

Impact of Service and Mobility Modelling on Network Dimensioning

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ABSTRACT

Objective of this work is to investigate the accuracy of network dimensioning in two different aspects. The first case is in terms of source modelling of different services of modern communication systems and second being with respect to mobility modelling distributions used in past and present networks. Finally impact of service and mobility modelling accuracy is investigated in network dimensioning aspects. First issue compares the impact of different burst distributions on MAC performance in Email sessions and WWW browsing applied to an example GPRS MAC mechanism. The results conclude high delay in Cauchy Email connection sizes and Pareto WWW burst sessions compared to exponential connections / bursts. Also this delay increase is mainly due to the congestion occurred by different types of bursts / connection distributions. Therefore the bursty traffic such as WWW browsing which demonstrates self-similarity at the aggregate level influence the MAC protocol performance than in traditional traffic models. As network dimensioning has to be carried out per cell basis, the residence time has great influence on the aggregate traffic. There are many work reported in the literature concerning the distribution of residence time in the cell. In the second issue investigation of the accuracy of common assumption of exponential cell residence times and the effect of that on channel holding time in terms of capacity evaluations is also studied. This work concludes cell residence time follows a shifted Gamma distribution not assumed as exponential distribution. Also the parameters of this shifted Gamma distribution relates to the user mobility variables velocity, cell radius and handover margin. It is revealed the assumption of exponential cell residence times underestimates the capacity. This diversity calls up rethinking of resource management issues and network dimensioning area.

1 INTRODUCTION

Future and present mobile networks carry significant amount of traffic due to non-voice services such as Email sessions, WWW browsing and other interactive services. Also recent traffic measurement findings and modeling of these services argue for different burst distributions diverging from traditional exponential burst duration models. Section I will compare the impact of different burst distributions on MAC performance in Email sessions and WWW browsing applied to an example GPRS MAC mechanism. The first part focuses on service modeling followed by GPRS MAC architecture and finishing with discussion of results.

Depending on whether a call is originated in a cell or handed over from neighbouring cell, two different cell

residence times can be specified. The new call cell residence time is defined as the length of time a mobile terminal resides in the cell where the call originated before crossing the cell boundary. Similarly, the handover call cell residence time is defined as the time spent by a mobile in a given cell to which call was handed over from a neighbouring cell before crossing to another cell. Due to tractability in analytical methods exponential cell residence times are more common assumptions in the literature. Section II focus on investigation of assumed cell residence times against actual cell residence times in reality. This section comprises of description and analysis of mobility model applied followed by discussion of results. Finally impacts of these assumptions are assessed in terms of *channel holding time distributions and capacity*.

2 SECTION I

2.1 Service Modelling Issues

2.1.1 Email Sessions

The Email sessions are presented by the FUNET model, which is based on statistics collected on Email usage from the Finnish University and Research Network. The probability distribution function $f(x:a,b)$ (Equation 1), of the Email connection sizes can be approximated by a truncated Cauchy ($a=0.8$, $b=1$) distribution with a maximum message size of 10 Kbytes [1]. The average size of the Cauchy Email connection is 830 bytes.

$$f(x : a, b) = \frac{b}{\pi(b + (x - a)^2)} \quad (1)$$

2.1.2 WWW Sessions

WWW session is a characteristic application of hierarchical call architecture. Browsing *session* consists of sequence of *packet calls* and during a packet call several *packets* may be generated constituting a bursty sequence of packets. It is very important to take this phenomenon in to account in the traffic model. This burstyness during the packet call is a characteristic feature of packet transmission in the network. In a WWW browsing session a packet call corresponds the downloading of a WWW document. After the document is entirely arrived to the terminal, the user is consuming certain amount of time for studying the information. This time interval is called the *reading time*. Hence typical behaviour of a WWW browsing model is based on distributions described by session arrival process, number of packet calls per session, reading time between packet calls, number of bursts within a packet call, inter arrival time between bursts and the size of the burst (Fig. 1).

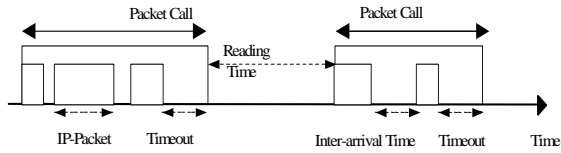


Figure 1. WWW Browsing Session

Modeling of WWW service application follows a Pareto burst size distribution ($a=1.1, b=81.5$), with maximum burst size of 66666 bytes [2]. Probability density function of the Pareto distribution is given in equation (2).

$$f(x : a, b) = \frac{a \cdot b^a}{x^{a+1}} \quad (2)$$

The average burst size of WWW browsing is 480 bytes.

2.1.3 Voice Calls

Voice calls are modeled with exponential call duration of an average of 120s. Equation (3) gives the probability density function of the Exponential distribution with a mean value of $(1/m)$. The arrival of voice calls, Email sessions, and WWW browsing sessions are assumed as a Poisson process.

$$f(x : m) = m e^{-mx} \quad (3)$$

2.2 GPRS Data Communication Architecture

General Packet Radio Service (GPRS) designated to support packet oriented data transmission is an extension of the Global System for Mobile Communications (GSM). Regarding the offered service, GPRS allows the subscriber to send and receive data in an end-to-end packet transfer mode, without using any network resources in circuit switched mode. This allows for autonomous operation of GPRS and best fits the bursty traffic characteristics. Radio communication between the mobile station (MS) and the GPRS network covers physical and data link layer functionality. The physical layer provides services for information transfer over a physical channel between the MS and the network. These functions include data unit framing, data coding, and the detection and correction of physical medium transmission errors [3].

The data link layer has been separated into two distinct sublayers. Radio link control/medium access control (RLC/MAC) mediates access to the shared medium between multitudes of MSs and the network. Packets, which are received from the network layer, are transmitted across the air interface using the logical link control (LLC) protocol. LLC layer operates above the MAC layer. An LLC frame in the RLC/MAC layer is segmented into radio blocks, which are formatted into bursts on the physical layer. Size of the block depends on the applied coding scheme. Each radio block comprises 4 normal bursts in consecutive TDMA frames (Fig. 2).

As a hybrid frequency division/time division system, GSM organizes radio transmissions by assigning carriers and time slots to logical channels. The frame duration is 4.615 ms, and each frame is divided into eight time slots (Fig. 3). A cell that supports GPRS shall allocate one or more shared packet data channels, which are taken from

the common pool of physical channels available to the cell and otherwise used for speech. A physical channel dedicated to packet data traffic is called a packet data channel. The need for efficient use of radio spectrum requires dynamic change of the mix of speech and data channels. It is also possible to interrupt a data transmission to one MS if a high priority service is to be sent to some other MS.

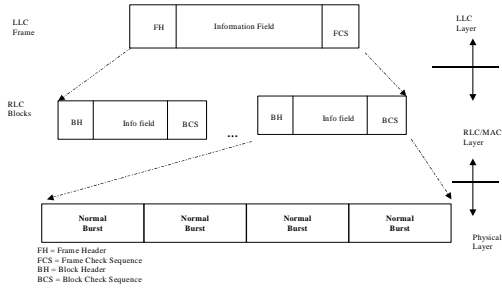


Figure 2. GPRS Radio Block Architecture

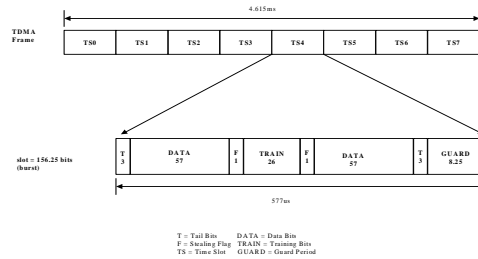


Figure 3. GSM/GPRS Burst Structure

2.3 Simulation Modelling Approach

GPRS cell environment occupying a single carrier is considered. Each TDMA frame consists of eight time slots. Out of these eight slots two slots are allocated for signaling resulting six physical channels to carry traffic across the air interface. In this study voice calls are allocated to the resources as in a circuit switched environment. Once a voice call is arrived if idle channels are available it is given to the voice call for the whole duration of the call. If there are no idle channels available, a data channel is pre-empted and allocated for voice. The voice call is blocked only when all the traffic channels are occupied with ongoing voice calls. The data sessions are given data channels if idle channels are available. If not they will be sent to a queue, which is served in between termination of voice calls or once data blocks have finished their transmission. The performances are evaluated in terms of average throughput, average queue size and average session delay characteristics, defined as follows.

Average Throughput: Average amount of accepted radio blocks that reaches the destination (Kbits/s)

Average Session Delay: Time in milliseconds from the arrival of a data burst at the source until the whole

burst is transmitted at the destination (i.e. this delay includes transmission delays as well as queuing delay of data sessions/bursts)

Average block arrival rate: This is a measure of congestion at the queue for different type of burst distributions. This gives the ratio between average queue size and available resources. The results obtained and the investigation of behaviour of different service modelling distributions on the performance of example GPRS MAC is discussed below.

2.4 Discussion of Results

2.4.1 Email Sessions

The session transmission delay is calculated for different burst size distributions presenting Email service. The first being Exponential burst distributions with an average size of 830 bytes. The second according to the FUNET Email model representing Cauchy burst distributions of maximum burst size of 10Kbytes. Single carrier cell environment is used with six physical channels for traffic.

All the results are acquired for coding scheme 1 (CS1). In addition to data services 1E voice load is also applied. (Fig. 4) represents the average session delay for an Email connection against Exponential and Cauchy burst size distributions.

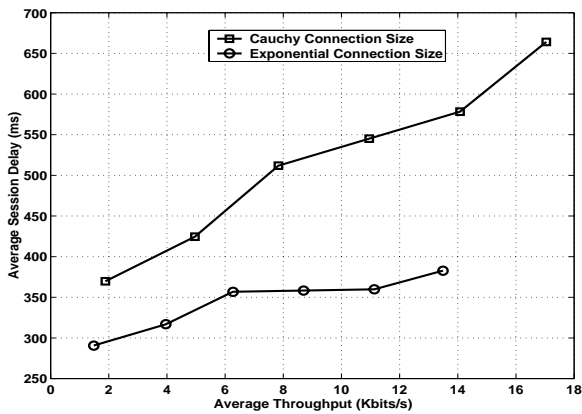


Figure 4. Average Session Delay – EMAIL Connections

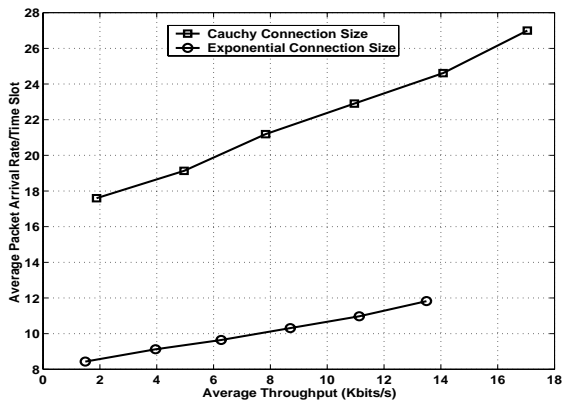


Figure 5. Degree of Congestion – EMAIL Connections

It can be seen clearly for Cauchy Email connection sizes the average session delay is much more higher than that of the Exponential connection sizes. Also with the increase of the throughput the rate of increase of average

delay is also high in the case of Cauchy distributed connection sizes. This presents the positive impact of different distributions, in Email service on performance of GPRS MAC architecture.

This can be validated once look at the congestion level in each situation (Fig. 5). As specified earlier, the degree of congestion is measured by the ratio between average queue size and available resources. It is clearly seen in both distributions (Exponential and Cauchy) with the increase of the throughput the degree of congestion also increases but with a constant rate. Apart from that in Cauchy distribution connection sizes degree of congestion is much higher than that of the Exponential case.

2.4.2 WWW Browsing Sessions

The same is investigated for WWW browsing service and the results are as in (Fig. 6) and (Fig. 7).

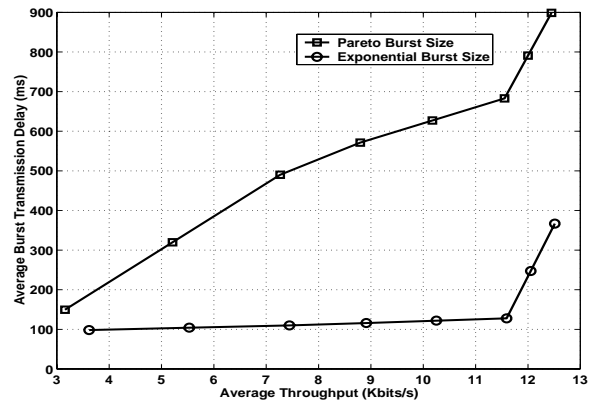


Figure 6. Average Session Delay – WWW Browsing

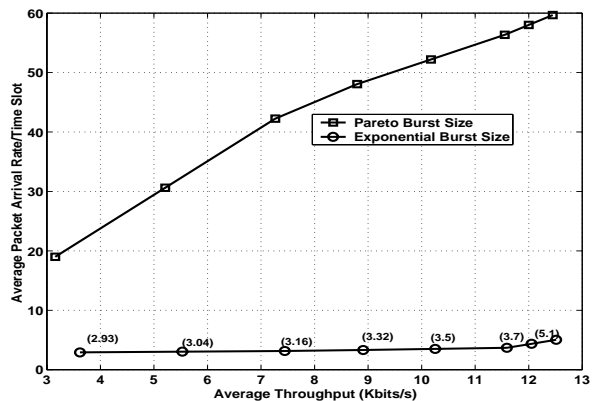


Figure 7. Degree of Congestion WWW Browsing

(Fig. 6) represents the comparison between the average burst transmission delay for Pareto and Exponential burst sizes. WWW browsing illustrates the burstiness behaviour of traffic source modeling. Therefore the impact on average session delay performance is much more higher in Pareto burst sizes than the Exponential burst sizes. This explains higher burst transmission delays compared with exponential burst distributions. The degree of congestion is investigated in (Fig. 7). For bursty traffic such as WWW browsing there is a significant difference in average delay characteristics

than in Exponential burst distribution model. Also the rate of increase of delay is much higher than in the case of Email as well as very high compared with traditional Exponential models. Once the degree of congestion is investigated in burtsy WWW traffic with that of Exponential bursts the congestion level is constant for Exponential bursts even with the increase of throughput. But for heavy tailed Pareto burst sizes the congestion level increases dramatically with the increase of throughput.

3 SECTION II

3.1 Mobility Model Description

This mobility model captures the parameters under most generalized conditions, so it can be tailored to be applicable in most cellular environments. Depending on the street structure, a mobile can move in different paths and may possess different speeds. The extent of a mobile's change in direction and/or speed of mobiles can be considered as equivalent to a change in the average distance travelled or time spent in the cell before moving out. Thus, any increase in a mobile's drift can be treated as contributing to an effective increase in the cell radius. Similarly, any increase in speed of the mobile can be treated as contributing to a decrease in the cell residence time or an effective decrease in the cell size. Depending on whether a call is originated in a cell or handed over from neighbouring cell, two different cell residence times can be specified. The new call cell residence time (T_n) is defined as the length of time a mobile terminal resides in the cell where the call originated before crossing the cell boundary.

Similarly, the handover call cell residence time (T_h) is defined as the time spent by a mobile in a given cell to which the call was handed over from a neighbouring cell before crossing to another cell. T_n and T_h are two random variables whose distributions have to be found. The channel holding time is a random variable defined as the length of time starting from the instant a channel in a cell is occupied by either a new call or a handover call, until the channel is released by either completing the call or handing over to another cell. The channel holding time is equivalent to the call duration in fixed telephone network. However in case of cellular networks it corresponds to the minimum between cell residence time and the call duration (Fig. 8) [5].

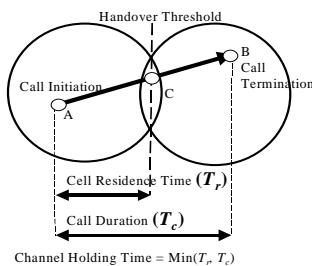


Figure 8. Cell Residence Time

It is assumed handover margin (h_{om}) and cell radius (R) determines handover threshold. When more overlapping between adjacent cells handover threshold is lower (Fig. 9).

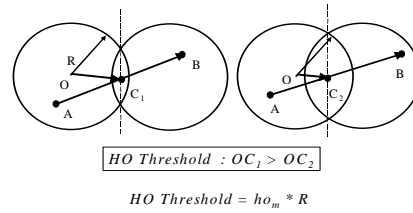


Figure 9. Hand Over Threshold

System is assumed of consisting circular cells generating same amount of traffic. At call initiation mobile is assigned a random initial position within the cell radius (R). Initial vector $A(r_s, \theta)$, where ($0 < r_s < R$) and θ measured relative to the x -axis in anti clockwise. Distance to destination $B(r_d)$ is uniformly distributed where ($0 < r_d < 2R$). Direction α of the mobile movement relative to x -axis measured in anti clockwise is also a uniform random variable. For a mobile initial position of r_s ($r_s < r_d < R$) and α value ($0 < \alpha < 2\pi$) there exists a single positive location for r_d inside the cell radius (Fig. 10). For this case shortest distance h between A and B is given by the equation (4).

$$h = -r_s \cos(\alpha - \theta) \pm \sqrt{r_d^2 - r_s^2 \sin^2(\alpha - \theta)} \quad (4)$$

If ($r_d > R$) then the call is handed over to the next cell without a change in direction α

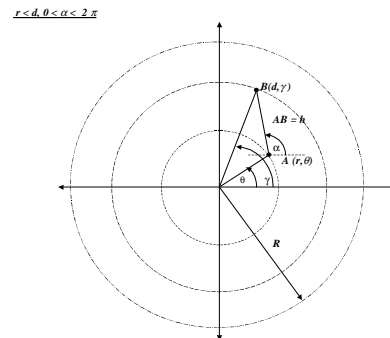


Figure 10. User Moves Towards Cell Centre

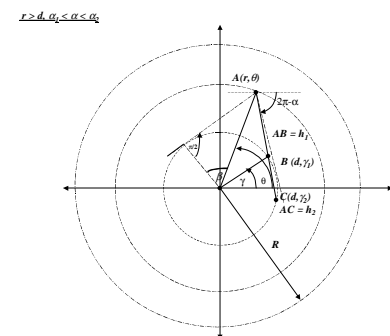


Figure 11. User Moves Outwards Cell Centre

If ($r_s > r_d$) there is a lower and upper bound of α . For any α ($\alpha_{min} < \alpha < \alpha_{max}$) there are multiple positive locations for r_d . But still equation (4) satisfies the shortest distance h (h_1) between A and B (Fig. 11). The limitation of α is given by;

$$\alpha_{min} = \pi + \theta - \beta \quad (5)$$

$$\alpha_{max} = \pi + \theta + \beta \quad (6)$$

Where 2β is the critical angle given by;

$$\sin(\beta) = (r_d / r_s) \quad (7)$$

To identify the variation of trajectory between new call and hand over calls, a simple hand over algorithm determined on distance is included. Once r_d is determined depending on the distance the mobile is handed over to a neighbouring cell. The user velocity is also a uniform random variable with a maximum value of V kmph and a minimum of $V/4$ kmph. The probability distributions of new and hand over call cell residence times are determined with the use of a simulation implemented according to the above. It is found that both hand over and new call cell residence time follow a shifted Gamma distribution with shape parameter α , scale parameter β and location parameter θ (Equation 8)[6]. The hypothesis of fitting shifted Gamma distribution was proved with Kolmogorov Smirnov test for hypothesis testing for 95% confidence interval [7].

$$f(\alpha, \beta, \theta; x) = \frac{\beta^{-\alpha} (x-\theta)^{\alpha-1} e^{-(x-\theta)/\beta}}{\Gamma(\alpha)} \quad \text{Where } x > \theta \quad (8)$$

Shifted Gamma distribution parameters relates to user mobility, resulting β to cell radius (R) where as α and θ to the velocity (V) of the mobile (Equations 9,10,11).

$$\alpha = K_1 V^{(a \ln V + b)} \quad (9)$$

$$\beta = K_2 R^c \quad (10)$$

$$\theta = 1 - e^{-A(V-V')} \quad (11)$$

With $K_1, K_2, a, b, c, A,$ and V' are constants Table (1). V' is the reference velocity at which location parameter θ is zero.

	K_1	K_2	a	b	c	A
New call	$e^{9.6651}$	$e^{-11.52}$	0.3309	-3.6024	1.013	0.1
Handover	$e^{8.7564}$	$e^{-30.75}$	0.2490	-3.0165	0.962	0.095

Table (1)

Effect of handover margins on cell residence time distributions is also included. In practical situations handover distance is less than the cell radius R . Handover margin has a direct impact on the effective cell radius. Handover threshold is determined by the hand over margin h_{om} , where $0 < h_{om} < 1$. Handover margin h_{om} is embraced in β estimation (Equation 12).

$$\beta = K_2 R_h^c \quad \text{where } R_h = h_{om} R \quad (12)$$

Compared to the cell residence time distributions available in literature this has the advantage of using under any environment to generate cell residence times associated with call arrivals. In literature cell residence time distributions are defined in terms of exponential distributions ([8], [9]) which are under very simple

scenarios where no longer appropriate or either as generalised Gamma distributions [5] where usage is impracticable because of the regeneration of these distributions under real parameters are either very difficult or impossible. In the next section Shifted Gamma distribution cell residence time is used for investigation of channel holding times as well as impact on capacity.

A single cell is assumed with independent and uniformly distributed users over the entire region. New call consists of two parameters, call duration T_c with exponential probability distribution (F_{T_c}) (Equation 13) and cell residence time (regenerated from the Shifted Gamma distribution F_{T_n} and F_{T_h}). From [5] the probability distribution of channel holding time ($F_{T_{ch}}$) is expressed in terms of mean handovers per call ($E[H]$), T_n, T_h and T_c is as given in (Equation 14).

$$F_{T_c}(t) = 1 - e^{-\mu t}, \text{ Where } \mu = 120 \text{ s} \quad (13)$$

$$F_{T_{ch}}(t) = F_{T_c}(t) + \frac{1}{1+E[H]} (1 - F_{T_c}(t)) * (F_{T_n}(t) + E[H] F_{T_h}(t)) \quad (14)$$

From (13) and (14) $F_{T_{ch}}(t)$ becomes;

$$F_{T_{ch}}(t) = 1 - e^{-\mu t} + \frac{e^{-\mu t}}{1+E[H]} (F_{T_n}(t) + E[H] F_{T_h}(t)) \quad (15)$$

Using numerical methods to solve (15), accuracy of simulation results are confirmed with analytical solutions.

3.2 Discussion of Results

Based on a mobility model of fluid flow theory, and assuming exponentially distributed cell residence times, Jabbari [9] came up with exponential channel holding time distributions. Comparison between cell residence time distributions for channel holding time evaluations in terms of capacity is shown in (Fig. 12). It is evident exponential cell residence times overestimate the channel holding time distributions thus resulting decrease in capacity. This is more obvious for smaller cell radii ($R < 6\text{km}$).

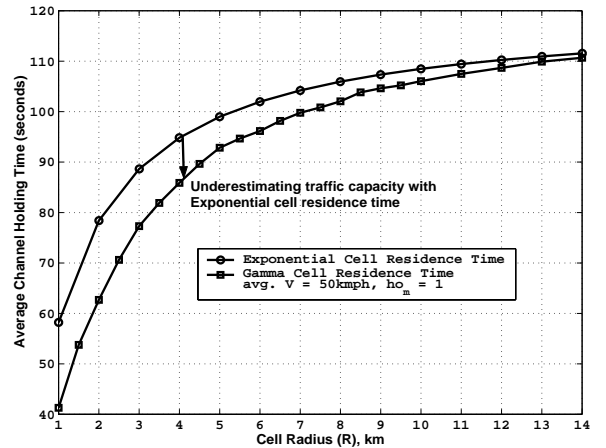


Figure 12. Capacity Estimation

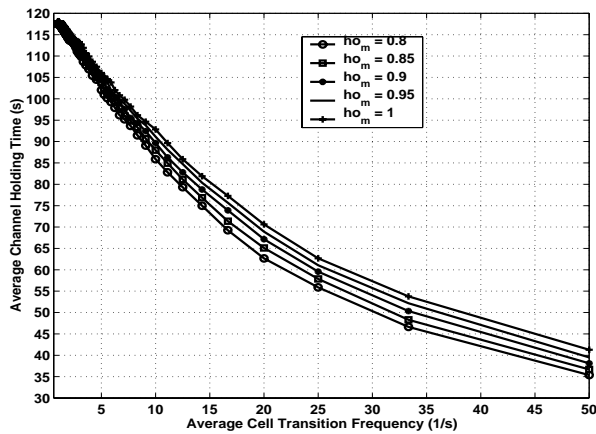


Figure 13. Effect of Handover Margin

The effect of handover margin (h_{om}) on channel holding time (T_{ch}) is also investigated and the results are as in (Fig.13). This has been performed under regenerated Shifted Gamma Cell residence time distributions. The average cell transition frequency (C_f) indicates ratio between V and R . It is evident for lower values of C_f , T_{ch} is independent of the h_{om} , whereas for higher values of C_f , T_{ch} depends greatly on h_{om} .

4 CONCLUSIONS

Section I illustrates the different service modeling distributions significantly changes the medium access control performance. This is validated against two popular service models for WWW browsing and Email connections. WWW browsing is modeled using heavy tailed Pareto distributed burst sizes characterizing self similarity at the aggregate traffic level. Email sessions are presented with the Cauchy distributed connection sizes. The service models are compared with Exponentially distributed burst/connection sizes having the same average value applied to an example GPRS MAC architecture. For Email services Cauchy connection sizes result in higher delay than in Exponential connection size. Apart from that for WWW browsing Pareto distributed burst sizes causes very high delays compared to Exponential burst sizes. This concludes the different service modeling distributions have a positive impact on medium access control performances. Also self similar traffic such as WWW influences the MAC protocol performance than in traditional exponential traffic models. In section II the disparity in terms of capacity is evaluated for assumed exponential cell residence times against the cell residence times distributions in reality. It is revealed cell residence time follows a shifted Gamma distribution not assumed as exponential distribution. The shifted Gamma distribution parameters are related to the user mobility variables velocity, cell radius and handover margin. The dependency between channel holding time and cell transition frequency is investigated and it is concluded for lower cell transition frequency the channel holding time is independent of the handover margin, whereas for higher cell transition frequency the channel holding time depends greatly on handover margin. Also it is shown

the assumption of exponential cell residence times underestimates the capacity.

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