Summary of Results	140
VI	CONCLUSIONS AND FURTHER RESEARCH	142
	Further Research	146
	REFERENCES	147
	APPENDICES	151
	A The Derivation of Queue Length and Waiting Time	152
	B The Derivation of Probability of Delay	155
	VITA	157



LIST OF TABLES

Table		Page
1.1	Traffic Capacity and Cochannel Interference.....	15



LIST OF FIGURES

Figure		Page
1.1	Frequency reuse in a cellular system	9
1.2	Common configuration of cellular patterns: (a) 1- cell cluster; (b) 3-cellcluster; (c) 4-cell cluster (the center cell is common to cluster); (d) 7-cell cluster; (e)12-cell cluster	11
1.3	Co-channel cell separations for different clusters: (a) 1- cell clusters;(b) 3- cell clusters; (c) 4- cell clusters; (d) 7- cell clusters; (e)12- cell clusters.	14
1.4	Cell Splitting	16
1.5	Overview of a cellular network	18
2.1	Demand allocation of channels on an FDMA basis.	29
2.2	A TDMA mode of operation: each channel groups eight subscribers (A to H), who send (and receive) messages as bursts. The number of base station transmitters is equal to the number of groups.	31
2.3	The frame, time slots, and messages relationship in TDMA	32
2.4	Frequency grid where patterns are: (a) 7 pattern. (b) 12 pattern	35
2.5	TIA cellular-network reference model	44
2.6	Call-origination message sequence.	48
2.7	Page-message sequence for terminating call on a subscriber station.	50
2.8	Page and page response for incoming call	51



2.9	Handoff (a) Cochannel interference reduction ratio Q. (b) Fill in frequencies.	57
3.1	Outage parameter Markov chain.	68
3.2	State- transition diagram for the one-dimensional birth-death process.	71
4.1	Markov chain model having k channels in outage	84
5.1	PB versus traffic intensity for different values of the system's outage probability, where number of channels 10 & $k=8$	96
5.2	PB versus different outage channel where outage probability is 10%	97
5.3	P_Q versus traffic intensity for different outage probability, $k = 3$.	100
5.4	P_Q versus traffic intensity for $k = 3,5,7$ as Pos 5%	101
5.5	P_Q versus traffic intensity for $k = 3,5,7$ as Pos 10%	101
5.6	P_Q versus traffic intensity for $k = 3,5,7$ as Pos 20%	102
5.7	P_Q versus different outage channels under different outage probability	102
5.8	P_W versus traffic intensity for different outage probability, $k = 3$.	104
5.9	P_W versus traffic intensity for $k = 3,5,7$ as Pos 5%	105
5.10	P_W versus traffic intensity for $k = 3,5,7$ as Pos is 10%	105
5.11	P_W versus traffic intensity for $k = 3,5,7$ as Pos 20%	106
5.12	P_W versus different outage channels under different outage probability	106
5.13	P_D versus traffic intensity for different outage probability, $k = 8$.	108



5.14	P_D versus traffic intensity for $k = 2,4,6,8$ as Pos 5%	109
5.15	P_D versus traffic intensity for $k = 2,4,6,8$ as Pos 10%	109
5.16	P_D versus traffic intensity for $k = 2,4,6,8$ as Pos 20%	110
5.17	P_D versus different outage channel under different outage probability	110
5.18	P_Q versus traffic intensity for different outage probability, $k = 3$..	113
5.19	P_Q versus traffic intensity for $k = 3,5,7$ as Pos 5%	114
5.20	P_Q versus traffic intensity for $k = 3,5,7$ as Pos 10%	114
5.21	P_Q versus traffic intensity for $k = 3,5,7$ as Pos 20%	115
5.22	P_Q versus different outage channels under different outage probability	115
5.23	P_W versus traffic intensity for different outage probability, $k = 3$..	117
5.24	P_W versus traffic intensity for $k = 3,5,7$ as Pos 5%	117
5.25	P_W versus traffic intensity for $k = 3,5,7$ as 10%	118
5.26	P_W versus traffic intensity for $k = 3,5,7$ as 20%	118
5.27	P_W versus different outage channels under different outage probability	119
5.28	P_D versus traffic intensity for different outage probability, $k = 8$..	121
5.29	P_D versus traffic intensity for $k = 2,4,6,8$ as Pos 5%	121
5.30	P_D versus traffic intensity for $k = 2,4,6,8$ as Pos 10%	122



5.31	P_D versus traffic intensity for $k = 2,4,6,8$ as Pos 20%	122
5.32	P_D versus different outage channels under different outage probability	123
5.33	P_Q versus traffic for different outage probability, $k=2$	126
5.34	P_Q versus traffic for $k=1,2,3$ as Pos 5%	126
5.35	P_Q versus traffic for $k=1,2,3$ as Pos 10%	127
5.36	P_Q versus traffic for $k=1,2,3$ as Pos 20%	127
5.37	P_Q versus different outage channels under different outage probability	128
5.38	P_W versus traffic intensity for different outage probability, $k = 2$.	129
5.39	P_W versus traffic intensity for $k= 1,2,3$ as Pos 5%	130
5.40	P_W versus traffic intensity for $k= 1,2,3$ as Pos 10%	130
5.41	P_W versus traffic intensity for $k= 1,2,3$ as Pos 20%	131
5.42	P_W versus different outage channels under different outage probability	131
5.43	P_D versus traffic intensity for different outage probability, $k = 2$.	133
5.44	P_D versus traffic intensity for $k =1,2,3$ as Pos 5%	133
5.45	P_D versus traffic intensity for $k =1,2,3$ as Pos 10%	134
5.46	P_D versus traffic intensity for $k =1,2,3$ as Pos 20%	134



5.47	P_d versus different outage channel under different outage probability	135
5.48	P_d for different models, Pos 5%	137
5.49	P_d for different models, Pos 20%	138
5.50	Probability between blocked calls and blocked calls delay versus different outage channel in the system, Pos 5%	139
5.51	Probability between blocked calls and blocked calls delay versus different outage channel in the system, Pos 20%	139



LIST OF ABBREVIATIONS

AC	Authentication center
BS	Base station
CGSA	Cellular geographic serving areas
DCA	Dynamic channel allocation
ESN	Electronic serial number
EIR	Equipment identity register
FCA	Fixed channel allocation
FCFS	First come first served
FIFO	First in first out
FOCC	Forward set-up channel
FCC	Federal communications commission
FDMA	Frequency division multiple access
GOS	Grade of service
HLR	Home location register
HCA	Hybrid channel assignment
MAC	Media access control
MSC	Mobile switching center
MS	Mobile station
MIN	Mobile identification number



PSTN	Public switched telephone network
RBS	Radio base station
SAT	Supervisory audio tone
SID	Home system identity
SS	Subscriber station
TDMA	Time division multiple access
TIA	Telecommunications Industry Association
VLR	Visitor location register



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

**PERFORMANCE MODELLING FOR MOBILE CELLULAR NETWORK
USING QUEUEING SYSTEM**

By

HUSSEIN MUZAHIM AZIZ BASI

March 1999

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

Faculty : Computer Science and Information Technology

Mobile networking technology has been in existence for more than twenty years, but only in the past decade has it become commercially popular. With computers however increasingly portable and networks more accessible, users are coming demanding to the same network services from mobile network as they have been accustomed to obtaining from stationary wireline networks. Mobile communication can be defined as any communications network in which at least one of the constituent entities (users, switches, or a combination of both) change location, relative one to another.

One of the most important problems in the design of a cellular system is deciding on the optimal configuration of it. The designers must evaluate the possible configurations of the system components and their characteristics in order to develop a system with greater efficiency. The parameters useful to measure



different parts performance of the system are: voice quality, frequency spectrum efficiency and grade of service (GOS).

The grade of service (GOS) gives a form to measure a system's performance, and with it the proportion of non-served calls can be known. GOS in cellular systems is effected not only by the systems traffic but also by cochannel interference (outage).

In this thesis, the analytical study of the grade of service (GOS) degradation in presence of outage for the mobile communication with queueing system is wanted.

Two analytical models are proposed, the first model is with fixed outage rate, while the second model is the traffic dependent outage, where the outage is often dependent on the number of channels in use. Thus, the number of channels in outage can be considered as an indicator of the traffic load variations in the system.

The performance parameters considered for the study from the above models are queue length, waiting time and probability of delay. The analytical results can show the benefit for considering the queueing in the cellular network, and can be used by designers in choosing appropriate design parameters to meet requirements.



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

**PEMODELAN PRESTASI BAGI RANGKAIAN BERSEL BIMBIT
DENGAN SISTEM BERGILIR**

Oleh

HUSSEIN MUZAHIM AZIZ BASI

Mac 1999

Penyelia : Prof. Madya Ashwani. K. Ramani, Ph. D.

Fakulti : Sains Komputer dan Teknologi Maklumat

Teknologi rangkaian bimbit telah wujud lebih dari dua puluh tahun, tetapi hanya pada dekad yang lepas ia telah menjadi popular secara kormesial. Dengan komputer menjadi semakin mudahalih dan rangkaian lebih senang dicapai, pengguna-pengguna mula menuntut perkhidmatan dari rangkaian bimbit sebagaimana yang mereka telah biasa perolehi dari rangkaian tetap. Komunikasi perhubungan boleh ditakrif sebagai mana-mana rangkaian perhubungan di mana sekurang-kurangnya satu daripada entiti-entiti terangkum (pengguna, suis, atau komunikasi kedua-duanya) berubah lokasi, relatif kepada satu dengan lain:

Satu daripada masalah yang paling penting dalam rekabentuk sistem bersel ialah dalam penentuan konfigurasi optimanya. Perrekabentuk perlu menilai semua konfigurasi yang mungkin bagi komponen-komponen sistem dan ciri-cirinya bagi membangunkan sistem dengan kecekapan yang lebih tinggi. Parameter-parameter



yang berguna bagi mengukur prestasi bahagian-bahagian sistem ialah : mutu suara, kecekapan spektrum frekuensi dan gred perkhidmatan (GP).

GP memberi satu kaedah bagi mengukur prestasi sistem, dan dengannya bilangan panggilan tak dilayan dapat diketahui. Bukan sahaja kesesakan sistem malah gangguan saluran bersebelahan (outej) juga memberi kesan kepada GP sistem bersel. Di dalam tesis ini, kajian beranalitik bagi kemelesetan GP dengan kehadiran outej bagi perhubungan bimbit dijalankan mengguna sistem berbaris gilr. Dua model analitikal dicadang, yang pertama dengan kadar outej tetap, manakala model yang kedua ialah outej bergantung kepada kesesakan, di mana outej kerap kali bergantung kepada bilapan saluran dalam penggunaan. Maka, bilangan saluran dalam outej boleh dipertimbangkan sebagai satu petanda bagi perubahan muatan kesesakan dalam sistem.

Parameter-parameter prestasi yang dipertimbangkan dalam kajian dengan model-model di atas ialah panjang giliran, masa penungguan dan kebarangkalian kelewatan. Keputusan analitikal boleh memberikan satu nilai kuantitatif untuk kelebihan bagi mempertimbangkan giliran dalam rangkaian bersel, dan boleh diguna oleh pereka bentuk dalam memilih rekabentuk parameter-parameter yang bersesuaian bagi memenuhi keperluan.

CHAPTER I

INTRODUCTION

Personal Communications System

James Clerk Maxwell, a professor of physics at Cambridge University, established the possibility of radio communications in 1864. Maxwell showed theoretically that an electrical disturbance, propagating at the speed of light, could produce an effect at a distance. Hertz, who demonstrated spark-gap communications over distances of several feet in the 1880s, first put theory into practice (Garry, 1993). Marconi, who by 1901 succeeded in transmitting Morse code across the Atlantic oceans, rapidly extended the distance. The vacuum tube made speed transmissions practical and by 1915 the American Telephone and Telegraph Company had sent speech transmissions from Washington, D.C., to Paris and Honolulu (Brailean, 1991). The first practical mobile communications occurred in 1928 when the Detroit Police Department finally succeeded in solving the instability and low sensitivity problems that had plagued their mobile receiver designs for seven years.



By 1933, a mobile transmitter had been developed, allowing the first two-way police system operates in Bayonne, New Jersey (Gregory, 1993).

The personal communications has become a hot topic, not because it is so revolutionary, but because growth in mobile telephone demand has reached a dynamic turning point.

In 1991 the policy statement (FCC), recommended that the substantial spectrum should be allocated to personal communications. The service should be defined broadly to include a whole family of related services. For instance, personal communications could include a public two-way voice service, a data service, or wireless (Gregory, 1993). This definition issue has been hotly debated in the telecommunications industry, and the definition any particular party sets forth depends in large part on what that party would do with the spectrum if it were a licensee. Because of the absence of a strong of consensus from industry, the trend has been to provide greater flexibility to licensees to provide different services. This flexibility allows licensees to respond quickly to consumer needs and allows licensees to use spectrum efficiently (Allen, 1993).

As is always true when existing users may have to vacate spectrum, the proposal is quite controversial in the point-to-point microwave community.

A significant factor in the need to move existing users is whether an overlay technology, such as spread spectrum, can coexist in the same spectrum with point-to-point microwave users (Gregory, 1993).

Personal communications was mentioned as one of the first beneficiaries of the new reserve. The reserve is 220 MHz of spectrum in the 1.8 to 2.2 GHz ranges. The existing licensees of this proposed reserve spectrum are mostly private and common carrier point-to-point microwave users.

Users vary from state and local governments, public utilities to cellular carriers and local and long distance telephone companies (William, 1989).

Interest in instituting personal communications has been sparked internationally as well. The visionaries see personal communications as a service, which can be used at, home, at work, etc. . With personal communications, people will call people, not places; building on the foundation set by cellular.

Cellular System

The most relevant history to the development of personal communications lies with the development of cellular service. Cellular was developed in the United States in the 1940s at Bell Laboratories (John, 1990).



There was no significant move to allocate spectrum for mobile telephone until 1968. Much of the reason for this delay was due to a policy battle with broadcasters who sought to retain control over the 800/900 MHz band (Gregory, 1993).

Broadcasters continued to fight the reallocation of spectrum. Private radio and public mobile telephone interests battled for what they viewed as their share of the spectrum. In 1970, the Federal Communications Commission (FCC) allocated 154 MHz of spectrum 806-960 MHz, to cellular and private radio services. Forty MHz of this spectrum was allocated to cellular (Gregory, 1993).

In 1981, the spectrum is split up the 40 MHz into two equal blocks to be allocated to a wireline carrier, or Telephone Company, and a nonwireline carriers in each metropolitan market. Also they felt that a minimum of 20 MHz was required to prove a viable service using frequency reuse techniques (John, 1990).

The cellular spectrum is allocated to the wireline telephone companies, granting a monopoly in any particular market. This proposal was extremely controversial, being challenged by many parties who sought to make open entry a reality. At this time, the demand for cellular service was not known and the technology was untested. At & T, for example, predicted that there would be 105,000 two-way customers nationwide by 1990 (Gregory, 1993).