Traffic Modeling in Mobile Communication Networks

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Abstract
This paper is focused on traffic modeling in Mobile Communication networks. This research is aimed at developing a traffic model that will predict a blocking probability for voice calls and handover calls blocking probability in mobile communication networks (GSM). The high number of block calls experience in mobile network, especially during the busy- hour as leads to poor Quality of Service (QOS) delivering in mobile network. The block calls experience in mobile network should be reduced (in line with NCC recommended value 2%) to a certain low values, to ensure good QOS. The developed traffic model is focused on new voice calls and handover calls in a cell. The developed traffic models are designed based on the number of channels resource available; these numbers of channels are partition into two segments in a cell network. The cell technology is homogenous in nature; therefore it is applicable to the entire mobile communication system. The analytical method is deployed, and the collection traffic data with equipment know as the Operation and Maintenance Center (OMC-counter) which is in built in the mobile communication network. The OMC-counter runs on Linux operation software, which helps to capture the number of arrival calls and service time in a specified interval. The arrival rate is assumed to be Poisson and the interarrival rate (the different between two arrival points or more) is also, assumed to be exponentially distributed and independence identical distributed. These parameters were assumed in the developed traffic model. The developed traffic models are blocking probability for voice calls and handover calls are shown in Equation (3) and (4). These traffic models are used to manage, a balance relationship between cost incurred in mobile communication by operators and service render to the mobile subscribers.
Keywords: Arrival rate, service time, exponential distribution, channels rate and traffic load in erlang.

Introduction

The mobile communication network is faced with serious challenges to ensure good Quality of Service (QOS).The Good QOS in mobile communication network is necessary at this, presence economic situation of global economic meltdown and competitive business environment with low tariff. In order to survive in this present economic situation, the network operators must put into consideration the effective use of their available resources, which leads to effective network design and network planning. The parameters used for effective network design and network planning are call blocking probability, handover blocking probability etc. These parameters operate base on available resource and traffic load in erlang in the mobile communication network. The block probability is used to control the number of block call experience in the mobile network and these block calls arises from lack of network capacity (channels) to accommodate or carry all the call at a particular point in time (Jangir H.et al, 2000; Marco A.et al, 2003).The blocking probability is determined from the number of available channels and traffic load in erlang. In evaluating the performance of handover blocking probability the following parameters must be consider as follows, handover rate, dropping probability, handover probability, call holding time and channel holding time (Yuguang F.,2005;Madhusmita P.et al,2008).The call dropping probability, it the probability that calls that originally (initially) granted access to the network channels (switches), but due to technical error(such are Electromagnetic causes, irregular user behavior etc) the calls are truncated during conversation (also called the forced termination), which is closely related to handover blocking probability. The handover rate is used to determine the handover traffic arrival rate, which is also needed to find the call blocking probability. The channel holding time is determined by the cell residence time (cell dwell time).The cell residence is affected by the subscriber mobility, the geographic situation and the channel allocation schemes used (or other factors such as fading). Channel holding time, this is the time a Mobile Station (MS) remains in the same cell during a call, while call holding time is the total call duration time when MS move from a cell to another new cell, the process is called handover process (cellular traffic-Wikipedia; Stefano et al,2008).

In order, to estimate the performance evaluation of the volume of traffic load place on network capacity and subscriber mobility, will deployed model.

From literature review, it was observed that queuing model have been successfully applied to area such a capacity planning and performance analysis (singh, 2007; yuguang, 2005).

A model is a mathematical expression or diagram or algorithms that represent traffic characteristics. This traffic model show the relationship between these components, channels resource (n), traffic load in erlang (A) and Grade of Service (GOS) or blocking probabilities. The relationship between traffic loads and services, state that as traffic load increases and the service decline in a constant capacity. Therefore there is need to predicted accurate traffic load in line with adequate capacity (channels) in mobile communication network to minimize block calls experience by subscribers (Georgeta B.et al, 2009; Cornel B.et al, 2010). The existing traffic model are Binomial, Poisson, Erlang B, Erlang C etc are used in network planning and network design, to minimized block calls experience by subscribers (ITU-D, 2006). The traditional traffic models (like Erlang B formula) are not adequate to this presence mobile communication network, with the inclusions of mobility and data service into the mobile network. Therefore, will required traffic models that will incorporate the subscriber handover calls (mobility) and data service into the voice call framework.

Modeling of a telecommunication system

In model of telecommunication system, it most involves the entire mobile communication network section. The modeling of telecommunication system is divided into three main elements in Fig1; these are traffic user (demand), structure (hardware) and operational strategy (software) (ITU-D, 2006; Sanjay, 2010).

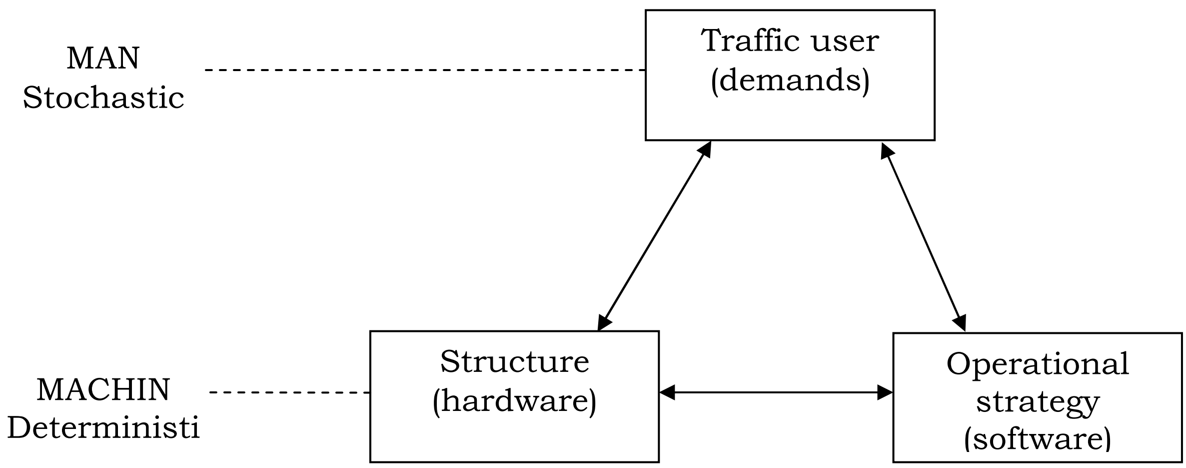

Fig. 1: Telecommunication system

In Fig1 Telecommunication system, is made up of two major statistical components, these are, the traffic usage (traffic demands) which is Random in nature and deterministic (machine) components are, structure (hardware) and operational strategy (ITU-D, 2006).

Traffic is trigger by the subscriber, and it's made-up of arrival rate and service time shown in Fig 2.

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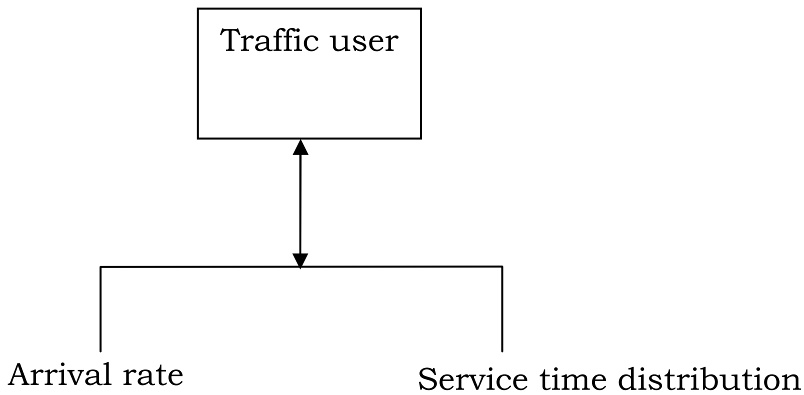

Fig 2. Traffic random component

Traffic user demands are random in nature, which means that subscriber generates calls in a random process. Random process is one in which one or more quantities vary with time in such a way that the instantaneous values of quantities are not determined precisely but are predictable with certain probability. These quantities are known as random variables (Sanjay, 2010).

Traffic user demands components are the arrival rate and service time distribution which is model by statistical properties (ITU-D, 2006).

Structure it's consider as the hardware in the system, example is identical channels (servers, trunks, slots) working in parallel. This is also referred to as homogenous group.

Strategy it's referred to as operational software the queue discipline, the order or manner in which customers are selected for service (ITU-D, 2006).Example of queues discipline are as follows, First–Come-First-served (FCFS), Last-Come-First Served (LCFS), Service in Random Order (SIRO) and Priority service. A call arriving at the system is accepted for service if at least one channel is idle. A call can not be block if the system is free, except all channels are busy in the system.

These are basic parameters consider for queuing model of traffic in mobile communication network, as follows (Zukerman, 2010; Sharma, 2010).

1. Arrival process(inter- arrival distribution)
2. The service time distribution
3. Number of parallel server (finite or infinite)
4. Capacity of the system (full or restricted availability)
5. Size of the population for the system
6. Queue discipline

From research work, the exist queue models does take different format such as M/M/1,M/G/1,G/M/1 and G/G/1.In all these models, M/M/1 model is the most disciplined and simple means of evaluating the network performance to estimate the queuing parameters, i.e. "Queue length" and "waiting time". This same queue model, assume exponential distribution in traffic situation (Singh L.K et al, 2007; Yuguang. 2005 and Stefano.et al 2008).

Methodology

An analytical approach was used to determine a traffic model, assuming a certain number of channels in cell system, which is also homogenous in the entire mobile communication network. The cell is assumed to contain a certain number of channels. The queuing theory was deployed as model technique, assuming the calls enter the system in an orderly sequence. The developed traffic model was design based on the arrival rate, holding time, subscriber making call within the cell and handover calls. The markov chain was used to analyze queuing theory which operates on memory less system, using steady transition state diagram. Also the generate data from develop traffic model was compared with the collected data from the OMC-counter network.

Model Description

Let us consider a cell system that has some certain number of traffic channels. These traffic channels in a cell are partition into two, as follows.

The V denote number of channels use for new voice calls, handover calls only and while, g channels are use for handover calls only. The voice calls and handover calls on v and g have a preemptive priority over data service on these channels. The two channels types can be access by data service based on availability of these channels. The new arrival voice calls and handover voice calls are based on first-come, first served (FCFS) using the TDMA technique.

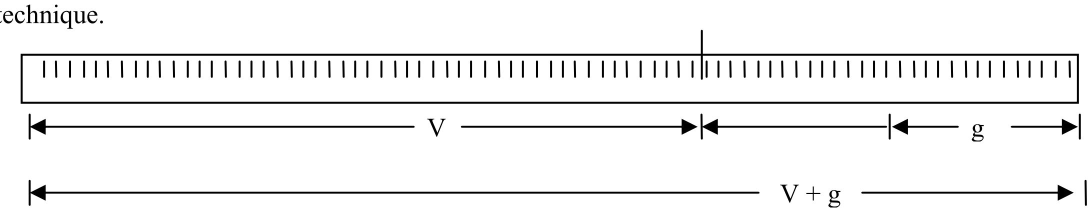

Fig. 3: Channels fragmentation

The V indicates the numbers of new voice channels, dedicated for voice call within the cell and handover calls. While, g represent the number of channels dedicated for handover calls only. The total number of channels in the system is V+ g for voice calls and handover calls, while these channels have a preemptive priority over the data service based on availability of the channels.

The voice arrival rate λ is assumed to follow a Poisson process and the service time (duration of calls is an exponentially distributed) random variable with mean $(1/\mu)$. Also, we assume that incoming handover calls request, follow a Poisson process, with arrival rate is λ_h (λ_h is derived by balancing the incoming and outgoing calls handover flows).

The total arrival rate in the cell is $\lambda = \lambda_V + \lambda_g$

λ_V = New voice call arrival rate

λ_g= Handover call arrival rate

The time spent by a subscriber within a cell (which is normally called dwell time or channel holding time) is assumed to be exponentially distributed with mean ($1/\mu_h$). The call activity time within a network is (call holding time) also a random variable with exponential distribution μ_h.

The total offered traffic in erlang A for voice call is

$A = A_V + A_g$

A_V = New voice call offered traffic in erlang

A_g = Handover call offered traffic in erlang

$\therefore\ Av = \frac{\lambda V}{\mu h} \qquad Ag = \frac{\lambda g}{\mu g}$

One dimensional state transition diagrams and the application of cut equation are used to express the responding state probabilities equation in term of P (o).

Lets consider, two possible state of k, where K is a discrete random process representing the number of occupied channels at discrete time. While P(K) is the probability of observing the system in state (k). And it as follows:

$$P(k)\begin{cases}\left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!}.P(0) & 0 \le k \le V \\ \left(\frac{\lambda}{V\mu}\right)^k \frac{1}{(k-1)!}.P(0) & V < k \le (V+g)\end{cases}$$

To obtained normalization Equation of the state probabilities for P (0).

$$1 = \sum_{k=0}^{\infty} P_K - - - - \text{---------------} (2)$$

The probability that all the channels are busy may be represented by a fraction of block calls, which is represented by blocking probability (P_b).

$$P_b = \frac{\frac{\left(\frac{\lambda}{\mu}\right)^V}{V!}}{\sum_{k=0}^{V-1}\left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!} + \sum_{k=V}^{V+g}\left(\frac{\lambda}{V\mu}\right)^k \frac{1}{(k-1)!}} \quad \text{..........} (3)$$

The failure of handover call is determine using handover blocking probability (P_{hf}).

$$P_{nb} = \frac{\frac{\left(\frac{\lambda}{\mu}\right)^{V+g}}{(V+g)!}}{\sum_{k=0}^{V-1}\left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!} + \sum_{k=V}^{V+g}\left(\frac{\lambda}{V\mu}\right)^k \frac{1}{(k-1)!}} \quad \text{..................} (4)$$

This is experienced when all the (V + g) channels are busy.

Validation

Validation is a quality assurance process of establishing evidence that provides a high degree of assurance that a product, service, or system accomplishes it intended requirements (Wikipedia, 2008). The accuracy of the developed traffic models in Equation 3 and 4 a validated, by using programs written in MATLAB. Various scenarios are experimented from low values to higher values of both traffic load in erlang and number of channels (V) to ensure accuracy in determination of the blocking probability traffic model in Equation 3 and handover blocking probability in Equation 4. The main assumptions in these traffic models are the interarrival rate which is assumed to be exponential distribution process and the total number of channels are divided into two segments (v+g) traffic channels.

The first scenario, from Equation 3, is the blocking probability experiences in a certain number of channels (V) only in the mobile network. The V represents the number of channels used for calls (subscribers) within the cell and handover calls process.

The input number of channels (V) values used in MATLAB program environment are (V= 7, 8, 9, 10 &11) very low values, used to determine the blocking probability against traffic load in erlang, showed in Fig 4.

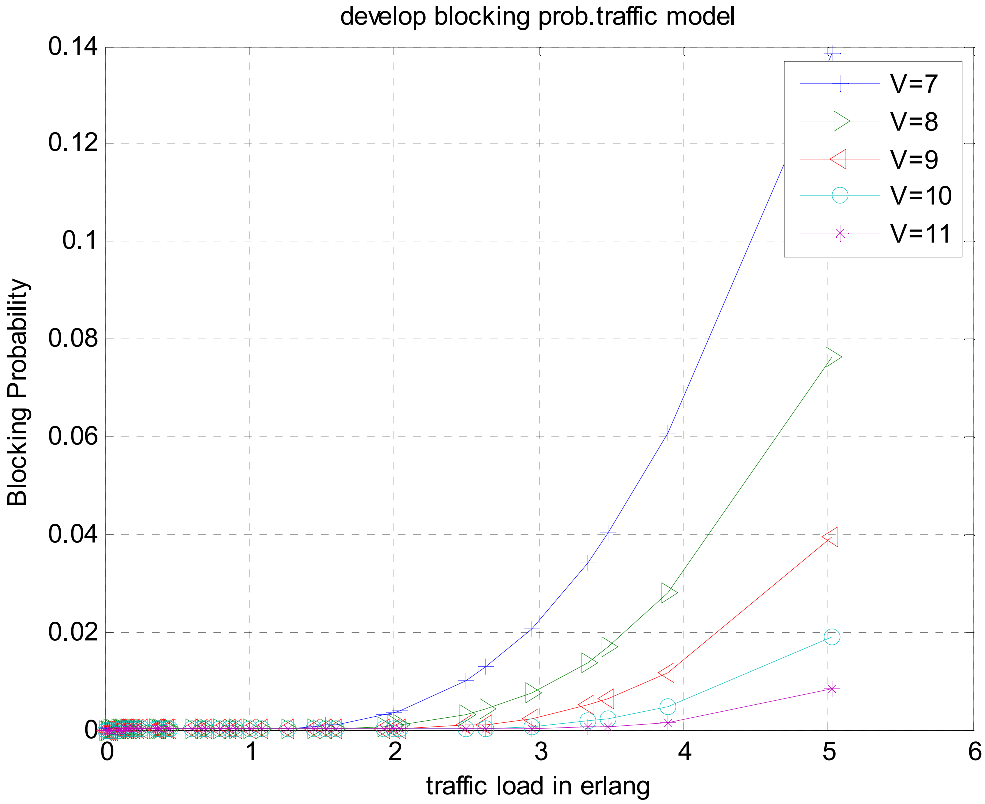

Fig 4 Calls blocking probability with low number of channels (V)

In Fig 4 and Fig 5, it were observed that teletraffic system is non-linear graph.Also observed that, as the value of traffic load in erlang increases the blocking probability valve also increases at a given or constant number of channels (V).The line graph or curve line experienced a linear path, with low blocking probability values within a low values of traffic laod in erlang (A). Thereafter, the curve line begin to move in upward direction in proportion to increase in blocking probability and increase in the traffic loan in erlang at constant number of channels (V). The blocking probability is highly influenced, with the function of traffic laod in erlang and the number of channels in the system.The system performance increases as the number of traffic load in erlang decreases(verse- versa) at constant number of channels(V).

Also, low number of channels (V) can be used in the mobile network, but the network calls will experience high level of blocking probability rate at a given traffic load in erlang. In Fig 4 shown only low number of channels (V) and Fig 5 shown high number of channels (V).The line graphs of both Figures show that, as the number of traffic load in erlang increases, also the blocking probability increases at constant number of channels.

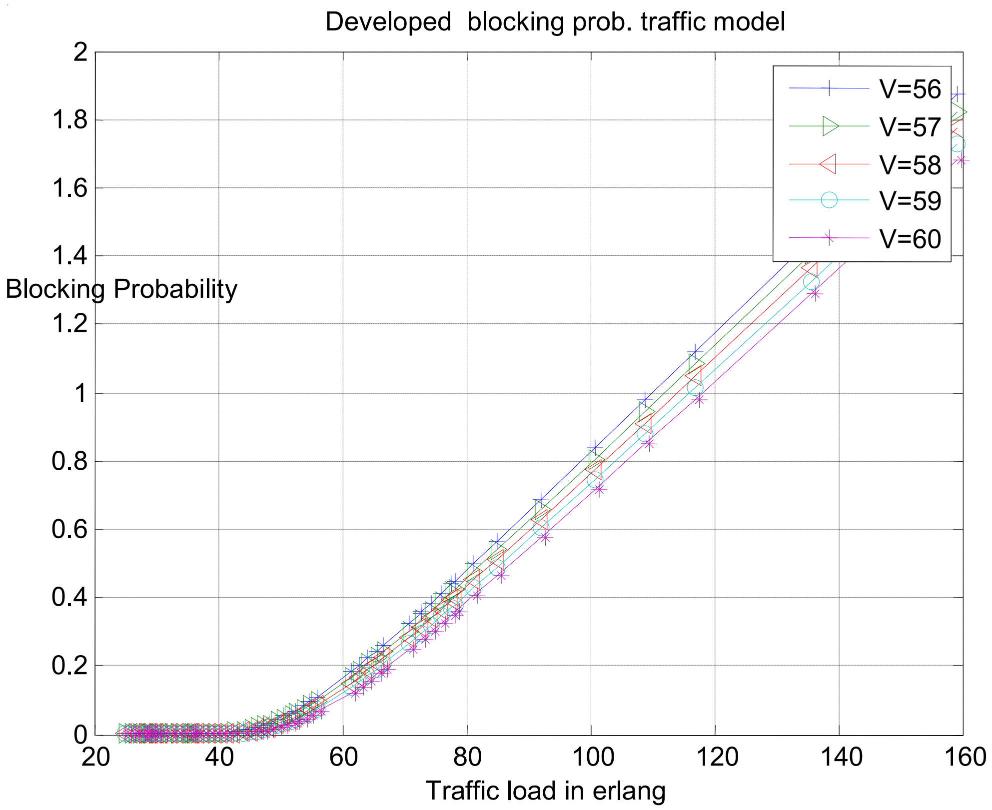

Fig 5 Calls blocking probability with high number of channels (V)

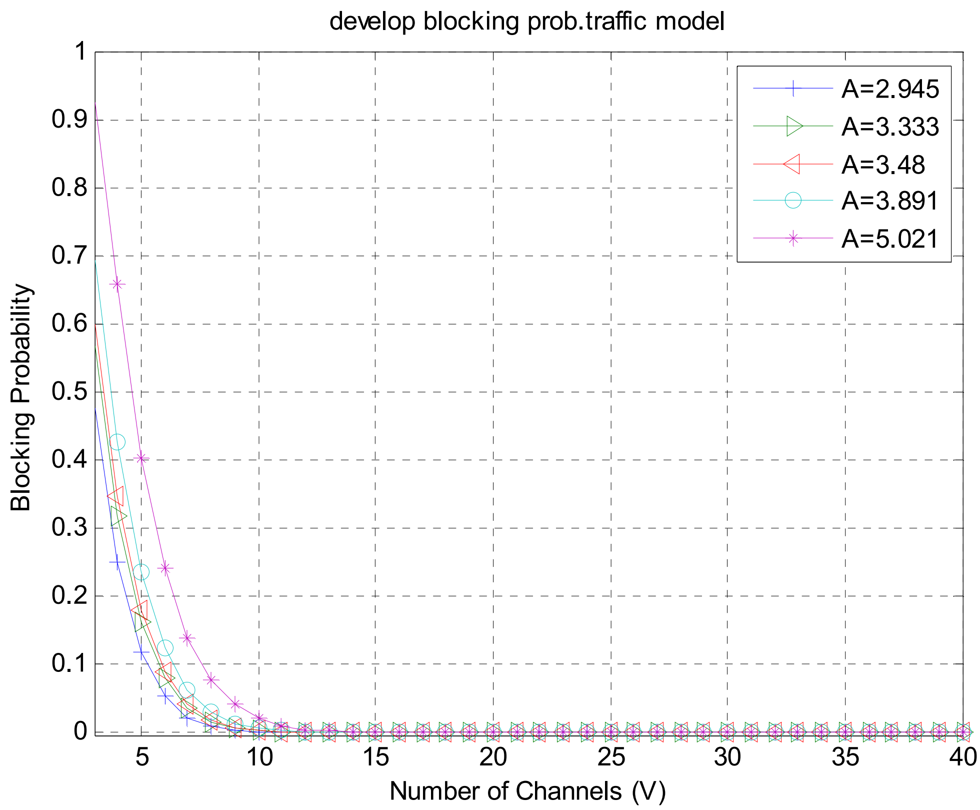

Fig 6 Calls blocking probability with low traffic load in erlang (A)

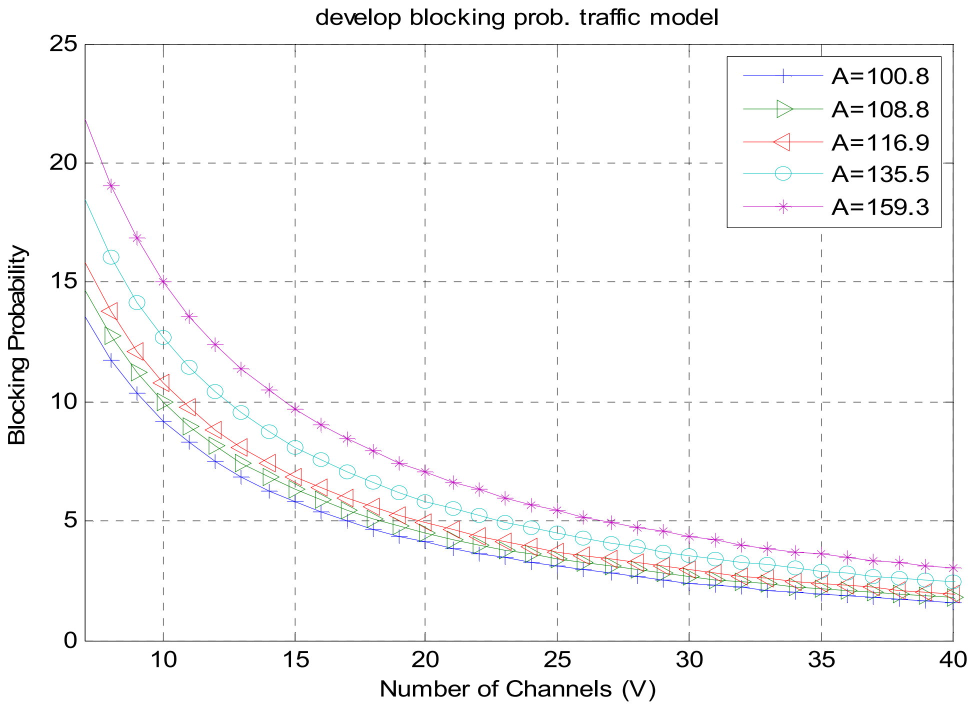

Fig 7 Calls blocking probability with low number of channels (V)

Fig 6 and Fig 7, show a MATLAB simulation obtained with a certain range of number of traffic load in erlang. In Fig 6, low number of traffic load in erlang are used, in Fig 7, high number of traffic load in erlang are used to determine the blocking probability with increasing number of channels (V).Its were observed that, there are high values of blocking probability at low number of channels at constant traffic load in erlang and as the number of channels increases at constant traffic load, the blocking probability decreases.

As the number of channels (V) increases, the blocking probability experience in the mobile network decreases. The blocking probability is influenced by the number of channels and traffic load in the system. Blocking probability is a major parameter used for evaluating good Quality of Service (QOS).Therefore, for efficient QOS, the blocking probability must be minimized to a certain level (2% recommend by NCC) to grantee good QOS in mobile network. The range of value in blocking probability has a corresponding number of channels (V) and traffic load in erlang to ensure minimum blocking probability in the network.

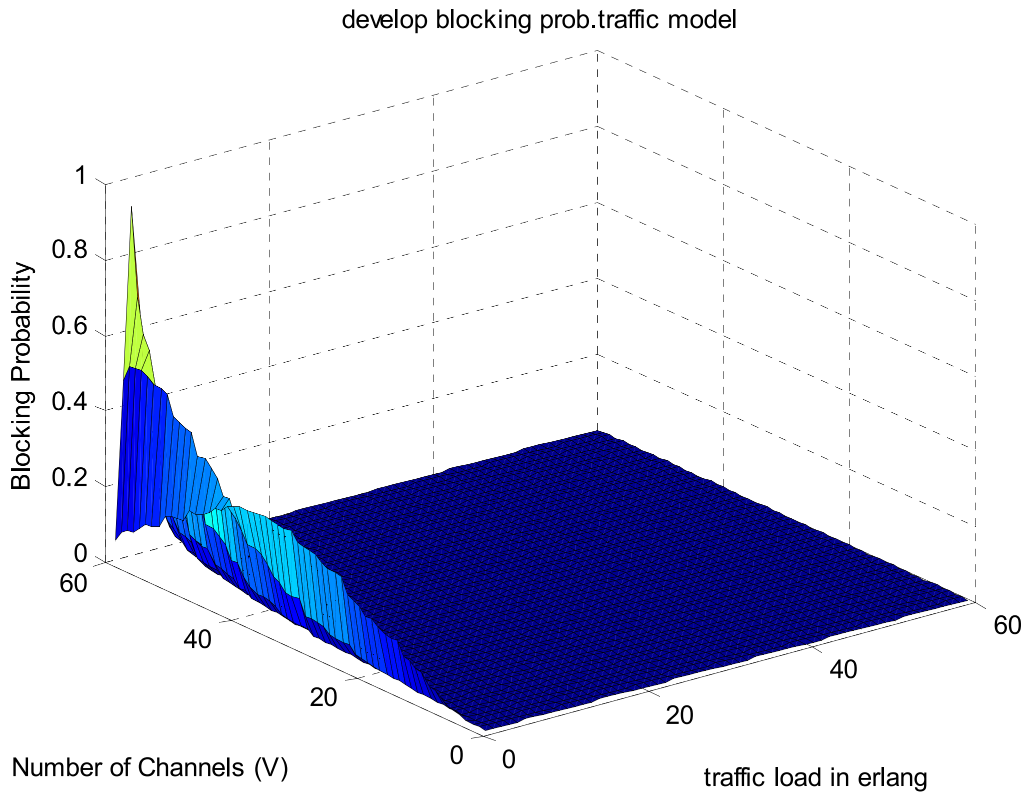

Fig 8 3D calls blocking probability

Fig8 shows a 3D graph, which indicates that blocking probability (P_b) on Z-axis is dependent on number of channels (V) on y-axis and on traffic load in Erlang (A) on x-axis. Therefore, blocking probability is a function of number of channels and traffic load in erlang (P_b=f(A,V)). The traffic model performance of system is based on decrease in blocking probability, as the number of channels (V) increases at a constant traffic load in erlang. In order to obtain satisfactory blocking probability, the number of channels must be increased in a proportion to traffic load in erlang.

The second scenario is based on handover traffic model; in Equation 4. This handover traffic model is developed based on the unique future (such as mobility of subscribers) associated with mobile communication. The mobile communication subscribers often experience handover blocking calls, or handover failure calls or handover dropping calls in the network. Therefore, there is need to evaluate the handover block calls experienced by the subscribers during the handover process, using Equation 4. This handover traffic model Equation is design based on assumptions that this total number of channels (V+g) are used by handover calls, handover calls are exponentially distributed and out going handover calls is equal to in coming handover calls. The number of channels V are used by calls within the cell and handover calls, while the number of channels g are reserved for handover calls only.

The Equation 4 is validated using the MATLAB program with low input number of channels parameters in are used Fig 9 and a high input number of channels parameters are used in Fig 10.

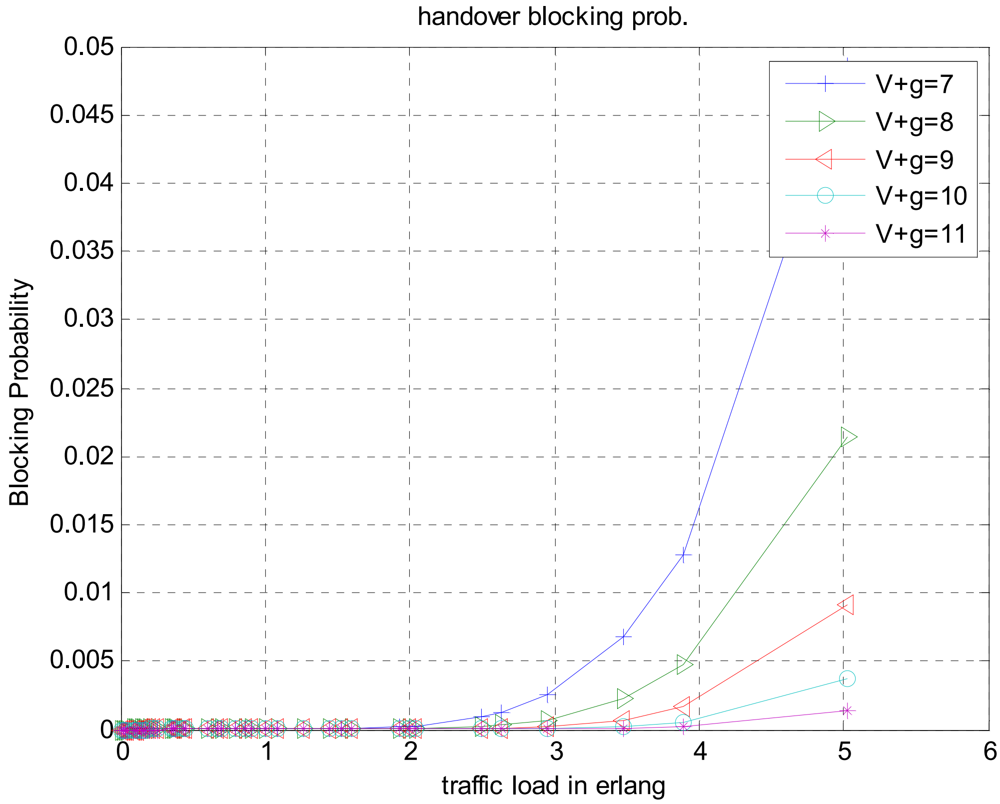

Fig 9 calls handover blocking probability with low number of channels (V+g).

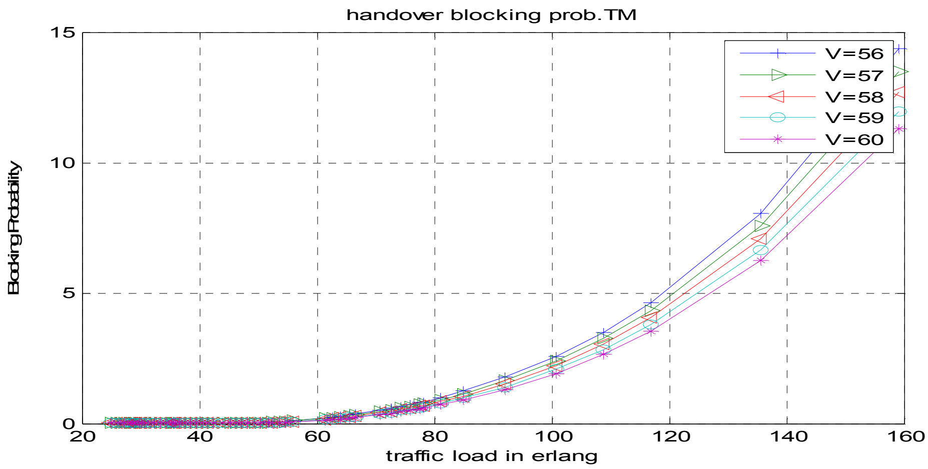

Fig 10 calls handover blocking probability with high number of channels (V+g).

It is observed that handover blocking probability is increased as handover number of traffic load in erlang increases at constant number of channels (V+g) for Fig 9 and Fig 10.

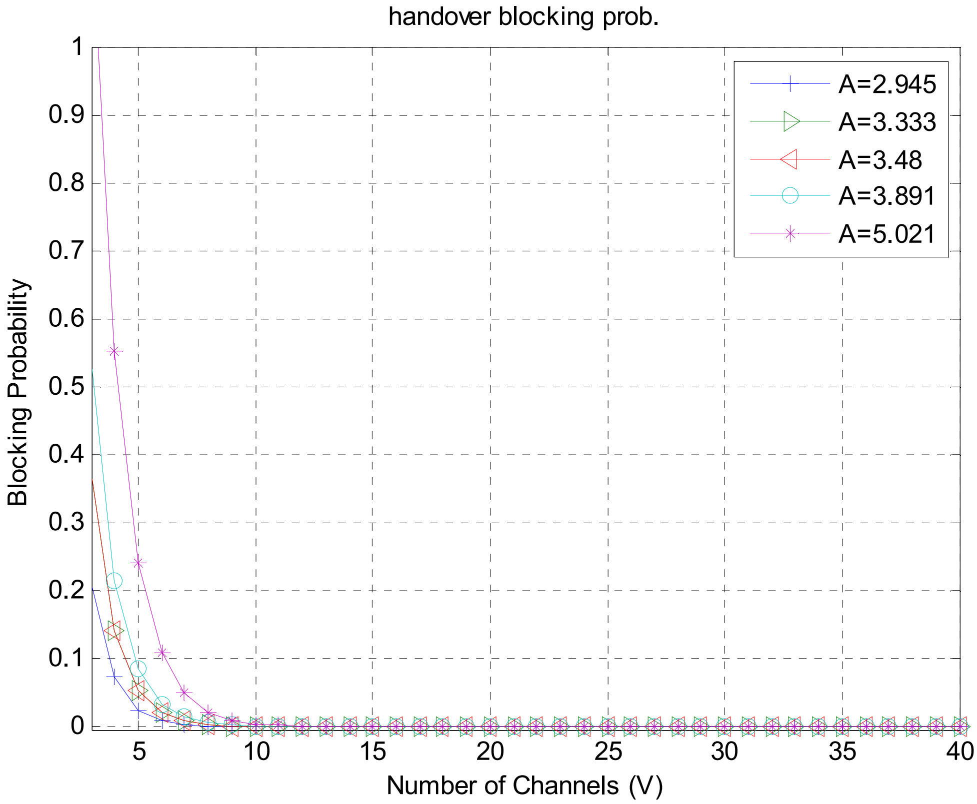

Fig 11 calls handover blocking probability with low traffic load in erlang(A).

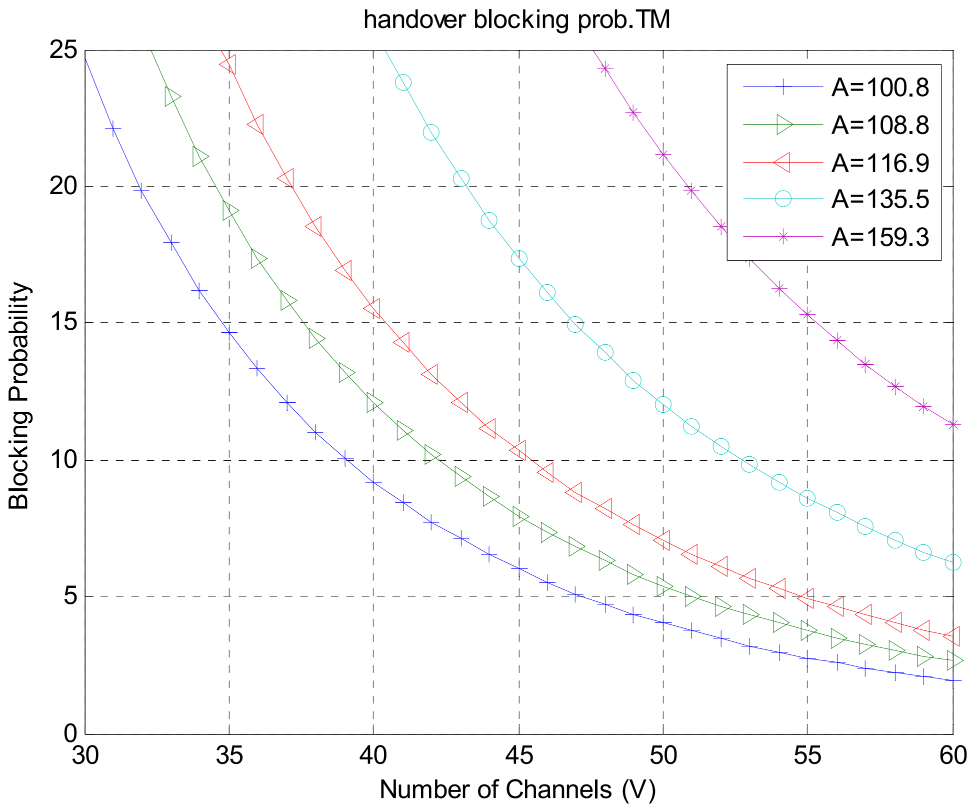

Fig 12 calls handover blocking probability with high number of traffic load in erlang(A).

In Fig 11 and Fig 12, a low traffic load in erlang and a high traffic load in erlang are used respectively in determination of the handover blocking probability with an increasing number of channels. It is observed that at constant traffic load in erlang (A), the system experienced, high number of handover blocking probability before dropping as the number of channels in the system increases.

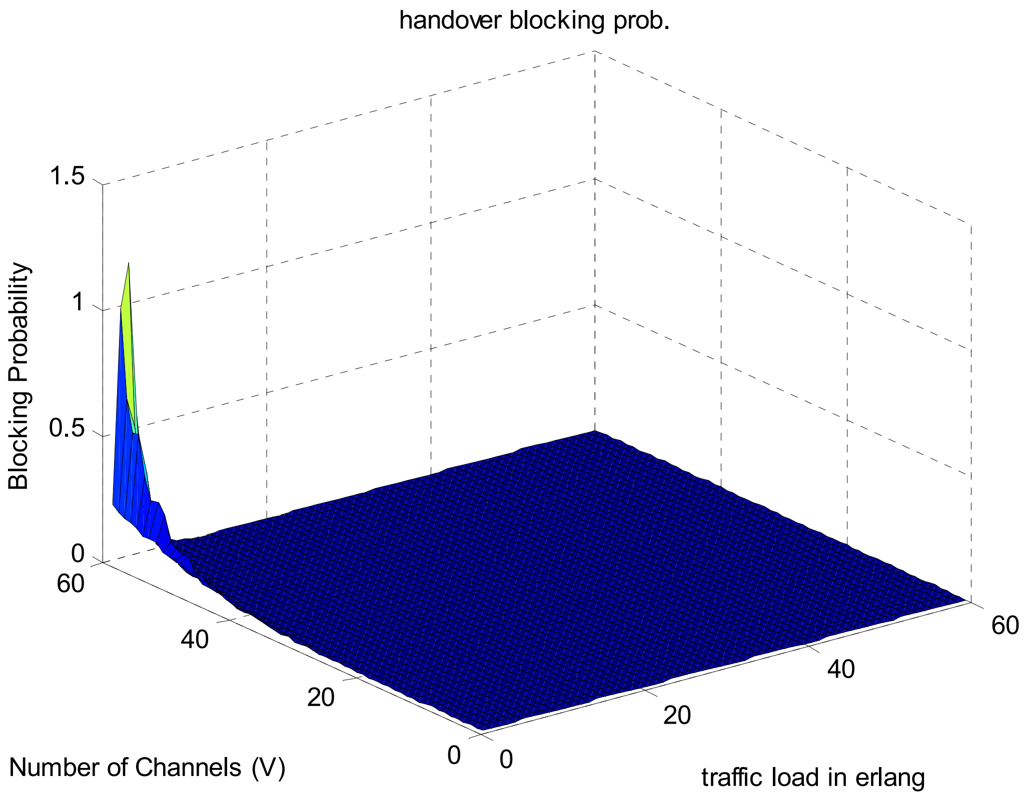

Fig 13 3D calls handover blocking probability.

In Fig 13, the 3D graph shows that handover blocking probability (P_b) on Z-axis is dependent on number of channels (V+g) on y-axis and on traffic load in Erlang (A) on x-axis. The handover traffic model performance of the system is based on function of handover blocking probability (P_b=f (A,(V+g)). The handover blocking probability decreases as the number of channels (V+g) and traffic load in erlang increases. In order, to obtain satisfactory handover blocking probability the number of channels must be increased in a proportion to traffic load in erlang.

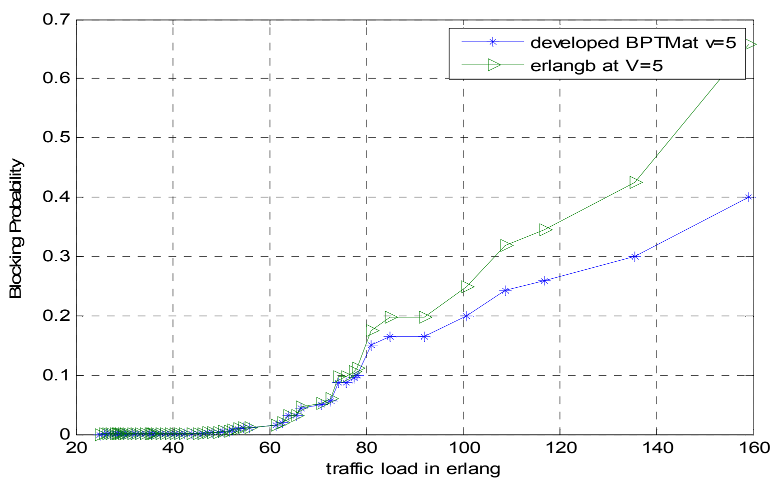

Fig 14 comparison of blocking probability traffic models between Erlang B and developed model (using low number of channels).

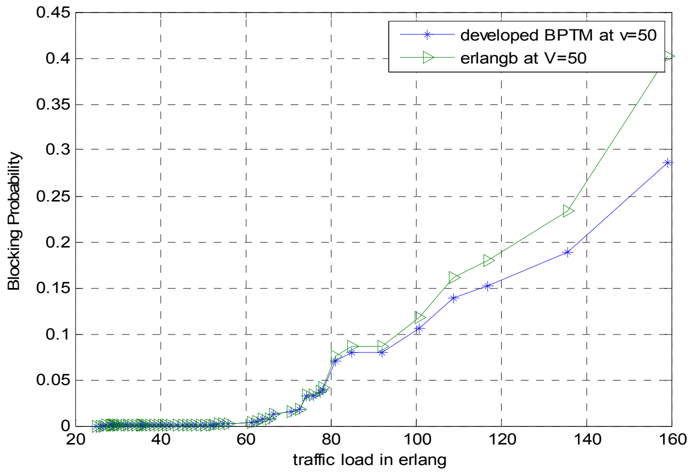

Fig 15 comparison of blocking probability traffic models between Erlang B and developed model (using high number of channels).

The accuracy of the developed traffic model in Equation 3 is compared with the prevailing Erlang B traffic model. These compared models in Fig 5.13a and Fig5. 13b are tested using the same input parameters, both low number of channels and high number of channels to ensure accuracy in the MATLAB program. It is observed in both Figures, that the line graph shows no significant variation due to less traffic load, until when the traffic load in erlang exceeds some certain range. This variation experienced between Erlang B and developed traffic model is due to extra number of channels g reserved for handover calls only. Also, as the traffic load in erlang increases, the blocking probability increases at a constant number of channels V. It is observed, that the developed traffic model has lower blocking probability compared to Erlang B, this is based on the extra number of traffic channels reserved for handover process.

The significant of these traffic models (the Erlang B, developed traffic model etc) are used to determined the number of channels required to carried or serve a certain traffic load in erlang in a particular geographical location (example are campus, highway, residential area, industrial estate etc) within a recommended (2%) blocking probability. The effect of high blocking probability, will leads to poor Quality of Service (QOS) resulting in high block calls experience in mobile communication network. Zero blocking probability, will also leads to wasteful of expensive channel resources in mobile communication network. Therefore, traffic model is used to manage, a balance relationship between cost incurred by mobile communication operators and service render to the mobile subscribers.

Conclusion

The analytical method is deployed in the developed blocking probability traffic models using queue theory with markov transition steady state diagram. These traffic models is designed based on these following assumptions, that interarrival rate is exponentially distributed, service time is exponentially distributed, no calls is loss when any of channels are idle, the number of channels are serve in order of First Come First Serve (FCFS), The number of channels is classified into two groups V and g, where the V channels are used by both calls within the cell and handover calls. While g number of channels is reserved for handover calls only.

These developed traffic models are validated using MATLAB program .Different range of values are the used for both number of channels and traffic load in erlang to ensure accuracy. It's observed from the graphs, the function of blocking probability dependents on the traffic load in erlang and the number of channels used in the system. The developed blocking probability traffic model is compared with Erlang B traffic model, having a significant result.

The significant of these traffic models (the Erlang B, developed traffic model etc) are used to determined the number of channels required to carried or serve a certain traffic load in erlang in a particular geographical location (example are campus, highway, residential area, industrial estate etc) within a recommended (2%) blocking probability. Therefore, traffic model is used to manage, a balance relationship between cost incurred in mobile communication by operators and service render to the mobile subscribers.

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