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Simulation Study of WATM Using MATLAB

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Abstract

Several measures for evaluating the performance of wireless Asynchronous Transfer Mode (WATM) have been published in the literature. Among them: Offered Traffic Load, Handover Traffic Load, Call Admission Control and others. To the best of our knowledge, there is no study that collects all these measures into one GUI simulator. In the present work, eight measures have been discussed and then simulated into friendly used GUI using MATLAB.

The proposed simulator enables the network administrator to: enter or select the values of the input parameters; plot and analyze the performance of WATM at different conditions. The graphical results, obtained from the simulator, can assist the administrator to take right decisions to improve the performance of the WATM.

Keywords: Wireless ATM, Load Traffic, Boundary Crossing Rate

الخلاصة

تحتوي الادبيات على عدة معايير لتقييم أدائية شبكات ATM اللاسلكية ومن بين هذه المعايير حمل Offered Traffic وحمل Handover Traffic و تحكم Call Admission. حسب أخر معلوماتنا لا توجد دراسة جمعت كل هذه المعايير في برنامج واحد بواجهة مستخدم رسومية.

في الدراسة الحالية أستخدم تطبيق MATLAB لدراسة وتمثيل ثمانية معايير في واجهة رسومية واحدة ، التمثيل المقترح يمكن مدير الشبكة من أدخال أو أختيار المتغيرات ورسم وتحليل أدائية الشبكة في ظروف عملية مختلفة. النتائج الرسومية للتمثيل المقترح تساعد مدير الشبكة في أتخاذ القرارات الصحيحة لتطوير أدائية شبكة ATM اللاسلكية.

1. Introduction

The rise of wireless communications, especially in the asynchronous transfer mode (ATM) technology signals gives the start of a new era in telecommunications. A new generation of mobile switching networks has come to the foreground to provide the infrastructure for these services. Wireless ATM (WATM) designed to provide high speed isochronous and asynchronous communications for users who may demand high speed data communications along with audio and video conferencing capabilities is proposed as a solution for the provision of these services, [1].

Wireless ATM has been widely considered as a solution for broadband wireless services. A WATM network is an integration of an access network with wireless base station and a 'mobile ATM' backbone which supports mobility functions. The mobility functions are, [2]:

- Location management which resolves the mobile user's location.
- Handover control which maintains the mobile terminal calls Connectivity when it moves from one wireless base station to another.

WATM is mainly considered for wireless access to a fixed ATM network; in this sense, it is mostly applicable to wireless LANs. A typical WATM network includes the following main components:

- Mobile Terminals (MTs), the end user equipment, which are basically ATM terminals with a radio adapter card for the air interface,
- Base station (BSs), the base stations of the cellular environment, which the MTs access to connect to the rest of the network,
- An ATM Switch (SW), to support interconnection with the rest of the ATM network.
- Control Station (CS), attached to the ATM switch, containing mobility specific software, to support mobility related operations, such as handover, which are not supported by the ATM switch.

In many proposals, the CS is integrated with the ATM switch in one network module, referred to as "Switch Base Station" (SBS). Even though this is the most common architecture, other schemes are possible.

In this principle, could expedite mobility and call control operations, but could also increase the overall cost of the system significantly, since the BSs need to be more complicated, implementing the full signaling ATM stack, [3].

2. Need for Wireless ATM

The success of cellular mobile communications has spurned the telecommunications industry to push the implementation Personal Communications Services (PCS). PCS will provide voice, text, video and data. As a result, the demand for higher transmission speed and mobility is even greater. Since the beginning the concept of ATM is for end-to-end communications (i.e. in a WAN environment).

The communication protocol will be the same (i.e. ATM), and companies will no longer have to buy extra equipment (like routers or gateways) to interconnect their networks. Also, ATM is considered to reduce the complexity of the network and improve the flexibility while providing end-to-end consideration of traffic performance. That is why researchers have been pushing for an ATM cell-relay paradigm to be adopted as the basis for next generation wireless transport architectures.

There are several factors that tend to favor the use of ATM cell transport for a personal communication network. Among them:

- Flexible bandwidth allocation and service type selection for a range of applications.
- Efficient multiplexing of traffic from burst data/multimedia sources.
- End-to-end provisioning of broadband services over wireless and wired networks.
- Suitability of available ATM switching equipment for inter-cell switching.
- Improved service reliability with packet switching techniques.
- Ease of interfacing with wired B-ISDN systems that will form the telecommunications backbone

In general, inter working may always be seen as a solution to achieve wireless access to any popular backbone network but the consequence, in this case, is a loss of the ATM quality of service characteristics and original bearer connections, [4].

3. Traffic Classes

According to ATM forum, five categories of classes have been identified for the ATM layer service architecture. These classes are described and summarized [2] in the following:

- Constant Bit Rate (CBR): This class is used for emulating circuit switching. The cell rate is constant. Cell loss ratio is specified Cell Loss Priority CLP=0 cells and may or may not be specified for CLP=1 cells. Examples of application that can use CBR include Interactive Audio e.g. Telephone Audio Distribution e.g. Radio Interactive Video e.g. Videoconference.
- Unspecified Bit Rate (UBR): This class is designed for those data applications that want to use any leftover capacity and are not sensitive to cell loss or delay. Such connections are not rejected on the basis of bandwidth shortage (no connection admission control) and not policed for their usage behavior. During congestion, the cells are lost but the sources are not expected to reduce their cell rate. Instead, these applications have their own higher-level cell loss recovery and retransmission mechanisms. Examples of applications that can use this service include: interactive text, data and image transfer, text, data and image messaging and remote terminal.

- Available Bit Rate (ABR): This class is designed for normal data traffic such as file transfer and email. Although the standard does not require the cell transfer delay and cell loss ratio to be guaranteed or minimized, it is desirable for switches to minimize the delay and loss as much as possible. Depending upon the Congestion state of the network, the source is required to control its rate. The users are allowed to declare a minimum cell rate, which is guaranteed to the connection by the network. Most connections will ask for minimum cell rate of zero. Those with higher minimum cell rate may be denied admission if sufficient bandwidth is not available.
- Variable Bit Rate (VBR) Real time and Non Real Time: This class allows users to send at a variable rate. Statistical multiplexing is used and so there may be small random loss. Depending upon whether the application is sensitive to delay or not this class is further divided into two categories: Real time and Non Real time VBR. While cell transfer delay is specified for both categories, cell delay variation is specified only for real-time VBR, [3].

4. Wireless ATM Architecture

Wireless ATM architecture is obtained by incorporating new wireless protocols at the access level and extensions into the standard ATM protocol stack as shown in Figure 1, at the access level, new protocols are needed for:

- Physical layer radio channels between the mobile terminals and base stations.
- Medium access control (MAC) to arbitrate the shared use of the radio channels by the mobile terminals.
- Data/logical link control (DLC/LLC) to detect and/or correct the radio channel errors and maintain end-to-end QoS.
- Wireless control to support such functions as radio resource management at the physical, MAC and DLC layers, as well as mobility management.

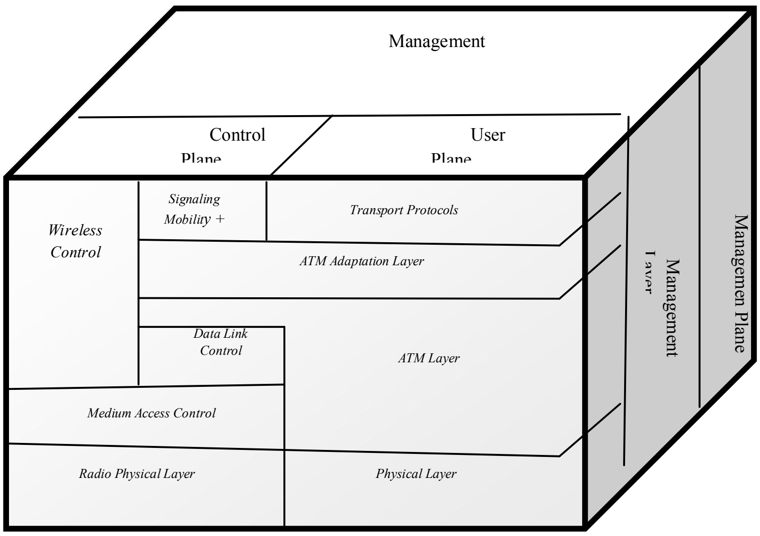


Figure 1: Protocol Architecture For Wireless ATM, [5]

4.1 Data Link Control

The DLC protocol is needed to decrease the cell error rate caused by the physical wireless channel and the MAC protocol, thus insulating the ATM layer above it from these errors. The noisy wireless channel is expected to suffer from relatively high bit error rates. Thus, a robust DLC layer is required for detecting these transmission bit errors and recovering from them either by bit correction Forward Error Control (FEC) or packet retransmission Automatic Repeat Request (ARQ), [5]. In addition, the MAC layer is prone to packet loss because of buffer overflow or blocking. Hence, the DLC must also recover from this MAC-level packet loss by retransmission. Whether employing ARQ or FEC, the bit error and fading impairments of the wireless channel makes it challenging for the candidate DLC protocol to support the standard ATM services (i.e. CBR, real-time VBR, non real-time VBR, ABR and UBR).

Bit errors cause frequent cell retransmission which, in turn, may cause excessive cell access delay. Fluctuations in channel characteristics will create large cell delay variation, [4,5].

This delay variation is a serious problem for real-time applications which require real-time VBR. In addition, signals received on the radio channel are prone to variable fading. This increases the probability of a cell to be received in error at the base station, hence increasing the cell access delay, [5].

The DLC layer exchanges 53-byte ATM cells (as data service units) with the ATM layer. The DLC protocol data unit may be a packet consisting of one or more cells. This packet is then transmitted by the MAC protocol as a single data unit. The use of a multi-cell DLC packet may reduce overhead but will require significant processing to convert between the ATM cell formats to the DLC packet format.

4.2 Medium Access Control

The wireless access channel must be shared by multiple users. Bandwidth demands on the channel are generated by active local users, new local users requesting access, and users coming from neighboring base stations via handover. Unlike traditional multi-access data or voice networks which deal with only one type of traffic, WATM networks must handle multimedia traffic with various characteristics and QoS requirements. Thus, the MAC protocol for wireless ATM must be selected to provide QoS levels of these services while maintaining acceptable radio channel efficiency.

In general, multi-access methods are classified into three categories: fixed assignment, random access and demand assignment (which combines fixed assignment and random access), [4]. Fixed assignment techniques such as TDMA and frequency division multiple accesses (FDMA) are inefficient for the burst WATM traffic environment.

Random access methods, such as ALOH and Carrier-Sense Multiple Access with Collision Detection (CSMS/CD), are able to guarantee the performance of integrated traffic. Also, carrier sensing is said to be not effective in the radio environment where transmissions from adjacent base stations interfere with one another. Therefore, random access methods are not suitable for WATM. Demand assignment access methods, combining advantages of both fixed assignment and random access; seem to be the most appropriate for wireless ATM. In demand assignment, user terminal utilizes a control channel on the uplink (terminal to base) to request or reserve access bandwidth, as needed, from the base station. In turn, the base station allocates bandwidth (e.g., time slots) dynamically to the requests, as available, [6].

4.3 Physical Layer

Wireless ATM requires a high-speed radio modem technology capable of providing reasonably reliable transmission and reception in the range of 100–500 m. The wireless ATM systems may operate in various frequency bands depending on the regulatory policies. Currently, they are usually associated with the recently allocated 5 GHz band in the US and the HIPERLAN band in the Europe. The expected operating frequency range is of the order of 20–25 GHz. Typical target bit rates for the radio physical layer of wireless ATM are around 25 Mbps and a modem must be able to support burst operation with relatively short preambles consistent with transmission of short control packets and ATM cells. [7].

4.4 Wireless Control

The wireless control sub layer is needed for the allocation of wireless radio resources to mobile terminals during connection setup and their management during handover. Wireless control messages are exchanged between base stations and mobile terminals and between base stations themselves to handle such functions as terminal registration and authentication, handover, disconnection, and connection state transfer during handover. The content of DLC/MAC buffers at a radio port is an example of connection state which must be transferred to the new radio port after handover. Using the MAC protocol, base stations exchange wireless control messages with mobile terminals using short signaling packets, [5,6].

5. Offered Traffic Load

For all traffic classes' $j \in J$, where J is an index set, with call arrival rate λ_j (call/sec) and call holding time h_j (sec), the input traffic load is given by:

$$a = \sum_{j \in I} \lambda j * hj \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Considering

i) ON-OFF source data activity y_j, where y_j is a ratio expressed as

$y_j = Lon /(Lon+Loff)$ ………… (2)

Lon is the on period of the ON-OFF source and the *Loff* is the off period of the ON-OFF source.

ii) $V_{j=}$ the data speed of the jth source (bps).

iii) C= the server transmission speed(bps), the offered traffic load can be modified as:

$$a = 1/c\sum_{j\in J} \lambda jhjVjYj \text{ …………..(3)}$$

The traffic load in equations (1) and (3) is dimensionless, [7].

6. Handover Traffic Load

Handover traffic load depends on the carried traffic load and the Mobile Terminal (MT) handover activities. The mobile terminal handover activities are affected by the following factors:

- Boundary crossing rate: how often the MT is moving across the boundary of geographical cell coverage area of each BS.
- Handover initiation rate: how often the MT initiates a handover request. This is the time when MT finds a destination BS with better quality than the current BS and makes handover request.
- MT calls activity: call arrival rate and call holding time.

The MT performs a handover only when the mobile is crossing the boundary, is at the time of initiating a handover and is during a call. [7] [8].

The active mobile terminal density is given by:

$$\sigma = M/A \text{ ……………………… (4)}$$

The MT boundary crossing rate is given by:

$$BCR = [\sigma v/\pi] \times L \text{ ……………… (5)}$$

Where

BCR= is average boundary crossing rate (1/s).

σ =is the active mobile terminal density (1/m^2).

M =is in number of mobile terminal one geographical cell.

A=is the area covered by one BS (m^2).

v = is the MT moving speed (m/s).

L= is the boundary length of the coverage area (m).

7. Estimated Signaling Overhead Required to Support Wireless Users.

Estimating the performance of a signaling network protocol requires the definition of a performance measure. The performance measure used is the overhead required for signaling. It can be seen not concerned with the signaling information being exchanged, but in the overhead required to carry that information. This performance measure is chosen because the signaling information needed to be communicated to perform network functions in any network remains roughly the same; however, the work performed in transmitting that information is a good measure of the efficiency of that network, [8].

The uniform fluid flow model approximates the wireless users as moving randomly in all directions between the cells and on the average it is an acceptable representation of traffic in and out of cells.

Equations that yield mean values for the registration transaction rates Lr, connection setup transaction rates Lc, and handover transaction rates Lh, in terms of Transactions Per Second (TPS) are given in, [7].

$$T = z/v \qquad (6)$$

$$e = h \times \lambda \qquad (7)$$

$$Lc = N \times p \times \lambda \ (1 + q) \qquad (8)$$

$$Lr = [(1 - s) \times (1 - RM) / \pi] \times N \times 4/T \qquad (9)$$

$$Lh = [(1 - s)(1 - RM) / \pi] \times N \times e \times 4/T \qquad (10)$$

Where

T= Average Cell Crossing Time.

z= Cell Size (one side of the square) (m).

v =speed of users (m / sec).

e = Probability of user being busy.

h=Call Holding Time (sec).

λ =Call Arrival Rate (call /sec).

N =Number of Mobiles Terminals.

p = penetration Ratio.

q= Successful Call Completion.

s =Stationary User Percentage.

RM= Ratio of Mobile Users that stay in one cell.

7.1 Traffic overhead

The traffic overhead ratio ξf, which is defined as the number of bytes forwarded to the neighboring the Foreign Agent (FAs) divided by total number of bytes sent by the sources, is:

$\xi f \equiv (24 \times v \times \tau) / \sqrt{3} \times r \times \pi$...........(11)

The data-forwarding period τ is a function as the (u), where u the waiting time for mobile terminal agent advertisement after handoff is over. u is modeled as a uniformly distributed random variable with expected value T/2. If representing T as mobile terminal advertisement period, the average value E [u] = T/2, [8].

8. Simulation Environment

For most modern applications, the design of WATM simulators software package using GUI tools is very powerful. The design of GUI elements is not necessary, as reusable classes already exist such as windows, icons, mouse operations, and a wide variety of other interactive functions.

In this work, comprehensive tests for the WATM software simulator designed and implemented. These tests include various scenarios for design of systems that study the mathematical analysis of WATM for different no. of mobile terminal, radius of cell, no. of connection per base station, no. of base station, no. of departure rate, no. of arrival rate and other input data to test the performance of WATM. Discussions of these are associated with different calling cases which have been carried out using Matlab 7.4.

8.1 The Proposed Simulator

Figure 2 shows the structure of the proposed simulator. As can be seen, it consists of eight main parts (measures). The Call Admission Control (CAC) includes three subparts, (CAC for real time connection, CAC for non real time connection and CAC with queuing mechanism). All these parts are executed repeatedly and in parallel; each part is implemented independently of the others but it is related to them with a special mechanism.

This paper will focus on the following:

1. Offered Traffic Load.
2. Boundary Crossing Rate.
3. Signaling Overhead Required to Support Wireless Users

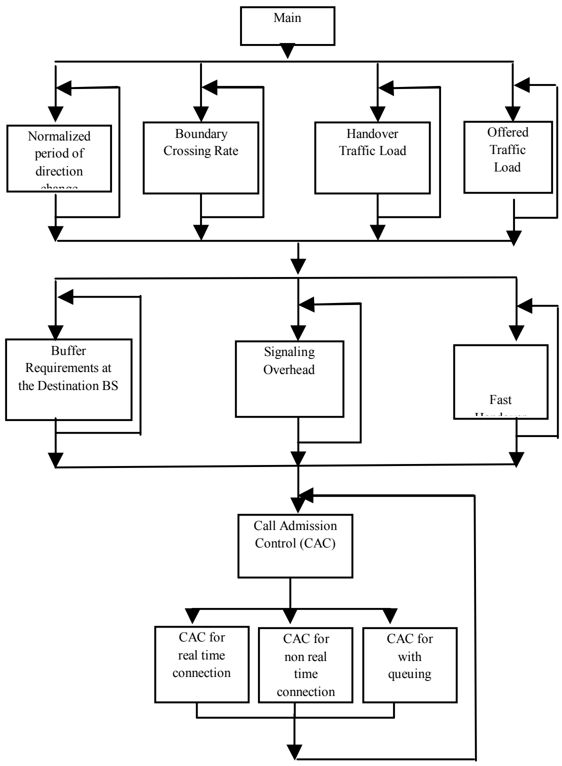


Figure 2: Software Main Program (Branches Operate In Parallel)

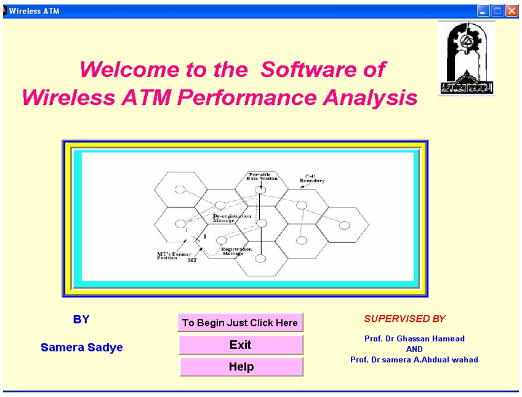
9. Graphical User Interface (GUI) of the Simulator

Figure (3a) shows the introductory window of the simulator, which includes "Help" button to describe how to use the simulator and how to select the measures. The user can move to the Measures Selection Window (Homepage), Figure (3b), by pressing "Start" button.

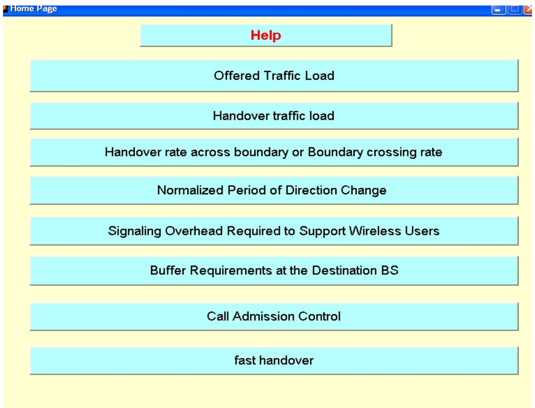
This figure lists eight measures used in analyzing and evaluating the performance of WATM network. Each measure has its own window, and most of these windows have the flowing:

- A main area for plotting the results of the measure.
- A text box to display a description of the measure.
- A dropdown list to select the parameters used in the measure.
- An input box to enter values of the parameters (not listed in the dropdown list).
- A picture box to display the equations and used in the calculation.

The code written for these windows handles the possibility of entering invalid values by the uses. A popup dialog box will be appeared informing the user about these invalid values and asking him to enter valid values.



(a)



(b)

Figure 3: GUI Presentation: (A) Introduction Window And (B) Measures Selection Window

9.1 Offered Traffic Load

The results for analyzing the WATM are dependent on traffic load. Where handover behavior is the focus, handover buffer stores ATM cells only during the execution of the handover procedure.

This measure represents the relation between the offered traffic load and number of MT. Figure 4 shows this relation as calculated by equation 3. Some parameters assumed to be constants in Table 1.

Table 1: List of Input parameters.

Parameter Name	Value
Base Stations	4,7,13
Mobiles Terminals	Choosing by designer
Call arrival rate	Choosing by designer
Call holding time	300 sec
Location update period	30 sec
Handoff initiation window width	(1-5) m sec

Three different reasonable values of number of call arrival rate (call/sec) are used as shown in figure 4. The network designer can determine the traffic load from this plot and concludes whether his network is loaded or not. If the designer hears any problems regarding the traffic load, the advice is to increase no. of BS in the network or decrease the radius of cell.

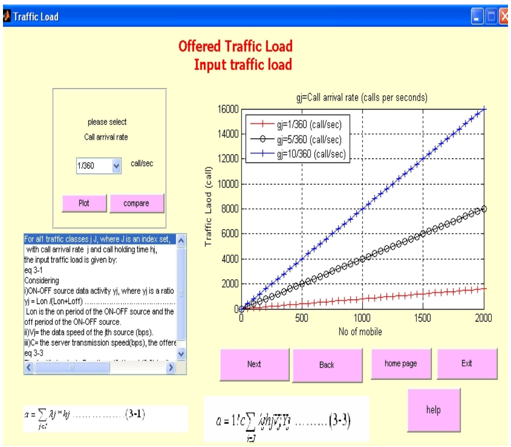


Figure 4: Offered traffic load

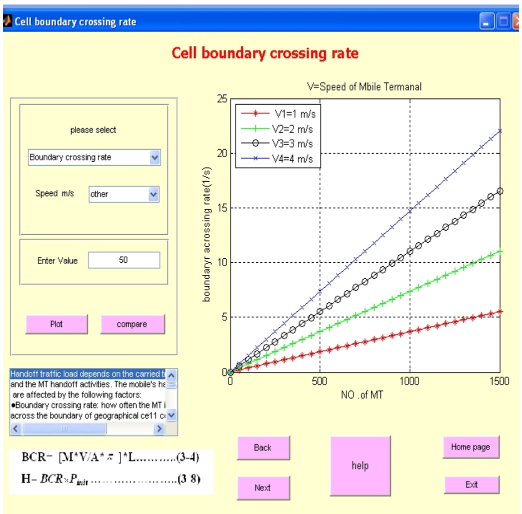
9.2 Boundary crossing rate

The requirement of the equation 5 is that the mobile terminals density is changing. The motion of the mobile terminals was modeled with three parameters: minimum speed, maximum speed and the direction change period.

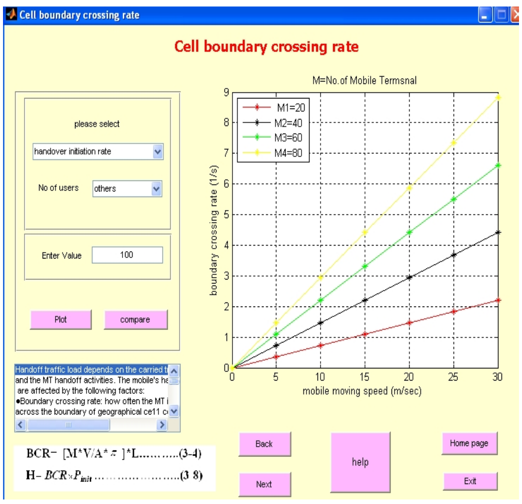
At each end of the direction change period, the speed of the mobile terminals was selected randomly in the range between the (1m/sec–30 m/sec) and the direction of the mobile was also randomly selected within (0, 2π).

When the direction change period is short, the motion of the mobile terminals is similar to a random walk. Figure 5 shows the GUI of this measure, where the network administrator can select between the boundaries crossing rate or handover initiation rate. The first part plots the relation as dependence with the MT densities in one geographical cell. The numerical results show that the boundary crossing rate is proportional to the MT motion speed. The second part shows the relation as dependence with no. of MT. As expected the crossing rate is proportional to both; the moving speed and the density of MT.

This plot can be used by the network administrator to troubleshoot his network. For example, if the boundaries crossing rate exceeds the normal value, he then either the area covered by the BS or advise his clients to decrease their moving speed.



(a)



(b)

Figure 5: Boundary crossing rate curve for different MT moving speed in one geographical cell.

9.3 Estimated Signaling Overhead Required to Support Wireless Users

Table 2 lists the definition of the terms used in the equations 6-10 for any given configuration that are accurately estimated within the limitation of being mean values for statistical variables. This measure represents the relation between the number of MT and handover transaction rate, connection setup transaction rate and registration transaction rate. Figure 6 shows the results of calculation for cell size 500m and call arrival rate 3/360 call/sec.

Table 2: List of Values used

Parameter Name	*Value*
Number of Mobiles Terminals in a Cell	Choosing by designer
Average Cell Crossing Time	Variable depended on cell size and velocity of MT
Call Arrival Rate (call Rate)	Choosing by designer
Call Holding Time	180 sec
Speed of mobile terminals	3 m/sec
Cell Size(one side of the square)	Choosing by designer
Penetration Ratio	0.25
Successful Call Completion	0.5
Stationary mobile terminals Percentage	0.50
Ratio of mobile terminals that stay in one Cell	0.45

Analysis of equations 6 to 10 shows that:

- All of the transaction rates scale linearly with the number of mobile terminals in a cell.
- The rate of registration transactions is not affected by call arrival rate or call holding time.
- The rate of connection attempts is not affected by the mobile terminals velocities.

Both the registration and handover transaction rates vary linearly with user velocities assuming that cell size and thus the number of mobile terminals in the cell remain the same.

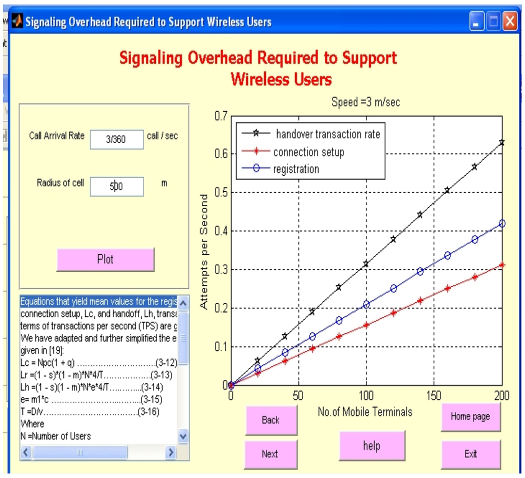


Figure 6: Signaling Transaction Rates. Cell Size = 500 Meters And Call Arrival Rate 3/360 Call/Sec

Figure 7 displays the relation between user velocity and both the registration transaction rate and handover transaction rate assuming cell size = 500 m and MT =200.This figure is very useful in analyzing the network. Suppose that the BS can handle registration rate of 1.5, then the maximum user velocity (without raising any problem in registration) is about 10 m/sec. If the designer hears any problems regarding registration process, he can increase the cell size to decrease the effect of user velocity on registration transaction rate, or he can advise the user's to decrease their movement while registrations.

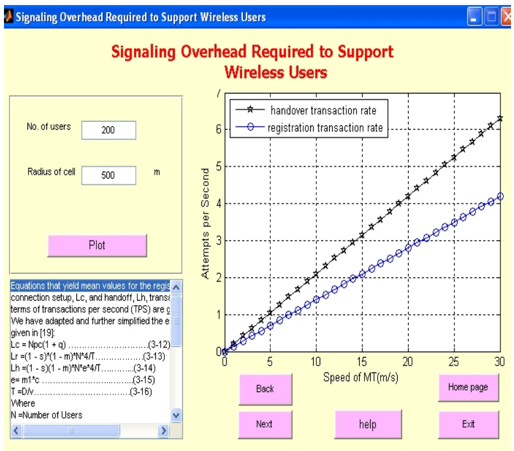


Figure 7: Signaling transaction rates. Cell Size = 500 meters and no. of users=200

9.4 Traffic overhead

Using equation 11, figure 8 shows the results of traffic overhead as a function of MT speed and agent advertisement period; using 200m-radius hexagonal. The plot reveals proportional relation between traffic overhead and these two parameters. The reason is that more frequent handover is required when the MT speed is faster and the forwarding period is longer when the agent advertisement period is longer due to the time taken for registration with the home agent.

Based on several studies, the traffic overhead falls within the order of $10^{-2} \sim 10^{-1}$ in the picocell environment when it is defined as the ratio of total forwarded bytes over total transmitted bytes. Note that traffic overhead ratio exceeding 10^{-1} occurs around a MT speed 8m/s or higher which is a somewhat extreme case in the picocell environment. In other words, based on the values implemented in equation 11, it is recommended to make the MT speed with range $\leq$ 8 m/s.

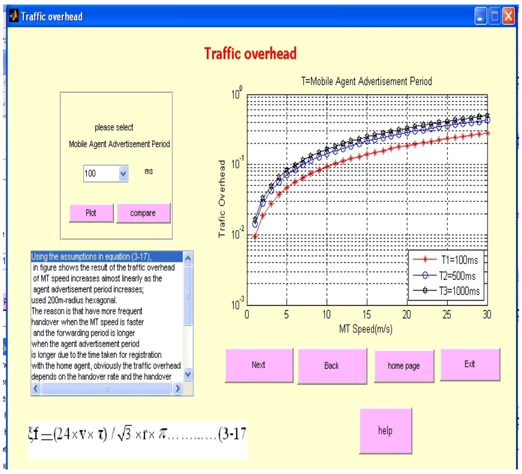


Figure 8: Traffic Overhead Curve For Different MT Moving Speed And Mobile Agent Advertisement Period

Conclusions:

Several measures have been used to evaluate the performance of WATM using newly designed GUIs, which enable the network designer to analyze his WATM and take right decisions to improve the performance. Analysis of some of these measurers shows that:

1. The number of packets lost during a handover depends on the data packet interval and offered load since all the packets arriving during the handover disruption time will be lost without any handover smoothing techniques.
2. The rate of registration transactions is not affected by call arrival rate or call holding time.
3. The traffic overhead falls within the order of $10^{-2} \sim 10^{-1}$ in the picocell environment when it is defined as the ratio of total forwarded bytes over total transmitted bytes.

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