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Comparative Study of Performance Evaluation Models for Cellular Communications Networks

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Abstract

Increased failure to access and engage communications channels, increased dropped calls and general poor quality of service are some of the persistent problems encountered in cellular networks. The effect of these on the level of customer satisfaction and consequently on the generated revenue have necessitated the research into developing techniques for improving the performance of telecommunications networks. This paper presents an overview of three important performance evaluation models for mobile telecommunications networks with emphasis on Grade of Service and the Poisson nature of traffic. The stochastic models used in the study are based on applied probability theorems that best describe the peculiar nature of user traffic. Equations from the models are derived for key performance indices, which can be used in future applications to design cost-effective systems that balance the inherent capacity-quality trade-offs that are characteristic of such networks.

Keywords: Performance Evaluation, Mobile Telecommunications Network, Blocking Probability, Models, Arrival

Introduction

Increased failure to access and engage communications channels, increased dropped calls, and general poor quality of service are some of the persistent problems encountered in cellular networks. Telecom service quality continues to be a major concern worldwide in the mobile telecommunications industry. In Nigeria, for instance, the National Assembly has ordered that the Nigeria Communication Commission track and record dropped calls because of legislative concerns and debate. (Adegoke, Babalola & Balogun, 2008)

The main objective of competitive service operators is to attract and retain subscribers by providing quality national coverage. However, as this is established, the quality of the service becomes a priority in relation to the capacity of the network and the growing demand for the mobile services of the operator. Inherent in the characterization of such networks is the trade-off between capacity and Quality of Service (QoS) (Litjens, 2011). Since there is a governing body that monitors the minimum quality requirements of such services, capacity limitation becomes a challenge especially in the light of the growing subscriber base and the quality of the diverse evolving services.

Network planning and radio resource management (such as frequency reuse applications) are two primary instruments used by the operator in strategically influencing the capacity-quality trade-off of such mobile systems. While network planning is a fixed (time-bound) solution that involves activities like: the selection of base station sites, optimizing of transmission direction of the antennas in the horizontal and vertical planes, and the assignment of radio frequencies to the different base stations, radio resource management is a dynamic solution that involves activities like: real- time allocation of the radio capacity, as established by the network planner, to the different sessions (calls); call admission control, i.e. the admission (or rejection) of call requests based on the available capacity, and frequency reuse. (Litjens, 2011)

Summary of Related Works

Kostic-Ljubisavljevic et al. (2011) developed software for network performance analysis to determine how routing and interconnection charging methods could influence network links load balance. Among other network logical units used in building the simulation software are: network initialization, generation of traffic demands, simulation of carried traffic demands and statistical processing. The logical units are then modeled to employ the varying routing protocols with the comparative results. In relation to the present project, this simulation is an extension of the existing system, as it does not take into consideration the initial state of the system before routing protocols are implemented.

Altiparmak, Dengiz, and Smith (2009) developed an encoding method for using neural network models to estimate the reliability of telecommunications networks with identical link reliabilities. This is an extension of the use of Artificial Neural Networks (ANN) for predicting and modeling network systems. The research has no correlation with stochastic nature of traffic, but it establishes models to resilience in the network by estimating all terminal network reliability.

Sarkar and Halim (2011) explored network performance from the software perspective by reviewing the simulations of telecommunication networks. They noted that a credible simulator offers more flexibility in model development, modification and validation, and incorporates appropriate analysis of simulation output data, pseudo-random number generators, and statistical accuracy of the simulation results. Network simulation can be used to verify analytical models, generalize the measurement results and evaluate the performance of systems and new protocols that are being developed.

Adegoke et al. (2008) did an appraisal of the performance of GSM operators using Nigeria as a case study and examined the problems facing the industry. Having evaluated the parameters that attributed to poor quality of service by operators, they came up with methods that are suggested towards improving network performance. The methods suggested did not take into consideration the nature of user demands and capacity of channels. They only focused on improving the performance of the network elements.

This paper provides an overview of key models used in performance evaluation of mobile telecommunications systems. Mathematical models are used in measuring key performance indices in well-defined units. The results show a relationship between grade-of-service and system capacity in such a way that it becomes a tool by which investments can be planned.

The Arrival Process

The arrival process of a cellular network is very critical to the network's design, operation and performance evaluation. Traffic such as calls arriving to a switching system or messages arriving to a server are random in time measurements and are described mathematically as stochastic point processes (point process- so that two arrivals can be distinguished from each other (Iversen, 2011). It is therefore necessary to use the tools of random process and statistics in general to model the arrival process. This process can get very technical and, while these technicalities are important, the problem solving procedure can become very cumbersome and its essence defeated. In this paper, we will deal more with critical concepts, in particular as they impact traffic engineering issues and especially on an intuitive level leaving out un-necessary technicalities that can be found in books on probability theory and random processes (Kakaes, 2003).

Characteristics of Poisson Point Processes

One major assumption, a most common one actually, is that all arrivals occur according to a ***Poisson process***. Poisson process, one of the most important point processes, is said to be the most random process and its analytical properties make it adequate in describing most real-life processes. "The more complex a process is, the better it will in general be modeled by a Poisson process" (Iversen, 2011).

A major characteristic of **all** point processes that will be critical to understanding and modeling the arrival process is stationarity. This is the implicit assumption that the statistical nature of the underlying problem (the arrival process in this case) remains the same over a period of time. The time period in question must be non-trivial i.e. it must be long enough to allow events take place and not too long to allow the dynamics of the problem remain constant. Stationarity is, therefore, assumed to exist with no major concern about how long it lasts even though for practical purposes, most engineers use one hour (Kakaes, 2003).

Another assumption is that arrivals in disjoint time intervals (i.e. non-overlapping time periods) are independent events and such arrivals are independent random variables although with identical distributions.

One last characteristic assumption important to the analysis of Poisson point processes, according to Kakaes (2003), is that the time between successive arrivals, referred to as the *interarrival time distribution*, X (i.e. the distribution of times between arrivals) are independent random variables, distributed exponentially with parameter, λ known as the mean arrival rate of the arrival process as shown below:

$$f(x) = \lambda e^{-\lambda x} \qquad x \geq 0 \tag{2.1}$$

Since the Poisson process is just one in a continuum of possibilities, there could be cases where the assumption that the arrival process is Poisson is challenged and proven wrong. In this paper, the critical point addressed is the PEAKEDNESS of the process. This is the ratio of the variance of the number of arrivals to the mean number of arrivals. (Kakaes, 2003) For a Poisson process for which there is no controlling mechanism, the Peakedness, denoted Z, is equal to 1 as shown below:

$$\text{Mean Number of Arrivals, } \overline{X} = \lambda T \tag{2.2}$$

$$\text{Variance of Number of Arrivals, } \sigma^2 = \lambda T \tag{2.3}$$

$$\text{Peakedness, Z = Variance / Mean} = \frac{\sigma^2}{\overline{X}} = \frac{\lambda T}{\lambda T} = 1 \tag{2.4}$$

Arrivals for which there is a controlling mechanism (implicit or explicit) that tends to bunch up traffic, leading to peaked traffic, then Z > 1 and are thus called "peaked (bunched up) traffic." The arrivals for which the controlling mechanism coordinates arrivals to occur on a regular basis leading to lowered variance and the effect that the traffic exhibits some smoothness, Z < 1 and are thus called “smooth (regular/ coordinated) traffic.”

Another set of performance measures critical to the analysis of cellular telecommunications networks as they can be used to establish dimensioning principles for the network designs of such networks are:

Time Congestion, denoted as *E*, is the fraction of total time for which all servers are busy during which no new call attempt may be admitted. This value can be measured at the exchange.

Call Congestion, denoted as *B*, is the fraction of all call attempts that finds all servers busy and are thus ‘blocked.’ This in Loss models is actually what is called the ‘Blocking Probability.’

There is no priori reason for E and B to be equal. However, with respect to Peakedness, the following hold true:

For Z > 1, Peaked Traffic, E < B, which means that utilization is fewer and blocked arrivals are higher.

For Z < 1, Smooth Traffic, E > B, which means that utilization is higher and blocked arrivals are fewer- a most desired effect.

For Z = 1, Poisson Traffic, E = B, which means that utilization is (fairly) equal to blocked arrivals (Kakaes, 2003).

The Blocking Concept

It is impracticable for all subscribers to be connected in the network at the same time since the expensive and limited network resources are shared among the teeming subscribers, but each subscriber is made to feel that he has unrestricted access to the network’s resources. It is expected that many subscribers can make calls during peak times. Subscribers who cannot complete calls are inconvenienced by wait periods or blocked calls. The goal is to reduce the number of blocked calls to acceptable levels without lowering standards. Depending on how the system operates, there are, with respect to access to network resources, three types: loss systems (where the subscriber is blocked and departs without being served when there are no available channels), waiting time systems (where the subscriber is entered into a queue until there is an available channel), and a combination of the first two (which is applicable where the number of waiting spaces is limited) (Iversen, 2011).

Analysis of Models

This section deals with the network performance aspects in the QoS concept pertaining to traffic. Therefore, the performance evaluation to be discussed in this project is on the traffic aspect of telecommunications networks.

It has been pointed out earlier that it is impracticable for all subscribers to be connected at the same time due to the expensive and limited network resources shared among the subscribers. One question that is easily asked is: “what is the probability that a system will be full and thus will be unable to serve a potential customer?”

A brief scenario can be used to provide an in-depth understanding of the problem. A telecommunications service centre has a limited pool of resources (channels, in this case) consisting of a number of ‘servers’. A ‘customer’ arrives with the intention of using one of the servers for a period of time (called the holding time) as shown in Fig 3.1 below. If one of the servers is available, it is ‘held/occupied’ by the arriving customer. If none is available, the arriving customer is ‘blocked.’

The entire (offered) traffic load of the system is then split into two: served load and blocked load. The question then is: "How much of the offered load is served and how much is blocked?" (Kakaes, 2003) The answer to this question can be used to determine the level of performance given a set of conditions.

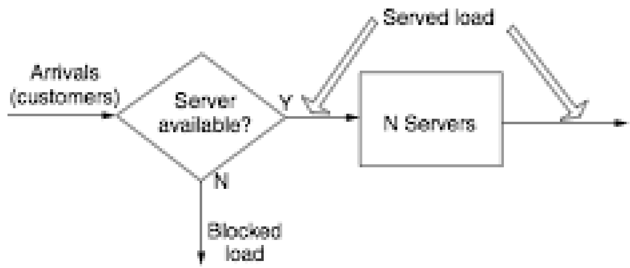

Fig 3.1: Schematic representation of a telecommunications network service centre. (Source: Kakaes, 2003)

One key quantity in the analysis of these networks is the OFFERED LOAD, A, which is the product of the average call arrival rate, λ, and the average holding time, $1/\mu$ (where μ is the service rate.) (Kakaes, 2003)

$$A = \lambda \times \frac{1}{\mu} = \frac{\lambda}{\mu} \quad 3.1$$

The unit of λ is $time^{-1}$ and the time for μ is also $time^{-1}$. Therefore, A is technically dimensionless. However, A has been given the unit 'Erlang' in honor of A. K. Erlang, the father of teletraffic engineering. (Wikipedia, 2011)

Erlang B Model

This is the most common model used for determining the 'quantitative' relationship among the offered load, λ, the number of channels, N and the Blocking Probability, B(A, N). It is also called the 'Erlang Loss system.' By Kendall notation, it is denoted M/M/n/n. The Danish mathematician, A. K. Erlang, developed it just as telephony was being born (Kakaes, 2003).

Modeling Assumptions:

The basic assumptions underlying this model (although modifications can be added) are:

1. The service system consists of a fixed number if 'servers' / channels, N per time.
2. Call arrive the system according to the Poisson process with an average arrival rate of λ calls per second.
3. All servers are equivalent in all senses. If a server is available on a call's arrival, it is seized. If more than one server are available, anyone is taken randomly without preference.
4. A call occupies the server for an amount of time that is distributed exponentially with parameter, μ (called the service rate) and it is independent of other calls, system state or anything else. Thus, the average holding time is $1/\mu$.
5. If all servers are occupied at a call's arrival instant, the call departs unserved i.e. it is blocked without attempting to try again or be served a little bit later.

According to Kakaes (2003), discussing state-space and state-transition diagrams, which will help in the development of the Erlang B formula, is critical in the analysis of this category of systems. For Markovian systems, the number of customers in the system is a state. Once all states are identified, they can be represented in any convenient manner as shown in Fig 3.2 below.

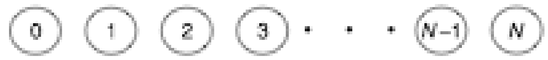

Fig 3.2: State space representation.

Traditional representations draw a circle with the state label inside. Arrows going from or to the respective states also represent transitions from one state to another. The arrows show the rate at which a 'departure' from a state occurs. A state-transition diagram is one showing the states of the associated transitions and is used for determining the steady-state (equilibrium) probability distribution of being in each state. (Iversen, 2011)

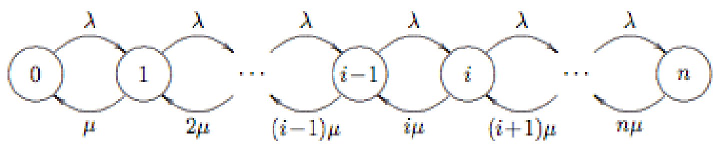

Fig 3.3: State transition diagram of the Erlang B model.

Flow Conservation Principle and Erlang B Formula

Considering a closed surface used to represent a state as shown in Kakaes (2003), transition to another state with rate, λ is as shown in Fig 3.4 below:

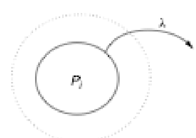

Fig 3.4: Flow representation.

Flow out of the state is given by:

$$\lambda \times p(i) = \lambda p(i) \qquad 3.2$$

The Flow Conservation Law states that "the flow out of a state is equal to the flow into the state" or "across any closed surface containing a set of states, the flow into the closed surface equals the flow out of it." From the state-transition diagram of M/M/n/n systems, transition from any state I < N to state (i+1) occurs with rate λ (the average rate of new calls). Also when the system is in state 1 and the one existing call departs, it moves to state 0 with rate μ (service rate). But if it moves from state 2 to state 1, there are two calls in the state and any can depart (since they are independent calls) with rate μ + μ = 2μ. Similarly, if the system is in state I < N, it departs to state (i-1) with service rate iμ.

For normalization i.e. sum up to 1, P_0 is then gotten as follows:

$$1 = \sum_{j=0}^{\infty} p(j) \qquad 3.3$$

Applying the flow conservation to the sequence of closed surfaces,

$$p(0) = \left\{ \sum_{j=0}^{n} \frac{A^j}{j!} \right\}^{-1} \qquad 3.4$$

The following, however, should be noted about the Erlang B formula:

Firstly, the Erlang Table (shown in Table 3.1 below) was developed for easy accessibility to the engineering community, as there was not enough processing power in the era of the development of the formula. There are simpler lines of codes to compute this these days.

The Blocking Probability, of the Erlang B system, is therefore given by:

$$p(i) = \frac{\frac{A^i}{i!}}{\sum_{j=0}^{n} \frac{A^i}{j!}}, \quad 0 \le i \le n \qquad 3.5$$

Secondly, the granularity (that is level of detail in the data) of the table is variable. For a given number of channels (N) and blocking probability, the maximum offered load could be computed. Many other tables have varying granularity.

Thirdly, it is important to note that the relationship between N, A and E_1 is non-linear even though it is quite monotonic. E.g. the blocking probability goes up for a fixed number of channels, as the load goes up. Therefore, interpolations and extrapolations can be misleading, leading to significant errors.

Fourthly and most importantly, the definition of capacity must be well defined with respective to **performance objectives**. Capacity is therefore defined, with respect to this model, as the maximum offered load that a system can sustain at a given blocking probability (which is the key element for level of performance.) In other words, the difference between the number of resources (N) and the amount of offered load at a given level of performance must be noted when capacity is being mentioned. In fact, increasing the number of channels by a certain factor doesn't actually increase the offered load proportionately and this is because of the level of blocking probability selected.

From the Table 3.1 below, if the objective of a service facility with 5 channels and desired blocking probability of not more than 2% will have a capacity of 1.66 erlangs. If the servers are increased to 10 channels (twice the previous number of channels) under the same blocking rule, the capacity becomes 5.08 erlangs, which is about 3 times more than the previous capacity.

A practical application is given thus: if a service facility has the following parameters: n = 6 channels, arrival rate, λ = 2 calls per time unit and departure rate, μ = 1 departure per time unit, the following is gotten from the state transition diagram:

$A = \lambda / \mu = 2$ erlang (capacity)

Blocking Probability, $E_1(A) = E_1(2) = p(6) = 0.0121$ (about 1%)

Table 3.1: Erlang B Example

i	$\lambda(i)$	$\mu(i)$	$p(i)$
0	2	0	0.1360
1	2	1	0.2719
2	2	2	0.2719
3	2	3	0.1813
4	2	4	0.0906
5	2	5	0.0363
6	2	6	0.0121
Total			1.0000

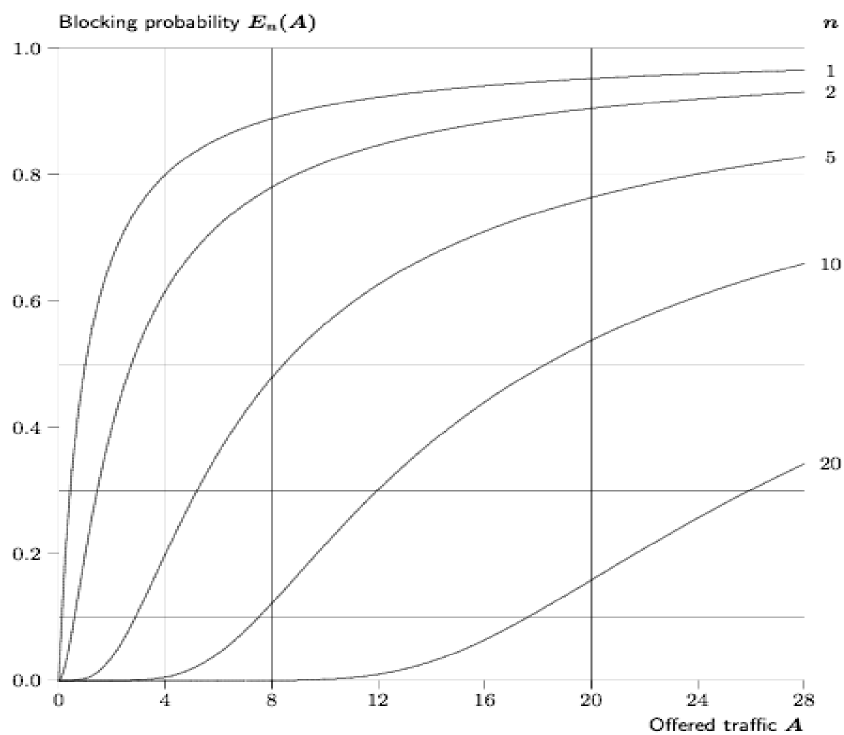

Fig 3.5: Graphical representation of the Erlang B table

The Erlang C Model

This is another variant of the Erlang B model. In other words, the basic assumptions for the model are just the same as those of the Erlang B model, but with the exception that the calls that find the system full are not ‘blocked’ in the traditional sense used in the Erlang B model; they enter a queue and are served by the facility on a first-come, first-served basis when there is an available channel. This is an M/M/N system (Iversen, 2011).

The state-transition diagram is as shown in Fig 3.6 below:

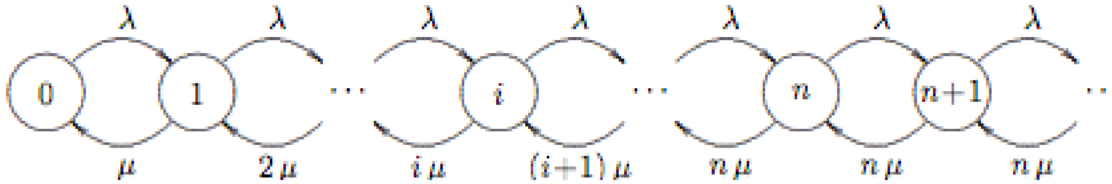

Fig 3.6: State transition diagram of the Erlang C model.

From the diagram, the following observations can be deduced:

1. The queueing room capacity is assumed to be infinite and as such, the state space is unbounded.
2. The state transitions are just the same as that of the Erlang B up to state N. Once the system is full, the departure rate is Nμ as only one of the customers in service can depart from that point on.
3. The concept of 'blocking probability' in the Erlang C model is different from that of the Erlang B model. While in the Erlang B model, the 'blocking probability' is the probability that arbitrary arrival that find the system full departs without being served, in the Erlang C model, it is the probability that such an arrival enters a queue once it meets the system full. In other words, in the Erlang C model, no arrival is 'blocked' in the traditional sense as all calls get served and as such the carried traffic, Y, is the same as the offered traffic, A. The question is now that of either being served immediately on arrival or first having to enter a queue for some time. (Iversen, 2011)

In applying the flow conservation equations to the state transitions as before and with A = λ/μ (according to Kakaes, 2003) the steady-state probabilities, p(i) becomes:

$$p(i) = \begin{cases} p(0)\cdot\dfrac{A^i}{i!}, & 0 \le i \le n, \\ p(n)\cdot\left(\dfrac{A}{n}\right)^{i-n} = p(0)\cdot\dfrac{A^i}{n!\cdot n^{i-n}}, & i \ge n. \end{cases} \qquad 3.6$$

Since the state space is assumed to be infinite, the probability must converge since the normalization states that the sum of probabilities be equal 1. The condition for this to be true is that A < N and this will be used also as an assumption in the development of this model showing that there is a steady state for this model.

For normalization,

$$1 = \sum_{i=0}^{\infty} p(i) \ , \qquad 3.7$$

Therefore,

$$p(0) = \frac{1}{\sum_{i=0}^{n-1}\dfrac{A^i}{i!} + \dfrac{A^n}{n!}\dfrac{n}{n-A}} \ , \qquad A < n, \qquad 3.8$$

Erlang C formula, according to Iversen (2011), is

$$E_2(A) = \frac{\frac{A^n}{n!}\frac{n}{n-A}}{1+\frac{A}{1}+\frac{A^2}{2!}+\cdots+\frac{A^{n-1}}{(n-1)!}+\frac{A^n}{n!}\frac{n}{n-A}}, \qquad A < n. \qquad 3.9$$

Since new arrivals are either served immediately or entered into the queue, the probability that the arrival will be served immediately, denoted as S_n is:

$$S_n = 1\text{-}E_{2,n}(A) = p(0) + p(1) + \ldots + p(n\text{-}1)$$

3.10

It is however important to realize that if the condition is not met i.e. if A > N, the system never reaches steady state and thus becomes unstable. This is because at the point A > N, every arrival finds the system filled and the queue grows beyond bounds as time evolves. The only solution to stabilize this will be to reduce the offered load (by increasing the number of servers, N.)

A practical example of the application of the Erlang C formula is as shown:

Given a service facility with n = 10 channels, arrival rate, λ = 480 calls per day and departure rate, μ = 15 minutes, the probability that a call enters the queue is given below:

The capacity, A = λ/ μ = 480 x 1/96 = 5 erlang (since 15 mins = 1/96 day)

$$E_2(A) = E_2(5) = \frac{\frac{5^n}{10!}\cdot\frac{10}{10-5}}{1+\frac{5}{1}+\frac{5^2}{2!}+\cdots+\frac{5^{n-1}}{(5-1)!}+\frac{5^n}{10!}\cdot\frac{10}{10-5}} = 0.0361$$

The following is observed about the Erlang C model:

First, technically, if A < N is violated, the system is unstable. However, it is often stated, and logically so, that if A > N, the blocking probability is 1. This means that all arrivals enter a queue. Whatever the case is, as A approaches N, the waiting time grows without bounds. (Kakaes, 2003)

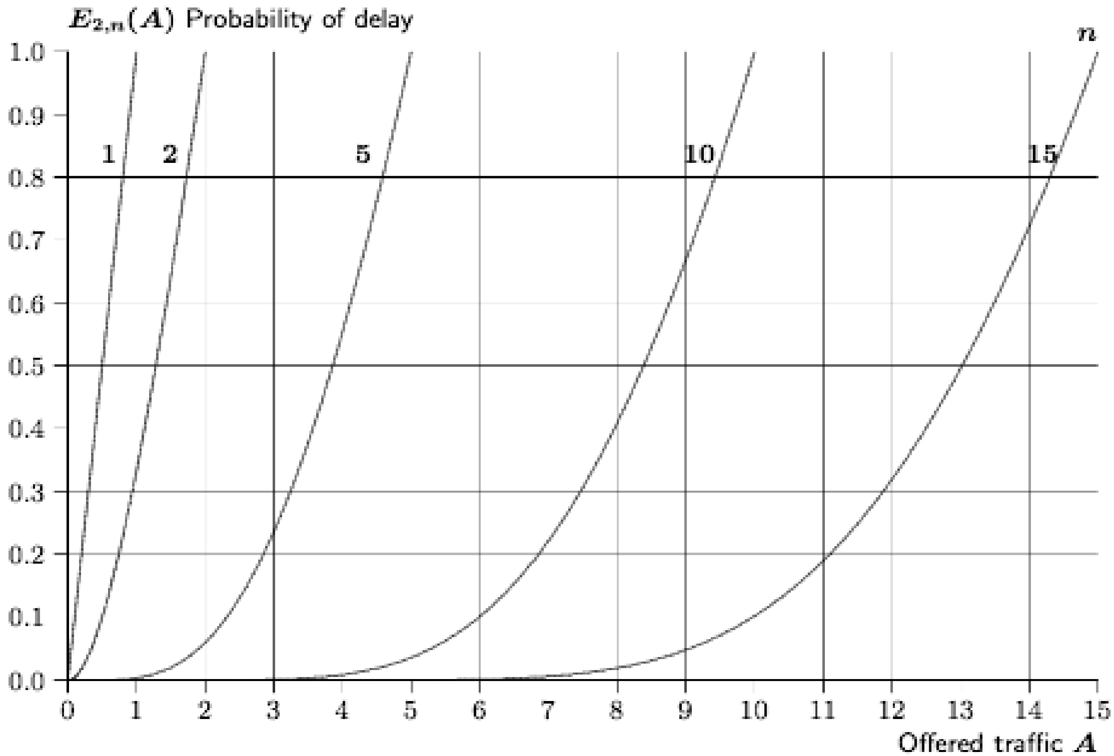

Fig 3.7: Graphical representation of the Erlang C table. (Source: Iversen, 2011)

Secondly, the Erlang B model is diametrically opposite to the Erlang C model. The first assumes that the blocked arrival departs immediately (and waits no time), while the second assumes that the blocked arrival waits an unbounded amount of time. The two Erlang models operate at two extremes. There has to be a model that can balance them. Welcome the Poisson Model!!!

The Poisson Model

This is an M/M/∞ model that assumes an infinite waiting room just like the Erlang C model. However, it differs in the sense that it assumes that arrivals that have entered the queue can depart unserved. The term 'Poisson' should not be misinterpreted to mean the arrival process as all three models mentioned have their arrivals follow a Poisson process.

The basic assumptions for the development of the Poisson model are the same as those of the Erlang models discussed above. They only differ in the manner a 'blocked' arrival is handled. In addition to the common assumptions, the Poisson model assumes that the waiting time has the same exponential distribution as the fundamental service time distribution. In other words, the amount of time an arrival is willing to wait on a queue is drawn from the same exponential distribution as the service time the arrival would expend in holding the channel for service. The exponential distribution is said to have a mean value, 1/µ and the waiting time is different from the holding time. (Kakaes, 2003)

The state-transition diagram for Poisson is as shown in Fig 3.8 below

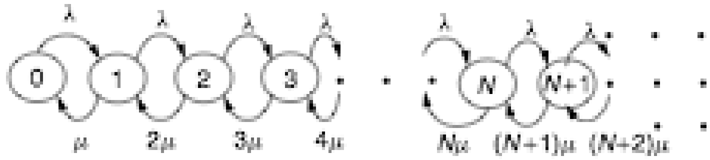

Fig 3.8: State transition diagram of the Poisson model.

For more on probability and its applications, check out Feller (1970, 1971) and Kleinrock (1975).

It is seen from the diagram that the departure rate is different from that of the Erlang C model.

Defining the blocking probability is quite difficeult as there are three possibllities observed in the operation of the model:

1. The arrival is served immediately and departs after service completion.
2. The arrival first enters a queue, waits for some time and departs unserved.
3. The arrival enters a queue, waits for some time and when a server becomes available, it starts its service. It departs on service completion.

It is clear that unserved arrivals should be called 'blocked' arrivals. However, what category is to be given arrivals that do get served after entering a queue remains unclear. Therefore, the blocking probability is defined as the probability that an arrival finds a system full and enters the queue. Whether or not and what fraction of these 'blocked' arrivals that do get served is not considered in the development of the model as the analysis will become too complex.

In applying the flow conservation equations to the state transitions as before, with A = λ/μ, the steady-state probabilities, p(i) becomes:

$$p(i) = p(0) \cdot \frac{A^i}{i!}, \qquad i = 1, 2, 3, \ldots \qquad 3.11$$

For normalization,

$$1 = \sum_{i=0}^{\infty} p(i) \ , \qquad 3.7$$

$$p(0) = \frac{1}{1 + \sum_{i=1}^{\infty} \frac{A^i}{i!}} = e^{-A} \qquad 3.12$$

The blocking probability is gotten , as usual, from the steady state probability distributions. The probability that an arrival will find the system full and enter a queue according to Kakaes (2003) is:

$$p(full) = 1 - e^{-A} \sum_{n=0}^{N-1} \frac{A^n}{n!} \qquad 3.13$$

This equationis valid for all values of A, unlike the Erlang model that depends on the condition A<N to be true. A practical example of the use is given: A new trunk group is to be created and used in an office. If the office is expected to make and receive 200 call per day with an average

holding time is 3 minutes and the blocking probability of not more than 1% is required, how many lines are needed? Assume that approximately 20% of the calls happen during the busy hour.

Note: The busy hour is the hour the office is most likely at full capacity and is the best means of predicting the future or expected optimal capacity of the office.

Number of calls made during busy hour = 20 % x 200 = 40 calls per hour

A = 40 x (3 x 60/3600) = 2 Erlangs (Since 3 mins = 3 x 60/3600 hours)

By extrapolation, the expected number of trunks required at 1% blocking probability = 7 trunks (which carries slightly over 2 erlangs of traffic)

Table 3.2: Poisson Model Traffic Table

Trunks	P(1%)	P(10%)	P(50%)
	Maximum Erlang to meet the above blocking rates		
2	0.149	0.532	1.678
5	1.279	2.433	4.671
10	4.130	6.221	9.669
15	7.472	10.29	14.64
20	11.08	14.52	19.64
25	14.85	18.84	24.65
30	18.74	23.22	29.65
35	22.72	27.66	34.65
40	26.77	32.13	39.65
45	30.87	36.64	44.65
50	35.03	41.17	49.65
55	39.23	45.73	54.65
60	43.46	50.31	59.65
65	47.72	54.90	64.65
70	52.01	59.51	69.66
75	56.33	64.13	74.66
80	60.67	68.77	79.66
85	65.03	73.42	84.66
90	69.41	78.07	89.66
95	73.80	82.74	94.66
100	78.21	87.41	99.66

(Source: TrafficFinder, 2011)

Comparison Among The Models

Although the term 'blocking probability' has different interpretations in the three models, there a few reasons to compare the results to be gotten from the three models as shown in Table 3.2 below:

From Table 3.2, the Poisson Model is 'in-between' the extreme cases of the Erlang models. The extreme cases are seen not practically feasible. The first extreme is that arrivals wait for no time at all. In fact, some networks provide for categorical queues, but even if no such queues are provided for, customers tend to ''redial,'' or try again in some way, thus creating somewhat of a virtual queue.

The second extreme is that arrivals that find the system full, ''wait forever,'' that is, for an infinite amount of time. This is not feasible as no customer can wait that long.

Table 3.3: Table showing the relationship between the offered load and the blocking probability of each of the models.

Number of Channels	Offered Load	Blocking Probability (%) for Erlang *B*	Blocking Probability (%) for Poisson	Blocking Probability (%) for Erlang *C*
5	2.5	6.97	10.88	13.04
	3.0	11.01	18.47	23.62
	3.5	15.41	27.46	37.78
	4.0	19.91	37.12	55.41
	4.5	24.30	46.79	76.25
	5.0	28.49	55.95	100.00
	5.5	32.41	64.25	100.00
	6.0	36.04	71.49	100.00
10	5.0	1.84	3.18	3.61
	6.0	4.31	8.39	10.13
	7.0	7.87	16.95	22.17
	8.0	12.17	28.34	40.92
	9.0	16.80	41.26	66.87
	10.0	21.46	54.21	100.00
	11.0	25.96	65.95	100.00
	12.0	30.19	75.76	100.00
20	10.0	0.19	0.35	0.37
	12.0	0.98	2.13	2.41
	14.0	3.00	7.65	9.36
	16.0	6.44	18.78	25.61
	18.0	10.92	34.91	55.08
	20.0	15.89	52.97	100.00
	22.0	20.90	69.40	100.00
	24.0	25.71	81.97	100.00

(Source: Kakaes, 2003)

Therefore, assuming some waiting time is good for the purpose of modeling the networks. Although the models discussed above are just three in a continuum of possibilities, a close look at the models can give a lot of insight onto the problem. From a practical perspective, system performance is a continuous function of the waiting-time distribution and so making certain assumptions about the waiting time distribution can help check the predicted performance with respect to what is being measured in a real situation. The information gotten from this comparison can be used to better calibrate the model of the problem at hand (Kakaes, 2003). The question is, therefore, not about which of the three models is the best, but about understanding the models and picking the one the bests describes the underlying dynamics of the problem at hand.

Summary and Further Studies

The aim of the study is to provide an overview into the means by which telecommunications networks can be evaluated based on performance. The future implication of this is to make the evaluation measurable in well-defined units through the use of mathematical models and to derive relationships between grade-of-service and system capacity (using the blocking probability and the Erlang tables) in such a way that the analysis becomes a tool by which investments can be planned whereby, systems are designed as cost effective as possible with a predefined grade of service when the future traffic demand and the capacity of system elements is known.

The results gotten from this study (capacity versus Grade of Service (GoS)) will be critical to the next step, which is the evaluation of key Quality of Service performance indicators when finding out the causes of problem in the networks with a view to find ways of ameliorating the observed defects found regarding abysmal Quality of Services (QoS) rendered by the GSM operators.

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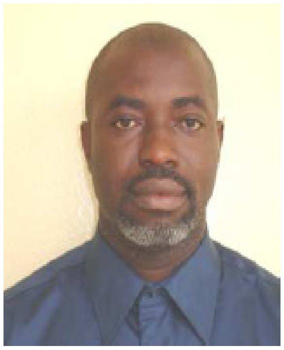
Biographies



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