Performance Analysis for Data Service in Mobile Telecommunication Networks

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Abstract

Wireless networks are becoming more and more popular and traffic over the networks is growing rapidly. Because the network infrastructure is expanding at a quick pace, especially the wireless Internet growth , both in size and in the types of applications, the performance issue and dimensioning issue of networks are becoming more critical. New wireless data applications are emerging over mobile telecommunication networks. These applications produce data that may have different characteristics from those of wired dada applications. In this case, a good evaluation of performance measures can help a system designer to make its strategic decisions concerning cell size and the number of channel frequencies allocated to each cell. In this paper we present a data services analysis in a mobile telecommunication networks based on simulation. In addition, we illustrate the need for a simulation in order to characterize the mix of several traffic types for capacity and quality of service (QoS) planning. We use the Pareto and heavy tailed Weibull distributions to simulate the data traffic and the resource occupation time for data service, respectively. Finally, we also comment some simulation results of third generation services where we analyze the QoS parameters of a mobile network, such as channel occupation time, handoff, new call blocking probabilities and traffic in Erlangs.

Keywords

Mobile Networks, Data Service, Third Generation, Quality of Service

1. Introduction

In the last decade mobile services have been experiencing an accelerated growth. One of the driving forces of the next generation of wireless communication and computing networks is the promise of high-speed multimedia services. The next generation wireless mobile networks, known as third generation (3G) mobile telecommunication systems, should take into account a variety of services (voice, data, video) and environments (e.g.: private, outdoors, indoors) as well as the user mobility behavior. The great difference between the next and the current networks is their ability to provide higher-rate data service, which are expected to fuel a mobile device of new application. Third generation systems, such as Future Public Land Mobile Telecommunication System (FPLMTS or IMT-2000) and the Universal Mobile Telecommunication System (UMTS), promise to provide multimedia services to mobile and fixed users via wireless access to the global telecommunication infrastructure [1, 2, 28, 31, 36]. The UMTS idea is to enable Mobile Users (MUs) to access differentiated services of *'anywhere'*, and *'anytime'*, using a single telecommunication device.

The cellular mobile networks evolution, pushed by a rapidly increasing number of subscribers, began in the field of telephony. Nevertheless, the mobile networks evolution also followed a second path: the packet radio networks for mobile data communication. These networks provide packet oriented data transfer to and from a mobile station. In addition to the integration of speech and data services, the ongoing network evolution progress is directed towards personal communications and mobility. Building integrated services mobile networks can be realized either by improving the service profile offered by existing cellular systems, or by adding air interfaces to existing wired networks.

Traffic modeling in wireless telecommunication system has to deal with two main issues, the Radio Resource Management (RRM) scheme and the effect of the user mobility on the traffic volume per cell [17, 25]. Data traffic in wireless telecommunication networks is emerging as one of aspects more important in third generation networks planning [16, 19, 37, 38]. Moreover, a mix of several traffic types of different services has required more resources and QoS planning. Therefore, from the telecommunications point of view we can model the different traffic types, such as voice and data traffic based on their behaviour.

Wireless data applications produce data that may have different characteristics from those of wired data applications and wireless voice data [21]. This article describes the data service in mobile (cellular) telecommnunication networks and it presents simulation results, using the simulator 'Simula2' [33, 34, 35], which take into account the self-similarity [7, 24, 29, 30] of the network traffic. We use the heavy tailed distributions Weibull and Pareto [20] to simulate the data traffic and the resource occupation time for data service, respectively. Basically, these distributions were used according to mobile traffic data studies from browser application that were measured on the cellular network of Bell Mobility in the Quebec and Ontario areas [3]. [9] studied the traces collected and he found that WWW traffic had the self-similarity nature. In addition, he also found that the distributions that better depict the real behaviour observed were heavy tailed. Specifically, the transmission time and document size distribution versus number of requests were Pareto.

The simulation provides simple analytical results regarding the traffic of different services and also provides means to estimate the following parameters:

- telecommunication traffic volume,
- telecommunication traffic intensity,
- handoff blocking probability,
- call blocking probability, and
- channel occupation time.

When a MU wants to communicate with another MU, it must first obtain a channel from one of the base stations that hears depending on signal power. If a channel is available, it is assigned to the user. In the case that all the channels are busy, the new call is blocked. This kind of blocking is called new call blocking and it refers to blocking of new calls. On the other hand, the procedure of moving from one cell to another, while a call is in progress, is called handoff. While performing handoff, the MU requires that the destination cell base station will allocate it a channel. If no channel is available in the new cell, the handoff call is blocked. This kind of blocking is called handoff blocking and it refers to blocking of ongoing calls due to the users' mobility [37]. Basically, the new call and handoff blocking probabilities is that allow to determine the cellular networks QoS.

In addition, the traffic volume and intensity, and channel occupation time are also parameters that will allow to evaluate the system behavior and the resource utility. The time interval that a call is keeping busy a channel or a set of them is called channel occupation time. Then the traffic volume may be defined as the sum of the channel occupation time. The traffic intensity is a measure of the one channel average occupation during a specified time period, normally a busy hour, measured in traffic units (Erlangs[1]). This is a dimensionless quantity and may be used to measured the time utilization of single or multiple channels. The results are obtained by assuming that voice and data service are available, while user moves.

The paper is organized as follows. In Section 2, the simulation organization and simulator characteristics are described. Simulation results and implications on QoS planning are given in Section 3. Finally, the conclusions and future directions, towards to the third generation systems are presented in Section 4.

2. Simulation Organization

We used the Manhattan Model [6, 26] that perfectly serves ours needs, and because of its simplicity, allows us to track hundreds of thousands of MUs. The square grid has 12.8 Km sides. The streets are spaced every 128 meters, and are numbered 0, 1, 2,...N, with each one accepting traffic in both directions. Speed of the MUs is controlled independently for the inner and the outer strees, typical values being 30 and 50 Km/h respectively. All cells have the same area, are circular and spread having minimum overlapping areas. The program allows us to define several areas within the city, which we call *regions of interest*. For implementation purposes we have limited these areas in:

- Traffic
- Residential
- Business
- Shopping
- Park/Lake

The information entered can then be stored, allowing us to have several different templates for simulation purposes. Hence it is possible in the simulator to create as many MU categories as needed, and divide the whole population among the categories such as to reflect a real situation.

When the MUs are created within a simulation, the program randomly assigns one Home location and one Work location for each MU. We can also built timetable to schedule the MU's activities, which are

[1] Erlang or Erl corresponds to measured unit that determine the occupation rate of a channel, for example: to use a channel of 1 Erl means that the channel is been used in its maximum capacity all the time.

used for traffic simulation. These timetables are defined using a simple ASCII editor. A typical example is shown on Figure 1.

```
CAT 1  ;24 delivery boy
CALLDIST POISSON 14 5
RECDIST POISSON 10 10
SPEED +10 5
SERVICES
;voice, 1 channel, exponential distrib. w/ mean= 80s, 90% of the connctions
Voice VOICE 1 EXPON 80 90
;www, 2 channels, weibull distrib. w/ mean= 180s, 9% of the connections
WWW DATA 1 WEIBULL, 180 PARETO 1000 9
;video, 4 channels, exponential  distrib. w/ mean= 3600s, 1% of the connections
Video DATA 1 EXPON 3600 PARETO 1000 1
MOVETABLE 0
00:00 24:00 ARnd
;-------------------------------------------------------
CAT 2   ;Common worker
CALLDIST POISSON 14 8
RECDIST POISSON 14 10
SPEED 0 10
SERVICES
Voice VOICE 1 EXPON 80 75
WWW DATA 1 WEIBULL 180 PARETO 1000 20
Video DATA 1 EXPON 3600 PARETO 1000 5
MOVETABLE 0
00:00  04:00 Home 98 ARnd 02
04:00  07:00 Home
07:00  12:00 Work
12:00  13:30 Work 75 Busi 20 Shop 05
. . .
;-------------------------------------------------------
CAT 3  ;Housekeeper
LIKE 2
SERVICES
Voice  VOICE 1 EXPON  80  80
WWW DATA  1 WEIBULL 180 PARETO 1000 15
Video  DATA 1 EXPON 3600 PARETO 1000 5
MOVETABLE 0
00:00  04:00 Home 98 ARnd 02
04:00  14:00 Home
14:00  18:00 Home 50 Resi 25 Shop 25
. . .
;-------------------------------------------------------
CAT 4  ; Taxis
CALLDIST POISSON 18 6
RECVDIST POISSON 13 20
SPEED +5 5
SERVICES
Voice VOICE 1 EXPON 80 80
WWW DATA 1 WEIBULL 180 PARETO 1000 10
Video DATA 1 EXPON 3600 PARETO 1000 10
MOVETABLE 0
00:00  07:00  Home
07:00  08:00  Busi
08:00  09:00  Resi
09:00  10:00  ARnd
. . .
```

Figure 1. *Timetable* **with location probability distribution given for 4 different MU categories**

In the Figure 1, we have 4 MUs categories. The originating and the receiving call distributions can be defined by the words CALLDIST and RECDIST respectively. For each category we can also define different services and its connection average. These services can be voice, data or video. Each service has different requiring of bandwidth. To determine the bandwidth that will be used by each service, a different channel amount for each one has been allocated (i.e., two channel to WWW service and four channel to video service). To determine the traffic volume over the area under study, we define that:

- On voice service the call arrival process is assumed to be Poissonian while the call duration is exponentially distributed.

- On data service the call arrival process is assumed to be Pareto while the call duration follow the heavy tailed Weibull distribution.
- On video service the call arrival process is assumed to be Pareto while the call duration is exponentially distributed.

To handle the handoff request we used the Priority II model, defined in [18], that considers handoff queue. In [23, 24] and in numerous other studies [7, 10, 11] network packet traffic appears "similar" when measured over a wide range of time scales. That is, the network traffic looks the same when measured over time intervals ranging [13]. Data traffic of this type is said to be *self-similar* or *fractal* in nature [23, 24]. Self-similar traffic is very different from both conventional telephone traffic and from the currently accepted norm for the packet traffic model.

An important parameter of a self-similar process is the Hurst parameter H. It is a parameter used to describe the degree of self-similarity and it can be estimated from the variance of a statistical process. Self-similarity is implied if $0.5 < H < 1$. We used one graphical method to test the self-similarity of the traffic: variance-time plot [4, 29, 24].

For the variance-time plot, the process is self-similar if the estimated asymptotic slope $\hat{\beta}$ is between -1 and 0. The Hurst parameter can then be estimated as $\hat{H} = 1 - (\hat{\beta}/2)$. We estimated the H value for one cell sample. The asymptotic slope estimated is aproximately -0.25, resulting in an estimate $\hat{H} \approx 0.88$ of the Hurst parameter. This method suggests that the traffic sequence is self-similar.

The self-similar process has been constructed by superimposing several processes *on/off*[2], where times between arrivals has a heavy tailed distribution It has influenced the blocking rate. So the Poisson process used to model the voice service requests arrival started by users, was not the same to the web documents arrival in a server. Since the transmissions of WWW and video documents are not completely started by user. For instance, a web page often contains several images and when user demands one of these pages the browser automaticaly generates a lot of additional requests to read these images. Therefore the blocking rates of WWW and video services were bigger than voice service due to the used model, which allows to simulate another additional request needed to provide these type of services. Power-tails distributions have been used to model network traffic behavior [15].

Intuitively, we consider heavy-tailed distributions as models for possibly large values in a sample. Such models have been taken as basis for more sophisticated models in teletraffic data transmission [14, 32]. In certain applications, in particular in queueing theory, more structure for the distribution tail is needed. The Pareto distribution is characterized by a linearly increasing mean excess function. In addition, it has finite mean, infinite variance, and it has been used to model traffic having fractal characteristics [30].

The data traffic from the wireless network is modeled by Pareto distribution, where the traffic is generated by use of distribution inverse function. Once WAP (Wireless Application Protocol) data service has quickly developed [22], we have obtained from a wireless carrier of this service the average data traffic in the network. In this case, the average data traffic has been used in the simulation is 1.52kbps.

Heavy-tailed service times, has been researched in [5, 14]. Specifically, in [5] has been proved that when the service time is lighter than the tail of a Weibull distribution with parameter $\beta = 0.5$, the number of arriving customers comes into the picture as well. Then the number of customers combination and the likely large service time the queue-length large.

[2]The periods *on* correspond to the web files transmission periods and the periods *off* correspond to the periods where the server is not receiving data.

The resource occupation time for data service is modeled by another heavy tailed distribution, called Weibull distribution. In the case of our simulation, we used the method of sucessive projections [8, 12, 27] to estimate the shape parameters. Thus the Weibull distribution inverse function has been used to generate the occupation time with average of 2.52 minute ($\approx$ 180 seconds).

3. Simulation Results

The simulation tool model both the traffic and users mobility behaviour offering ability to consider different service types and different MU categories. Morever, it allows to estimate the blocking propability and the radio resource utilization. In particular:

- Voice and dada service are available anywhere.
- New calls and handoffs are differently treated.
- We consider 162 channel per cell.
- The Simulation time is 24h.
- The Timeout to handoff queue is 2 seconds.
- The increase of the signal power occurs to 50 meters of cell's boundary.
- The Mean call from the originating and receiving rate for categories 1, 2 and 3 is 0.9 calls/hour/MU.
- The Mean call originating and receiving rate for category 4 is 1.7 calls/hours/MU
- See Table 1 for the distribution of MUs among categories. The mobility parameter in the third column gives the time percentage that MU moves into the simulator period.

Category	***% of UMs***	***Mobility (%)***	***Description***
1	18.2	90	24h delivery boy
2	35.3	50	Common worker
3	26.3	30	Housekeeper
4	20.2	60	Taxis

Table 1. Categories and the MUs distribution

- The Mean duration for voice service is 120 seconds, for data service is 180 seconds, and for video service is 3600 seconds.
- The MU speed varies between 30 and 50 km/h

Although, we are exploring data traffic for 3G systems, we use 162 channels per cell, a parameter used by 2G mobile systems, just for reference. The results are easily extended for a greater number of channels that it is expected in the next generation. The bands of 25MHz are divided into channels of 30 KHz, that give us 416 duplex channels, with 21 for control. We apply a reuse factor of 7, for the 395 remainder, then we have 56 channels per cell. There are 3 time slots per carrier, that gives a service capacity of 168 channels or user per cell. Depending on the interference between channels, for example, this number can be decreased (54 x 3 = 162). In the case of GSM (Global System for Mobile Communications) we could consider until 192 channels per cell (3 sectors, 8 carriers per sector, 8 slots per carrier).

Figure 2 shows the influence of the number of MU in the effective channel occupation time with different variations of reserved channels to the handoff procedure. We see that when the number of MUs is increased, this will mean that more calls being held by each cell, leading to a better channel occupancy. Relatively, we can also note that a variation on number of reserved channels to handoff does not interfere in the channel occupation time.

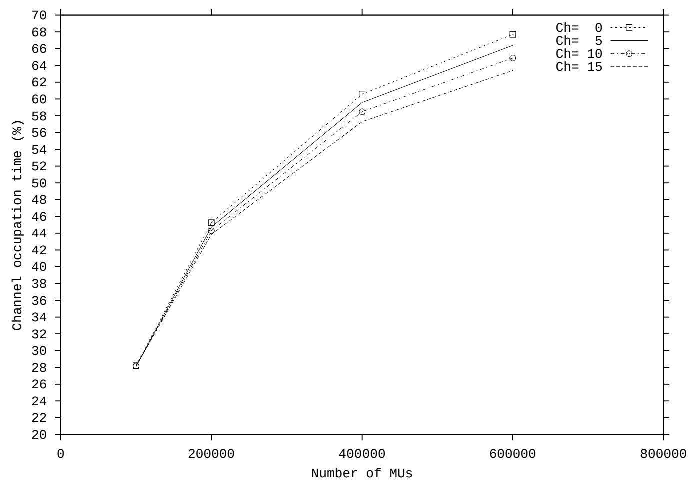


Figure 2. Channel occupation time in 3G telecommunication networks per number of MUs per cell (30/50km/h)

One of the main parameters used to measure QoS (Quality of service) is the blocking probability, i.e., the number of calls rejected because of lack in channel capacity. In practice, this value should not exceed 2% for new calls. In Figure 3 we observe that when the number of channels to handoff is increased, the new call blocking probability also raises. If we compare the new call blocking probability between 3G and current telecomunication networks, we could note a high blocking probability in 3G network. This happens because the same channels of current networks are used in 3G networks to move beyond of voice service, the video and data services. This implies in a larger resources consumption.

Specifically, there is a reduction in the number of channels available to answer new calls in the system in such way to attend the requests of handoff. If we consider that the number of MU has a tendency to remain either constant or increase, the new call blocking will increase. On the other hand the MUs can perform more handoff, but also the QoS of the network is damaged.

Figure 4 shows a new call blocking probability per service (voice, video, WWW), changing the number of reserved channels to handoff. We can note that the WWW and video services blocking rates are greater than voice service blocking rate when the number of reserved channels to handoff increases. This result may be explained by the fact that video connection requires a larger resources amount to maintain the minimum QoS and the connection percentage is small. On the other hand, for the WWW service, the resource amount necessary is smaller than the video resources, but the connection percentage is bigger.

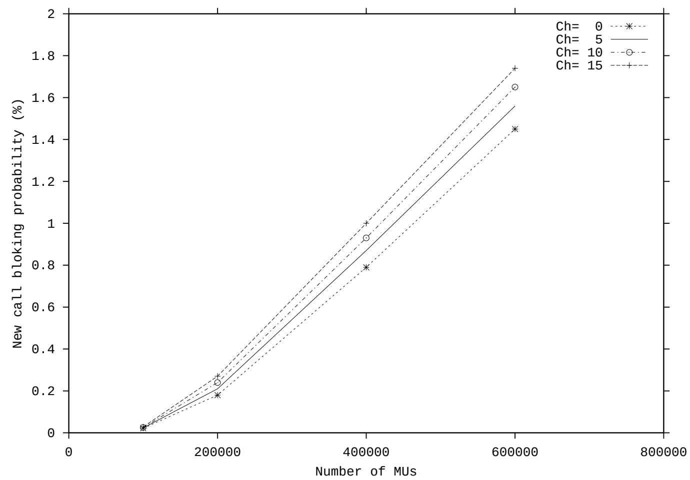


Figure 3. New call blocking probability in 3G telecommunication networks per number of MUs per cell(30/50 Km/h)

Besides that, the 162 available channels to meet the new calls demand are decreased in the same amount of with the reserved channels to handoff. In addition, the low blocking probability of voice service may be explained by the fact that this service uses only one channel for each connection.

The simulator mobility model tries to control a blocking probability per cell around 1%. Considering different number of reserved channels to handoff call, Figure 5 indicates that as the number of MUs increases and the number of reserved channels to handoff decreases, the handoff blocking probability also increases. We can also note that the handoff blocking probability in 3G network tends to 0 when the number of reserved channels to handoff procedure are greater or equal 5.

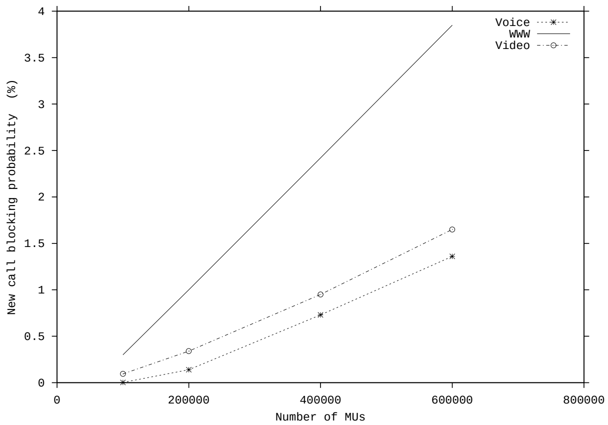
In Figure 6, we analyze the variation of MUs speed fixing the number of channels to handoff in 5. We can note how the MU mobility degree, might influence in the quality of service of the network. We observe that as the MU's speed and the number of MUs increases towards high values, the handoff blocking probability raises.

Therefore, when users move very slowly, the handoff blocking rate tends to zero. In this case in the very low mobility environment, the probability that a call will need to perform one handoff is negligible. On the other hand, when users move very rapidly, the rate of handoff blocking tends to increase as shown in Figure 6.

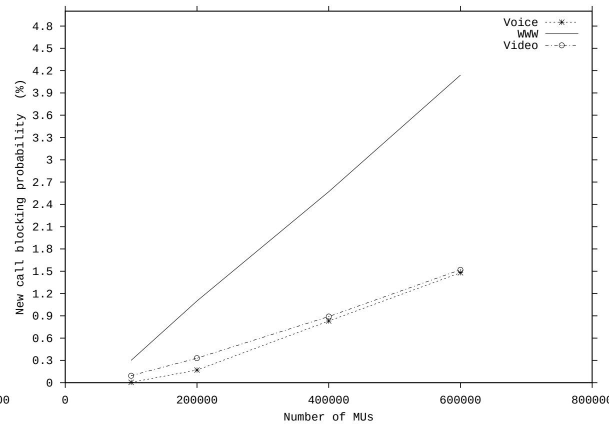
Figure 7 shows the handoff blocking probability in 3G network per service with MU speed between 30 and 50 Km/h, changing the reserved channels to handoff. When the number of reserved channels to handoff is increased, the blocking probability reduces. In this case, the number of MUs must remain unchanged.

We also see that both voice and WWW service blocking probability tends to 0 for handoff channels greater or equal 10. While the video service blocking probability tends to $2.0 * 10^{-5}$, so it require larger resources amount, in agreement with established criteria in the simulation.

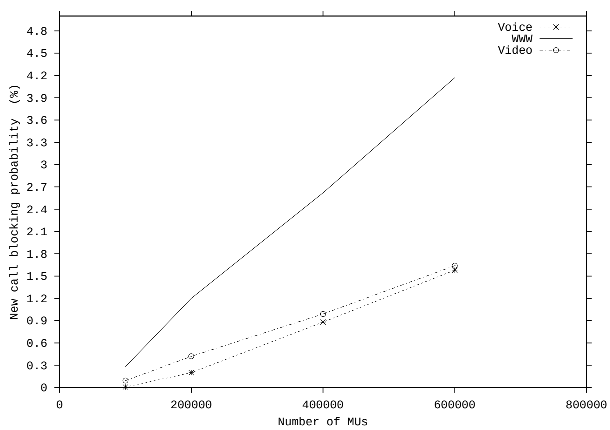
Figure 8 shows the carried traffic (in Erlangs) per cell. In this case, we vary the number of reserved channels to handoff procedure. We can note that rising the number of handoff channels, the carried traffic tends to decrease. This result can be explained by the fact that the number of channels to serve



(a) Ch. Handoff = 0



(b) Ch. Handoff = 5



(c) Ch. Handoff = 10

Figure 4. New call blocking probability in 3G telecommunication networks per type of service per cell(30/50 Km/h)

new call is decreased, while we increase the number of reserved channels to handoff.

If we vary the MUs speed as is showed in Figure 9 and fix the number of available handoff channels in 5, then we observe that, independent of MU speed, the carried traffic (in Erlangs) keep unchanged as we can note by superimposing the curves.

Specifically, when we increase the number of MU at system the carried traffic varies clearly. On the other hand, a increasing in the number of available channels to handoff procedure, causes a reduction in the number of available channels to new call, but also there is a reduction of the performed handoff number. In this case the traffic volume remains stable, but also there is no guarantee of quality to users who are demanding access to the services.

Figure 10 shows the carried traffic (in Erlangs) to 3G networks per category of MU with *inner/outer* speed 30/50 Km/h with variation of the reserved channels to handoff. We can note that the carried traffic

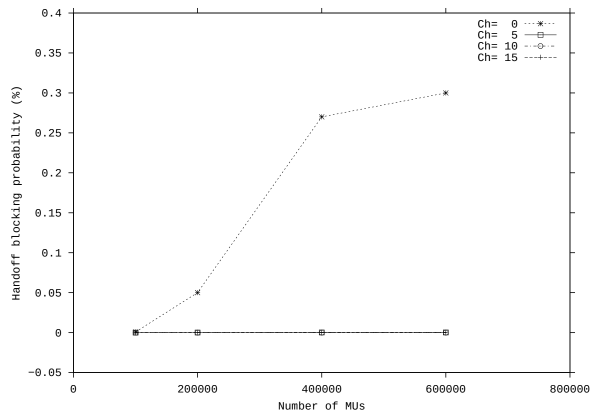


Figure 5. Handoff blocking probability in 3G telecommunication networks per number of MUs per cell (30/50 Km/h)

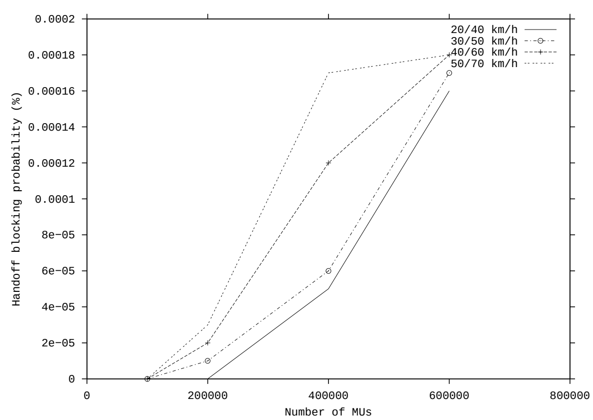


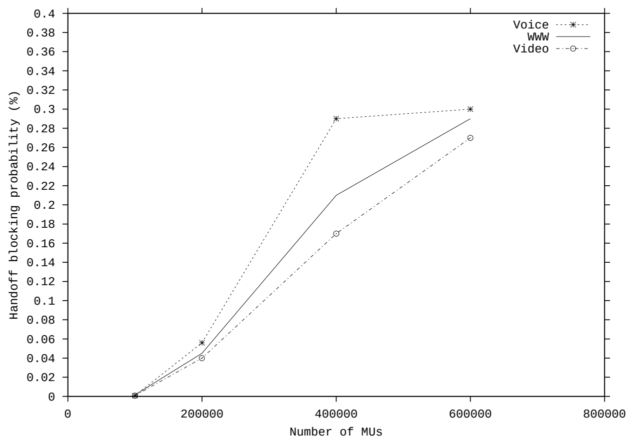
Figure 6. Handoff blocking probability in 3G telecommunication networks per number of MUs per cell changing MU's speed

per category is little influenced by changes in the available channels to handoff.

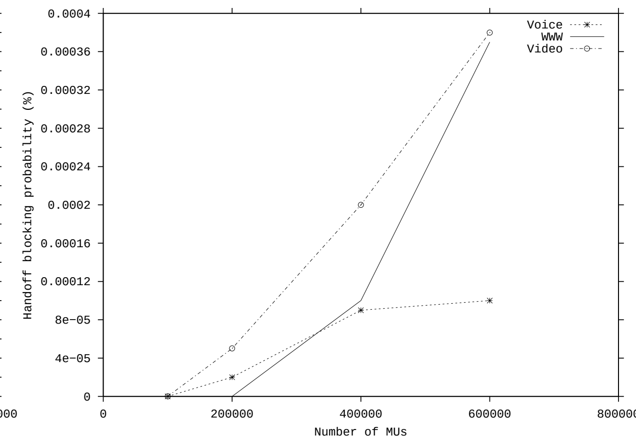
We can still verify that the category 2 (common worker) tends to have a larger traffic, that is delineated by the large number of connections performed to the 3G services for this type of user. This implicates in a rising on channel occupation time, generating a rise in the traffic volume of network.

Figure 11 shows carried traffic (in Erlangs) to 3G networks per service per cell. The number of available channels for handoff procedure is increased and MUs remains with *inner/outer* speed of 30/50 Km/h.

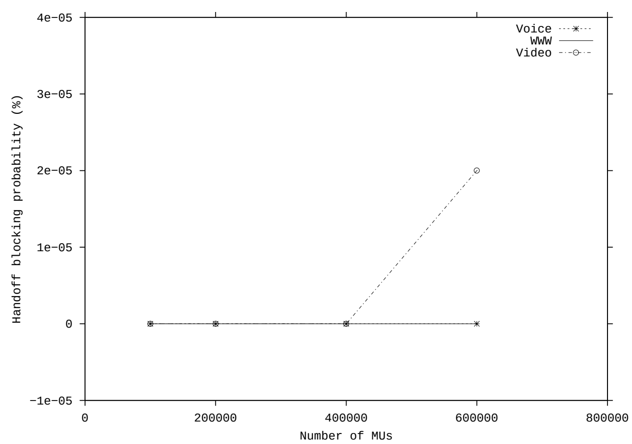
We observe that carried traffic in the network does not depend on available channels to handoff. We still note that the tendency is that the voice service traffic is bigger than the video and WWW services traffic. This happens because a large number of requests is generated by voice services. These requests can use any of the 162 channels for a generated new call, they can decrease when we increase the number



(a) Ch. Handoff = 0



(b) Ch. Handoff = 5



(c) Ch. Handoff = 10

Figure 7. Handoff blocking probability to 3G mobile telecommunication network per service per cell (30/50 Km/h)

of reserved channels to handoff. In this case, the new call blocking probability increases, reducing the traffic volume in the network. This traffic volume depend on channel occupation time, what imply in a reduction of the carried traffic.

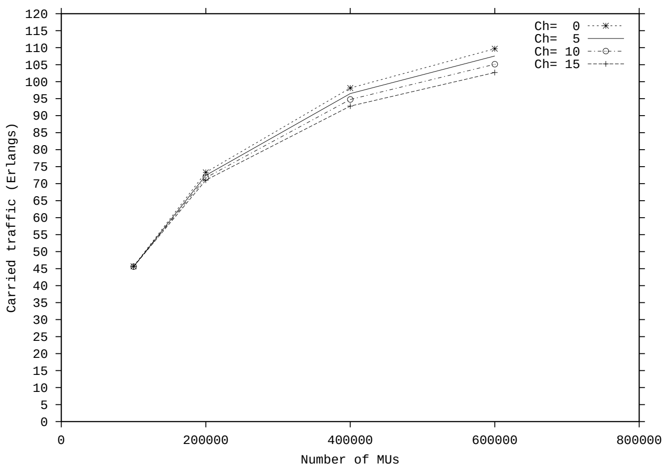


Figure 8. Carried traffic (in Erlangs) per cell to mobile telecommunication networks (30/50 Km/h)

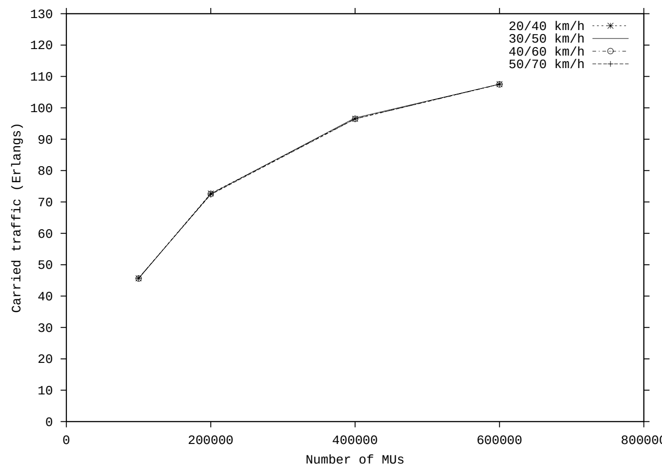
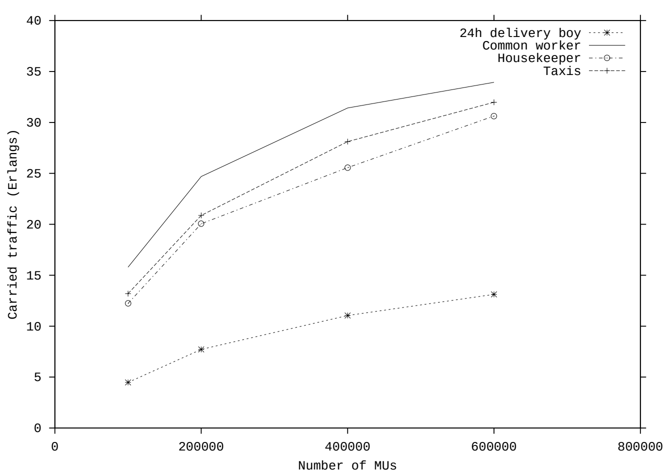
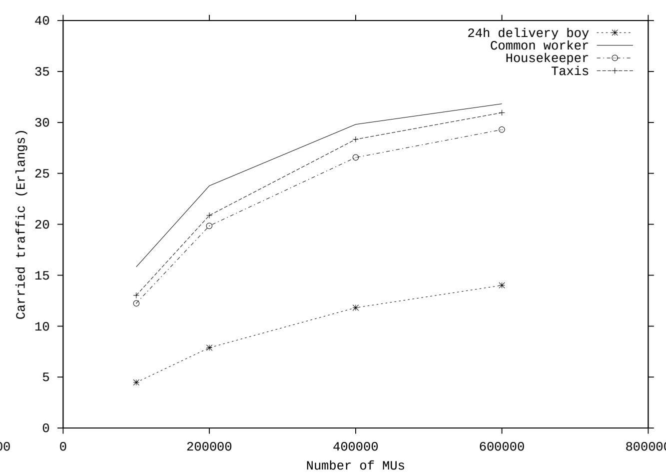


Figure 9. Carried traffic (in Erlangs) per cell to mobile telecommunication networks for different MUs speeds

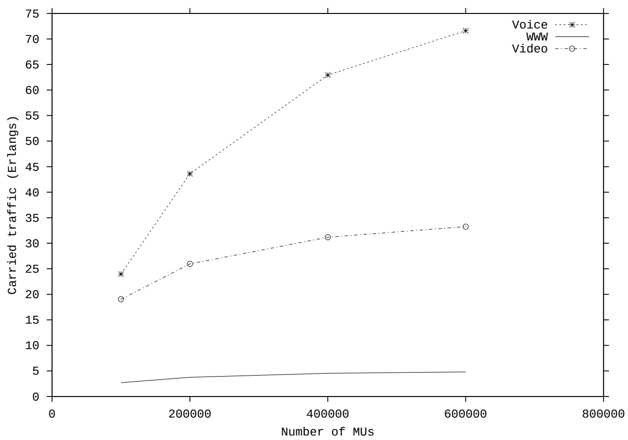


(a) Ch. Handoff = 0

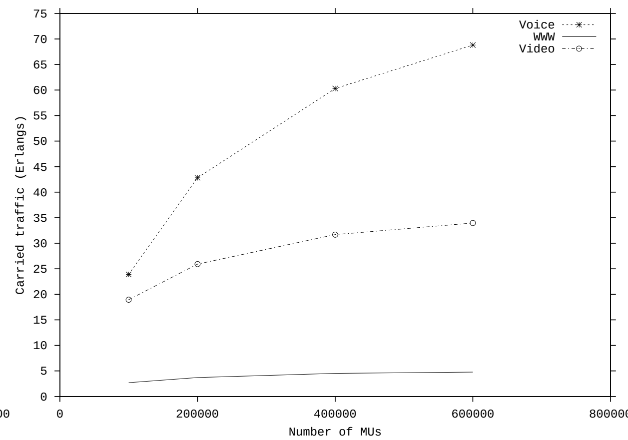


(b) Ch. Handoff = 5

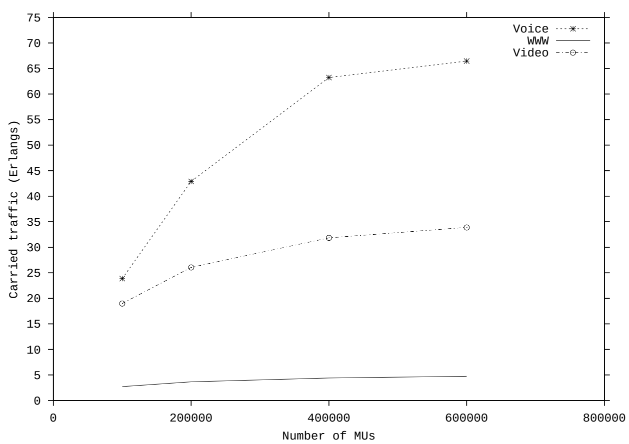
Figure 10. Carried traffic (in Erlangs) per category per cell to mobile telecommunication networks



(a) Ch. Handoff = 0



(b) Ch. Handoff = 5



(c) Ch. Handoff = 10

Figure 11. Carried traffic (in Erlangs) per service per cell in 3G mobile telecommunication networks (30/50 Km/h)

4. Conclusions

In this paper we have presented a performance analysis of mobile telecommunication networks, using a simulator. We have considered some parameters, such as new call and handoff blocking probability, carried traffic (in Erlangs), and channel occupation time that make possible evaluate the mobile networks QoS. Traffic analysis for future mobile systems should take into account a variety of services (voice, data, video) and environments (e.g.: private, outdoors, indoors) as well as the user mobility behavior.

The simulator presented in this paper incorporates all the above mentioned features, besides it considers the self-similar network traffic (in this case we have used the heavy tailed distribution to simulate data traffic self-similarity). In the case of the voice service: the call duration has been exponentially distributed and the arrival process of new calls have been Poissonian.

These results clearly show that the mobility directly influences in the network quality of service and that the different available types of services depend on other issues as carried traffic, bandwidth, etc. These features are essential part of mobile communication system design. Each type of traffic has different characteristics. Then, the capacity planning becomes a hard task with a variety of data applications, such as Internet access, email, file transfer, and with a variety of data rates and mix of traffic. Hence, in 3G network planning is crucial to use capacity planning techniques which give accurate results, because it directly affects the number of cells required to serve a given area. The simulation is one of the aspects that make possible the wireless provider to prepare for 3G wireless networks.

In addition, each application has its own special requeriment for data transport, some requiring high data rates e others, for example video, requiring time-bounded data transport, i.e. low delay. It is important that the implications of these requirements are well understood so that the wireless connection can meet the relevant requirements. In our work, we considered that each service has a minimum requiring to effective a user connection. This minimum requiring has based in the number of channels. In this case, the traffic for each cell and the call blocking have clearly depended on type of service.

Based on the knowledge of the traffic for each cell, the number of traffic channels and hence transceivers can be determined. In addition to normal calls, handoff requests also require radio resources. In a real network, the number of handoffs per call is dependent on the length of the calls as well as the mobility pattern of the users. The contribution of handoffs to the total traffic loading is difficult to predict and is normally assumed as an acceptable overhead to a system. In the future work, we intend to detect an high handoff volume in a cell. In this case techniques will have be taken to bring it under control. Specifically, we could change the handoff thresholds and reduce the overlap between adjacent cells.

Moreover, future research must focus on methods to reduce the blocking probability and to maximize the utilization of the bandwidth according to the traffic and type of service. Priority techniques must be included in the simulator to consider QoS constraints and dynamic channel allocation tecniques. We can still define techniques to predict possible co-channel interference caused by reusing frequencies, in this case we can use network optimization techniques in the simulator.

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