



**AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING**

Electronics and Communication Engineering Department

**Wireless Network Traffic Modeling for Different  
Channel Holding Time Probability Distributions**

**A Thesis**

**Submitted in Partial Fulfillment of the Requirements  
For the Degree of Master of Science in Electrical Engineering  
(Electronics and Communication Engineering)**

Submitted By

**Eng. Fadi Hassan Ahmed El-Ghitani**

Supervised By

**Prof. Dr. Hadya El-Hennawy**

**Associate Prof. Dr. Hesham El-Badawy**

**Cairo – Egypt**

**2012**



**AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING**

Electronics and Communication Engineering Department

**Examiners Committee**

**Name:** Fadi Hassan Ahmed El-Ghitani  
**Thesis:** Wireless Network Traffic Modeling for Different Channel Holding Time Probability Distributions  
**Degree:** Master of Science in Electrical Engineering (Electronics and Communications Engineering)

Approved by:

Name and Title	Signature
<b>1- Prof. Dr. Magdy Saeed El Soudani</b> Professor in Electronics and Communication Dept., Faculty of Engineering, Cairo University	..... (Examiner)
<b>2- Prof. Dr. Magdy Mahmoud Ebrahim</b> Professor in Electronics and Communication Dept., Faculty of Engineering, Ain Shams University	..... (Examiner)
<b>3- Prof. Dr. Hadya El Hennawy</b> Professor in Electronics and Communication Dept., Faculty of Engineering, Ain Shams University	..... (Supervisor)
<b>4- Associate Prof. Dr. Hesham El Badawy</b> Network Planning Department, National Telecommunication Institute, Ministry of Communications & Information Technology	..... (Supervisor)

## STATEMENT

This dissertation is submitted to Faculty of Engineering, Ain Shams University for the degree of Master of Science in Electrical Engineering (Electronics and Communications Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communications Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

**Name:** Fadi Hassan Ahmed El-Ghitani

**Signature:**

**Date:** / /2012

---

*To my mother who loved me, and to my  
father who inspired me*

**ABSTRACT**

**FADI HASSAN AHMED EL-GHITANI**  
**MASTER OF SCIENCE THESIS, AIN SHAMS UNIVERSITY**

The aim for the current work is to investigate and derive a model for the channel occupancy time. This had been done as well as the teletraffic performance assessment as well. Teletraffic performance (for both fixed and mobile systems) depends mainly on channel occupancy distribution and number of channels. Earlier assumptions assumed that the channel occupancy time can be modeled by exponential distribution. This will greatly simplify the problem and the system can be modeled as an M/M/c queueing system. However it has been proved that for the channel occupancy time to be strictly exponentially distributed, cellular dwell time and call duration should be exponentially distributed too. This is a very unrealistic assumption, for at least cellular dwell time distribution which depends on user mobility profile and cell geometry.

In this thesis, an algorithm for analytical modeling of mobile teletraffic performance is developed. This algorithm works for any cell dwell time distribution (distribution of time spent by users inside a cell). In order to validate the proposed analytical model, simulation model is built to compare its results to that of the analytical model. The impact of mobile system parameters such as cell radius and user speed is also investigated.

In order to test the proposed algorithm, blocking and forced termination probabilities were taken as performance metrics and were calculated under various traffic loads. To validate the obtained results, they were compared to that of a (DES) model. The results worked as expected, the more the number of phases used, the more accurate results obtained.

**Key Words:** Teletraffic performance, dwell time, heavy-tailed distribution, phase distribution, channel occupancy time

---

**Thesis supervisors:**

- Prof. Dr. Hadya Mohammed El-Hennawy  
Ain Shams University,  
Cairo, EGYPT.
  - Associate Prof. Dr. Hesham Mohammed El-Badawy  
National Telecommunication Institute,  
Cairo, EGYPT.
-

## ACKNOWLEDGEMENT

I would like to praise GOD for his numerous gifts to me throughout the duration of my Thesis. GOD has given me hope whenever I needed it. This work would have never seen the light without GOD's will.

I would like to present my deepest gratitude to Professor Dr. **Hadya El Hennawy** for her precious help, valuable guidance and continuous support. Professor Dr. **Hadya** inspired me a sense of enthusiasm, optimism and motivation and she provided me with a lot of her wide knowledge and experience.

I would like also to express my heart full thanks to Associate Professor Dr. **Hesham Mohammed El-Badawy** for his inspiration, valuable guidance and his great efforts in supervising my thesis. Throughout my research period, he provided me with lots of valuable ideas and many stimulating suggestions. Dr. **Hesham** gave me much of his valuable time whenever I asked and kept encouraging me to work harder. Really, I will never forget the research memories with Dr. **Hesham**.

In addition, my sincere appreciations for my colleagues, in National Telecommunication Institute (NTI), for supporting me throughout the course of this thesis.

Finally, special thanks go to my parents, who have given me help and support along the way and who have done the impossible to help get me to where I am today. All of my achievements have been due to their boundless love and support.

---

# TABLE OF CONTENTS

	<u>Page</u>
<b>List of Figures.....</b>	<i>xi</i>
<b>List of Tables.....</b>	<i>xiv</i>
<b>List of Symbols.....</b>	<i>xv</i>
<b>List of Abbreviations.....</b>	<i>xvii</i>
<b>CHAPTER 1 INTRODUCTION</b>	
1.1. General Background.....	<i>1</i>
1.2. Problem Statement.....	<i>2</i>
1.3. Thesis Organization.....	<i>2</i>
<b>CHAPTER 2 MOBILE COMMUNICATION and CELLULAR CONCEPT</b>	
2.1. Brief History.....	<i>3</i>
2.1.1. First Generation Cellular Networks.....	<i>3</i>
2.1.2. Second Generation Cellular Networks.....	<i>4</i>
2.1.3. Third Generation Cellular Networks.....	<i>4</i>
2.1.4. Fourth Generation Cellular Networks.....	<i>5</i>
2.2. Basic Mobile Network Architecture.....	<i>5</i>
2.3. Cellular Concept.....	<i>7</i>
2.3.1. Introduction.....	<i>7</i>
2.3.2. Frequency reuse.....	<i>8</i>
2.3.3. Handover.....	<i>11</i>
2.4. Radio Planning and Optimization.....	<i>13</i>
2.4.1. Dimensioning.....	<i>14</i>
2.4.2. Coverage Planning.....	<i>16</i>
2.4.3. Capacity Planning.....	<i>16</i>
2.5. Conclusions.....	<i>17</i>
<b>CHAPTER 3 BIRTH-AND-DEATH QUEUEING MODELS</b>	
3.1. Introduction.....	<i>19</i>



3.2.	Basic Characteristics.....	19
3.2.1.	The Input or Arrival Pattern of Customers.....	20
3.2.2.	The Pattern of Service.....	20
3.2.3.	The Number of Servers or Service Channels.....	21
3.2.4.	The Capacity of the System.....	21
3.2.5.	The Queue Discipline.....	21
3.3.	Markov Chains and Birth-Death Process.....	22
3.3.1.	Markov Process.....	22
3.3.1.1.	Discrete-Time Markov Chains.....	25
3.3.1.2.	Continuous-Time Markov Chains.....	29
3.3.2.	Birth-Death Processes.....	37
3.3.2.1.	M/M/1 Queue.....	37
3.3.2.2.	General Birth-Death Processes.....	42
3.3.2.3.	Multi-Server Systems.....	45
3.4.	Conclusions.....	46
<b>CHAPTER 4 TRAFFIC CONCEPTS AND DWELL TIME DISTRIBUTION</b>		
4.1.	Concept of Traffic and Traffic Unit.....	48
4.2.	The Blocking Concept.....	49
4.3.	Mobile Communications Teletraffic Modeling.....	50
4.4.	The Exponential Model.....	53
4.5.	Inadequacy of the Exponential Model.....	57
4.6.	Cellular Dwell Time Modeling.....	60
4.6.1.	Analytical Modeling.....	60
4.6.2.	Simulation Modeling.....	66
4.7.	Conclusions.....	69
<b>CHAPTER 5 ANALYTICAL MODELING UNDER GENERAL DWELL TIME</b>		
5.1.	System Model.....	70
5.2.	Analytical Modeling.....	71
5.2.1.	Proposed Algorithm.....	71
5.2.2.	Calculation Of Dwell Time Distribution.....	71

5.2.2.1. Proposed Simulation Algorithm.....	72
5.2.2.2. Algorithm Testing.....	75
5.2.3. Approximation of Dwell Time Distribution by a Suitable Phase Distribution.....	77
5.2.3.1. Approximation via Moment Matching.....	77
5.2.3.1.1. Matching the First Moment.....	78
5.2.3.1.2. Matching the First Two Moments.....	79
5.2.3.1.3. Matching the First Three Moments.....	84
5.2.3.2. Approximation via Curve Fitting.....	90
5.2.3.2.1. Introduction.....	90
5.2.3.2.2. Fitting using Hyper-Exponential Distribution	90
5.2.4. Integrating Phase Distribution into an (MDBD) Process.....	93
5.3. Building Simulation Model.....	97
5.3.1. Events Generation.....	98
5.3.2. Finite State Machine.....	99
5.3.3. Collecting Statistics.....	101
5.3.4. Simulation Model Validation.....	102
5.4. Numerical Results.....	104
5.4.1. Dwell Time Distribution.....	104
5.4.2. Blocking and Forced Termination Probabilities.....	106
5.4.3. Effect of Changing Cell Radius and User Maximum Speed.....	108
5.5. Conclusions.....	110
 <b>CHAPTER 6 CONCLUSION AND FUTURE WORK</b>	
6.1. Conclusion.....	111
6.2. Future Work.....	112
<b>Appendix A</b> Brief Tutorial on Phase Type Distributions.....	113
<b>Appendix B</b> Numerical Solution of Markov Chains.....	117
<b>EXTRACTED PAPERS</b> .....	126
<b>REFERENCES</b> .....	127

## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
<b>Figure 2.1</b>	GSM system architecture	6
<b>Figure 2.2</b>	Illustration of the cellular frequency reuse concept	10
<b>Figure 2.3</b>	Intracell and Intercell Handover	12
<b>Figure 2.4</b>	Radio System Planning Process Phases and their Key Parameters	14
<b>Figure 3.1</b>	M/M/1 Queue	37
<b>Figure 3.2</b>	Markov Chain representing M/M/1 Queueing System	39
<b>Figure 3.3</b>	Markov Chain of a General Birth-Death Process	43
<b>Figure 3.4</b>	Multiserver Queueing System	45
<b>Figure 3.5</b>	Markov Chain for Multiserver Queueing System	46
<b>Figure 4.1</b>	An Arbitrary Mobile User Trajectory	52
<b>Figure 4.2</b>	Markov Chain for an M/M/c Queue of zero Queue Length	54
<b>Figure 4.3</b>	Dividing Call Duration among Channel Occupancy Times	56
<b>Figure 4.4</b>	Illustration of distance from point A (where the call is originated) to point C (where the user exits the cell)	60
<b>Figure 4.5</b>	Residual Dwell Time PDF for $t_{th} = \frac{2R}{V_{max}} = 10$ seconds	64
<b>Figure 4.6</b>	Illustration of distance from point A (where the call is originated) to point C (where the user exits the cell) for handoff call	65
<b>Figure 4.7</b>	Handoff Call Dwell Time PDF for $t_{th} = \frac{2R}{V_{max}} = 10$ seconds	66
<b>Figure 4.8</b>	Trajectories of five sample users passing through a cell of 3 Km radius	67

<b>Figure 4.9</b>	New Call Cellular Dwell Time Distribution using Simulation and its Approximating Gamma Distribution	68
<b>Figure 4.10</b>	Handoff Call Cellular Dwell Time Distribution using Simulation and its Approximating Gamma Distribution	68
<b>Figure 5.1</b>	Algorithm for calculation of dwell time sample	74
<b>Figure 5.2</b>	New Call Dwell Time Distribution for Simple User Mobility Profile	76
<b>Figure 5.3</b>	Handoff Call Dwell Time Distribution for Simple User Mobility Profile	76
<b>Figure 5.4</b>	Markov Chain representing a Single Phase Distribution	79
<b>Figure 5.5</b>	Markov Chain representing two phase Erlang distribution	79
<b>Figure 5.6</b>	Markov Chain representing two stage hyperexponential distribution	82
<b>Figure 5.7</b>	Markov Chain representing n-phase Erlang-Coxian phase distribution	85
<b>Figure 5.8</b>	EC-distribution is combined to an exponential distribution in parallel	88
<b>Figure 5.9</b>	EC-distribution is combined to an exponential distribution in series	88
<b>Figure 5.10</b>	Phase Diagram of Hyperexponential Distribution	91
<b>Figure 5.11</b>	Two-Phase, Three stage phase distribution	94
<b>Figure 5.12</b>	Discrete Event Simulation Steps	98
<b>Figure 5.13</b>	Algorithm that controls transition between system states	101
<b>Figure 5.14</b>	Blocking probability results for both simulation and Erlang-B formula	103
<b>Figure 5.15</b>	Complementary CDF of cell dwell time	104
<b>Figure 5.16</b>	Original distribution cdf (solid line) and fitting hyperexponential distributions of (single-phase, 2-phases, 3-phases)	106

<b>Figure 5.17</b>	Call blocking probability under original cell dwell time distribution (using simulation) vs. single, 2-phases and 3-phases hyperexponential distributions	<i>107</i>
<b>Figure 5.18</b>	Forced termination probability under original cell dwell time distribution (using simulation) vs. single, 2-phases and 3-phases hyperexponential distributions	<i>108</i>
<b>Figure 5.19</b>	Blocking and forced termination probabilities vs. cell radius	<i>109</i>
<b>Figure 5.20</b>	Blocking and forced termination probabilities vs. user maximum speed	<i>109</i>

**LIST OF TABLES**

<b><u>Table</u></b>		<b><u>Page</u></b>
<b>Table 4.1</b>	Types of Loss Performance Measures	<i>50</i>
<b>Table 4.2</b>	Difference between time intervals used in teletraffic modeling	<i>51</i>
<b>Table 5.1</b>	Comparison between the three solutions for matching the first three moments using EC distribution	<i>86</i>
<b>Table 5.2</b>	Cellular dwell time parameters used in simulation	<i>104</i>
<b>Table 5.3</b>	System parameters used in analytical modeling	<i>106</i>

## LIST OF SYMBOLS

$a$	Demand for service
$A$	Offered traffic
$A_c$	Carried traffic
$A_l$	Rejected traffic
$C$	Number of channels available in a system or cell
$C_h$	Number of channels reserved for handoff calls only
$\bar{h}$	Average number of handovers per call
$p_{ij}(n)$	Single-step transition probability from state $i$ to state $j$
$P_B$	Blocking Probability
$P_{FT}$	Forced Termination Probability
$P(n)$	Single-step transition probability matrix
$q_{ij}(t)$	Average transition rate from state $i$ to state $j$
$Q(t)$	Average transition rate matrix
$R$	Cell radius
$T_{Ch}$	Channel Occupancy Time for handoff calls
$T_{Cn}$	Channel Occupancy Time for new calls
$T_D$	Cellular Dwell Time
$T_{DN}$	Cellular Dwell Time for new calls
$T_S$	Unencumbered session time
$T_r$	Residue of session time
$V_{max}$	User maximum speed
$\alpha$	Maximum drift
$\lambda$	Average arrival rate
$\lambda_h$	Average arrival rate for handoff calls
$\lambda_n$	Average arrival rate for new calls
$\mu$	Mean service rate
$\mu_C$	Channel release rate
$\pi$	Steady-state probability distribution