

**LOAD ESTIMATION OF NON-STATIONARY AND  
BURSTY TRAFFIC OF DAP MULTI ACCESS PROTOCOL  
IN CELLULAR NETWORKS**

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT  
OF THE REQUIREMENTS  
FOR THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY  
COMPUTER SCIENCE AND TECHNOLOGY

By

**AKALABYA SAHU**



**SCHOOL OF COMPUTER & SYSTEMS SCIENCES  
JAWAHARLAL NEHRU UNIVERSITY  
NEW DELHI-110067**

**January 2004**

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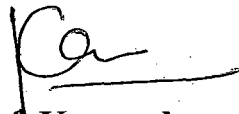
SCHOOL OF COMPUTER AND SYSTEMS SCIENCES

**CERTIFICATE**

This is to certify that the dissertation entitled "*Load Estimation of Non-stationary and Bursty Traffic of DAP Multi Access Protocol in Cellular Networks*" which is being submitted by Mr. Akalabya Sahu to the school of Computer and systems sciences, Jawaharlal Nehru University, for the award of *Master of Technology in Computer Science and Technology*, is a record of bonafide work carried out by him.

This work is original and has not been submitted in part or full to any university or institution for the award of any degree.

Date: 5.1.2004  
Place:

  
Prof. Karmeshu  
Supervisor & Dean, SC& SS,  
Jawaharlal Nehru University,  
New Delhi-110067

## DECLARATION

This is to certify that the dissertation entitled “*Load Estimation of Non-stationary and Bursty Traffic of DAP Multi Access Protocol in Cellular Networks*” which is being submitted to the school of Computer and system sciences, Jawaharlal Nehru University, for the award of *Master of Technology in Computer Science and Technology*, is a record of bonafide work carried out by me.

This work is original and has not been submitted in part or full to any university or institution for the award of any degree.

**Date:** 05/01/2004  
**Place:** JNU, Delhi

Akalabya Sahu  
**Akalabya Sahu**

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**Place:** JNU, Delhi

**Date:** 05/01/2004

*Akalabya Sahu*  
**Akalabya Sahu**

*...dedicated to my mother*

## **ABSTRACT**

Increase in the number of mobile users and expansion in mobile computing leads to heavy traffic on wireless channels. Traditionally cellular traffic is being modeled as Poisson process. One way to incorporate more realism is to consider the non-stationary traffic. Further if the bursty nature of traffic is also considered, then the traffic can no longer be Poisson, rather it becomes self-similar. If more than one user wants to access the same channel in some time slots, then the main problem is to resolve the multiple accesses to the single channel and to efficiently use the channel so as to increase the channel utilization at high load periods and decreasing the delay at low load periods. One approach to solve this multi-access resolution problem is through dynamic access probability (DAP) protocol. As per this protocol, each user is assigned a probability for accessing the channel depending on the load on the channel. The access probability is varied dynamically for different intervals according to the load calculated. The access probability decreases with high load on the channel and approaches to unity at low load periods. DAP protocol was evaluated under the assumption that the input traffic is Poisson. The results thus obtained will not hold well when the traffic becomes regularly bursty. In the current work the DAP protocol is reevaluated under the assumption of self-similar type of load. Performance and channel utilization of this protocol using self-similar traffic is analyzed. Results indicates that the DAP protocol with self-similar load characterization can handle bursty traffic in cellular networks.

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# Chapter 1

## INTRODUCTION

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The wireless medium is a shared resource, because of limited bandwidth. Hence controlling channel access becomes important. Therefore, the primary focus is on the design and implementation of Multiple Access Control (MAC) [13] protocol for mobile wireless networks. Here in this work an efficient MAC protocol is explored and performance analysis of this with other protocols is discussed. This protocol can cope with the next generation networks with a very large number of users and bursty traffic [2, 11], where the traditional Multi-access schemes fail.

For designing a better multi-access protocol for cellular networks, the cellular traffic characterization is crucial. This traffic is mostly determined by the number of users inside the cell who needs to access the channel and the handover users [6] from the adjacent cells. If at the same time two or more users access the channel, then collision occurs. So these nodes should retransmit their packet and these nodes form a group of backlogged nodes. Hence, the net traffic generated inside a cell is the total of the fresh users, backlogged users and the handover traffic. Hence, most of the time this traffic is bursty. One more inherent problem in wireless networks is poor collision detection capability and poor channel sensing (section 2.1). The bursty rate can be modeled by self-similar traffic. The present work, simulation of a multi-access protocol, can cope

with a very large number of users with bursty transmission rate and is suitable for the networks with poor collision detection and channel sensing capability.

For the design of the multi-access protocol for cellular networks, discussed in this paper, the system has the following components and assumptions [4, 13]:

1. A set of stations (users/nodes), each of which may need to send a packet to the central station.
2. All stations use a single channel (signaling channel) for gaining access and then transmitting data frames. Generally there are two channels are required for uplink and downlink traffic in case of wireless networks.
3. The multi-access protocol should resolve the contention for the signaling channel to efficiently manage the channel.
4. All users inside the network are uncorrelated and can transmit a packet at any time. Giving users a probability for accessing the channel can only control the user's access to the channel. The shared channel performs synchronization between stations. If a packet of a user forms collision then the user waits for an acknowledgement for a time-out period. After time-out period the station is placed in the group of the backlogged nodes, those will again retransmit.
- 5 The time is partitioned into very small discrete units called slots. The protocol is decentralized so that stations obtain knowledge of the state of the system only through the shared channel. There is no single station whose failure will cause the failure of the entire system.

## **Organization**

The organization of the chapters is as follows: In chapter 2 multiple access protocols for cellular networks are described and the proposed work by prof. Naor et al [1] is discussed. The performance of the DAP protocol and other protocols for Poisson traffic is introduced. In chapter 3 the basics of my work is introduced. Brief introduction to non-stationary and self-similar traffic is discussed in this part. Then based on our assumption of the traffic in cellular network to be self-similar, the DAP protocol is implemented. The design and result part is discussed in chapter 4. Some part of the simulation work is given in the appendix.

## Chapter 2

# MULTI-ACCESS PROTOCOL IN CELLULAR NETWORKS

---

### 2.1 Introduction

Mechanisms to manage a large user population and to efficiently use the radio resources are commonly termed as multiple access protocol (MAC) [3, 11] protocol. A multi-access protocol is a set of rules that all the users follow for partitioning the channel into time or space intervals for the transmission of packets. MAC protocols are mainly divided into (i) Fixed assignment protocols or collision-free protocols that restrict data transmission for a fixed population of stations to fixed time intervals and/or frequencies and (ii) Dynamic allocation protocols, which require the knowledge about the current traffic conditions. Different kinds of MAC protocols are:

#### Collision Free Protocols

In these set of protocols the total system bandwidth is statically allocated to all users in the network. If some more users come inside the network, then providing a channel to them is not possible due to fixed allocation of the channel. These protocols are efficient where the number of users is constant and limited. And one more advantage of this kind of protocols is that there is no interference and accordingly collisions are avoided. Some of these kinds of protocols are TDMA, FDMA [3, 4] etc.

In case of TDMA, time is slotted into the number of users. When a user has some data, it can transmit in its assigned slot. The whole bandwidth is allocated to the user. If in reaching its slot, the user has no data to transmit, then the time and bandwidth is wasted in that slot.

In case of FDMA, the total bandwidth is divided into different channels, and each channel is assigned to a user. If some user has nothing to transmit then also the allocated bandwidth is wasted.

### **Contention Protocols**

When a large number of users are assigned a single channel, contention for the channel takes place. In these kinds of protocols whenever a user has data to send it sends without the knowledge of what other users are doing. Contention protocols [1, 13] are useful when a very few users want to access the channel at any given time. Hence these protocols are very useful at low traffic and these are inefficient at high traffic due to collisions. ALOHA and CSMA [3, 4] base protocols are contention protocols.

In case of simple ALOHA protocol, whenever a user has something to transmit, it transmits. So the probability of collision increases. To minimize the collisions, there is different control parameters attached with ALOHA protocol. And hence various versions of ALOHA were proposed. In case of slotted ALOHA the time is slotted. So when a user gets something to transmit, it sends in the beginning of the next time slot. In both the cases the probability of transmission is 1. So when the load increases, this protocol becomes unstable with large number of collisions. To avoid more number of collisions, a probability is associated with the transmission. These types of protocols are p-persistent slotted ALOHA [12]. So a user transmits with a probability  $p$ . In all the versions of ALOHA protocols the main problem is with collision of data when the number of users want to transmit varies dynamically. When a collision occurs, all the nodes whose data collided are backlogged. Backlogged nodes retransmit again. So with the increase in the number of backlogged nodes the load on the channel increases gradually and the system performance degrades.

In case of CSMA version protocols, carrier-sensing capability of the network should be efficient. Each user senses the channel before transmission. But in case of wireless networks the channel sensing is poor and inefficient. The problem of poor collision detection capability and poor channel sensing is due to the following facts. The main reason is due to the attenuation of the signal when it propagates away from the transmitter. So carrier sensing is possible by a node if it is in the transmission range of a transmitting node. This location dependent carrier sensing can have two more problems of hidden and exposed [5, 14] nodes that can affect channel efficiency. These problems lead to poor quality of collision detection.

### **Limited contention protocols**

One way to make the multiple access protocols better is to use both contention protocols and collision free protocols time to time. When the load on the channel decreases contention protocols should be used and when the channel load increases collision free protocols should be applied. This protocol depends on the immediate collision detection capability. In a network like cellular network the detection of collision is not easy, due to poor collision detection capability of the wireless networks and poor channel sensing. Both the problems occur in wireless communication due to near-far and exposed terminal [5] problem.

### **Dynamic Access Probability (DAP) Protocol**

Number of wireless users is always increasing in an exponential manner. Hence to deal with the increase in number of users in a network with poor collision detection capability, a better protocol is devised. DAP [1] protocol can be implemented in such type of networks. DAP protocol dynamically calculates a probability, with which a user will transmit. A central station calculates the load on the channel; based on the load it calculates a probability to access the channel. In a simple case if for some slots (interval), let  $v$  users be transmitting per slot then the probability to access the channel in the next interval should be minimum of  $1/v$  and 1 [10]. i.e. if there are less than one

user are transmitting then the probability of accessing the channel should be 1. Otherwise probability access decreases. DAP protocol can overcome the inherent limitations of wireless media that prohibit a user to detect collision or sense the channel efficiently.

## **2.2 Goals of Multi-Access Protocol**

Goals [1, 13] of a multi-access protocol are

1. To maximize the throughput by efficiently distributing access to the channel between the users. So that at a time one user only allowed.
2. To Minimize the response time. The delay for accessing the channel should be reduced.
3. To attain Stability when the channel load is increases with more number of collisions.
4. To utilize the channel properly with the known real-time constraints like managing the channel access when the arrival rate is predictable or predictable variability of cannel load.

## **2.3 Cellular Network Concept**

Cellular network is based mainly on wireless communication. Hence for designing a Access Protocol we need to Know all the characteristics of wireless transmission. Here we will briefly discuss about the model of a cellular network and the wireless channel characteristics.

### **2.3.1 Cellular Model**

Cellular networks are formed with a group of cells [5, 15]. Cell is a small area which is created by partitioning a large area, where the primitive operations are performed. In a cell there are some mobile units or Mobile Stations (MS). There is a central station known as base station (BS) that coordinates and controls all transmissions within the cell. The cell area is determined by the transmission range of the BS. Base station communicates with a node on a downlink channel. And the nodes transmit to base station with an uplink channel. Nodes have access to the uplink



channels only. One of these uplink channels is reserved by the base station for collecting control information from the users and this channel is control channel. A user requests for a free uplink channel for data transmission, by sending a request packet through the control channel.

As illustrated in Fig. 2.1, we have assumed that a wireless cellular network mainly has the following components;

Mobile terminal (MT)

Base station (BS)

Mobile switching center (MSC)

A set of adjacent cells has a unique MSC. Its main purpose is for location updating of a MS when it crosses the cell boundary. The wireless channel is divided into the data channels for transmitting user data and the signaling channel for the signaling packets.

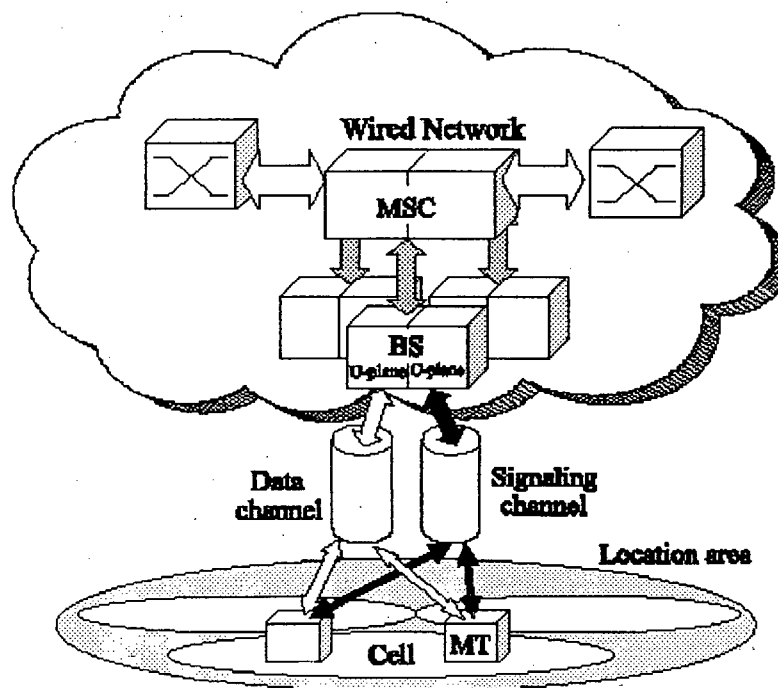


Figure 2.1 Cellular Network Components.

### 2.3.2 Logical Channels:

In cellular networks the total bandwidth can be broadly divided into two types: traffic channels (TCH) and control channels (CCH). Most of the bandwidth is used for traffic channels that are usually for speech or data transmission purposes. Control channels are used for different controlling purposes giving access to the data channels. Three types of control channel are broadcast (BCCH), common (CCH), and dedicated (DCCH). Each channel again divided for different purposes. In the following figures 2.2 and 2.3 the partition of traffic and control channels respectively are shown.

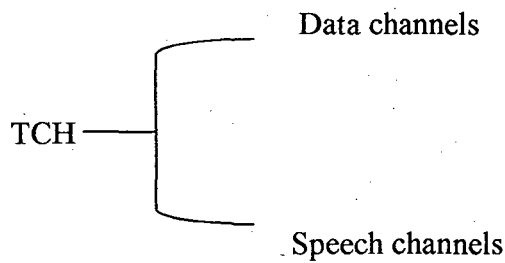


Figure 2.2 Traffic channel

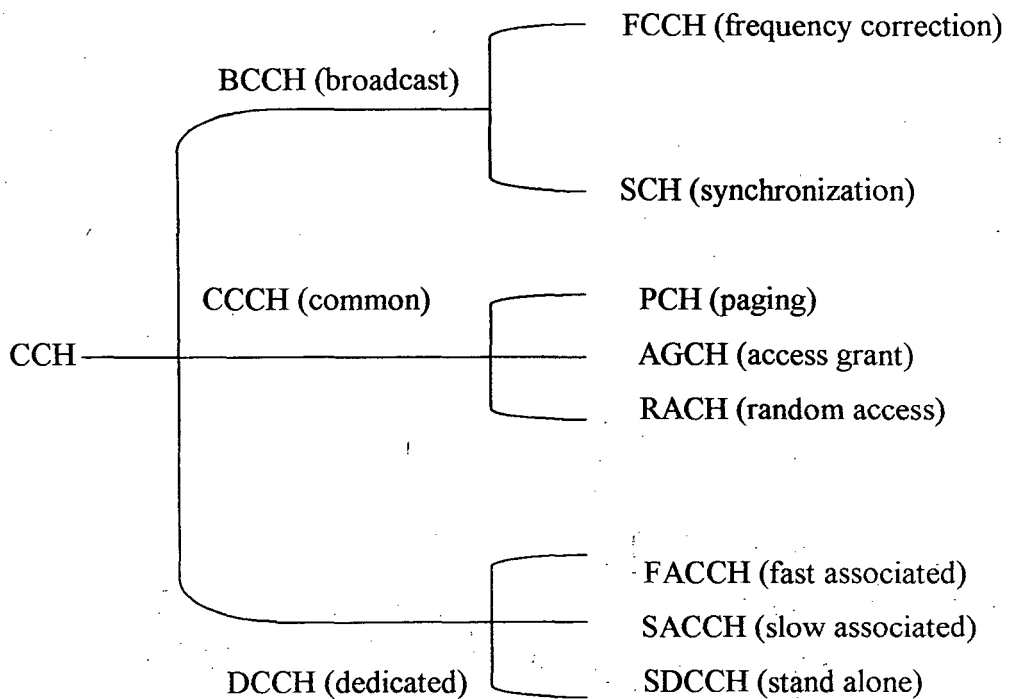


Fig. 2.3 Control Channel

For the control of the traffic channel, each traffic channel type (data/speech) is associated with a control channel (associated control channel).

The broadcast control channel (BCCH) is a unidirectional (base station to mobile) channel that is used for continuous broadcasting of different information regarding the current cell and neighboring cells. Other functions are frequency correction and synchronization.

For uplink (mobile to base) or downlink (base to mobile) communications, common control channel (CCCH) may be used. PCH and AGCH channels operate for the downlink communication purposes. The AGCH channel is used for access grant to a mobile with some free data channel. In this channel the clear-to-send (CTS) message is broadcasted, if there is some free channel in the network that can be allocated to the user who have requested with a RTS (request-to-send) message.

The Dedicated control channels (DCCH) are used for call setup, or for measurement and handoff, and are assigned to a single mobile user. SACCH channel is used for sending call request packet (RTS).

## **2.4 Dynamic Access Probability (DAP) Protocol**

The underlying idea of this multiple access resolution protocol is, to allow a user to transmit a packet with some probability ( $p_{\text{access}}$ ). This probability depends on the load on the channel. The probability of accessing the channel at low load approaches unity whereas at high load the probability becomes small. This protocol is useful when there are large numbers of users accessing a shared channel with small collision detection facility. This type of situation emerges in cellular networks on the control channel. Here the  $p_{\text{access}}$  is determined according to the load on the channel and it broadcast to all

users. As the load keeps varying one has to deal with Dynamic Access Probability protocol. For this protocol the system must have:

- (a) An access authority for determining an access probability to a shared channel by calculating total access to the channel, and
- (b) An access broadcaster for broadcasting the access probability to the users wishing to access the shared channel.

For example In case cellular network, the shared channel includes an up-link signaling channel, the access authority is selected from the group consisting of a mobile switching center (MSC) and a base station (BS), and the access broadcaster is the base station. The announced access probability is transmitted through the existing down link control channel (e.g., DCCH in GSM systems). More preferably, for either the cellular network or the satellite network, the user attempts to transmit a Request-to-Send (RTS) message according to the access probability on the up-link signaling channel. Using DAP scheme network can reduce the likelihood of collisions, without causing any degradation in system performance.

## **2.4.1 PROBLEM DEFINITION**

Naor and Levy [1] in their work considered a network having a shared channel. The network consists of many independent stations wishing to communicate with/through a central station via the shared channel. The problem addressed in their paper is the allocation of the shared channel among many competing independent stations wishing to use it. They have assumed that new transmission attempts are generated according to a Poisson distribution. For getting a good approximation, they have taken the number of users as infinite, time is slotted, and transmissions occur only at the beginning of a time slot. All packets are of the same length, and each time slot can accommodate the transmission of exactly one packet. As the total number of users is considered as infinite, hence the total number of ready users consisting of new arrivals and backlogged transmission can also be taken as Poisson.

### 2.4.2 Load and Probability Access Estimation

The network computes an access probability, which depends on the load, and announces it, as a broadcast message, to the users. Each user who wishes to use the shared channel, attempts to access the channel with the announced probability. The load determines the access probability: Whenever the rate of transmission attempts per time unit exceeds a predefined threshold, it decreases. On the other hand, whenever the rate of transmission attempts per time unit drops below (another) pre-defined threshold, it increases. Hence, by listening to the shared channel, and counting (or estimating) the number of transmission attempts per time unit, we can optimize the access probability to achieve optimal channel efficiency. The shared channel DAP algorithm is as follows:

Repeat:

Central Administrator (Base Station)

1. Estimate the average number of transmission attempts per time unit, say  $n$ , by listening to the channel.
2. Find the optimal user access probability  $p_{\text{access}}$ , based on the value of  $n$ , and the previous  $p_{\text{access}}$  value and announce it to all users, as a broadcast message. Initial  $p_{\text{access}}$  is set to 1.

Ready User (New arrival/ Backlogged transmission):

1. Get access probability, say  $p_{\text{access}}$ .
2. Attempt to send a Request-To-Send (RTS) message, with probability  $p_{\text{access}}$ .
3. Wait for acknowledgement (Clear-To-Send [CTS] message).
4. When CTS is received, send data, following the instructions specified in the received CTS message.

This above algorithm proposed by Naor and Levy, for multiple access resolution in wireless networks, works well than other existing protocols.

## Chapter 3

# TRAFFIC VARIATIONS AND DAP

---

### 3.1 Non-Stationary Traffic

Cellular traffic can be modeled as non-stationary [8] for some cases; the arrival pattern can be modeled by non-homogeneous Poisson process. This type of traffic pattern is applied where the load changes with time. i.e. the load at some period of time becomes very high and other times it is constant low. This traffic pattern can be well understood by the case of the arrival of number of customers at lunchtime and dinnertime of a Restaurant. During these periods the number of customers is very large and may form large queues. One more significant case occurs for this kind of traffic is to predict the load variability for the system. In case of cellular network, traffic pattern is non-stationary. So for heavy load periods the system should be designed to avoid more number of collisions. This pattern can be well understood by the queuing theory. Queues formed randomly when the load becomes high. In case of predictable variability the queues are formed in a predictable manner. DAP can efficiently handle the traffic at such high load periods, by giving a very small probability of accessing the channel to all the users who want to access the channel in cellular networks. Here in case of DAP

protocol in cellular networks, the queues keep the backlogged users who need to retransmit in the next interval. If the arrival pattern for the predictable variability can be modeled by some mathematical function then the implementation of DAP becomes simple. The expected number of users wishing to transmit over an interval can be found by integrating the arrival rate with respect to time.

$$\Lambda(t) = E(\text{arrivals between time } a \text{ and time } b) = \frac{1}{(b-a)} \int_a^b \lambda(t) dt \quad (3.1)$$

$\lambda(t)$  : The number of users wishing to use the channel at time  $t$ .

The estimation of  $p_{\text{-access}}$  is carried out by first calculating the load. Hence, the main operations inherent with this multi-access protocol are load estimation, estimation of  $p_{\text{-access}}$  and announcing the  $p_{\text{-access}}$  to all users. For this estimation, the time slots are grouped to form estimation interval. In the estimation interval the average load on the channel is calculated. Then the  $p_{\text{-access}}$  is calculated which is applied for the next interval. The optimal access probability is calculated for the subsequent intervals based on the load and  $p_{\text{-access}}$  of the previous interval. The optimal access probability for the next interval can be calculated by using the standard result of R.L.Rivest et al [7]:

$$p_{\text{-access}}(t+1) = \min\left(\frac{P_{\text{-access}}(t)}{\lambda(t)}, 1\right), \quad (3.2)$$

where  $\lambda(t)$  is the arrival rate for the previous interval,  $p_{\text{-access}}(t)$  corresponds for the previous interval.

If the expected arrivals during some periods where the plot of the function  $\Lambda(t)$  becomes linear, then we can take the arrival rate for that time period to be a constant, equal to the slope of the line. So we can apply simply Poisson process instead of non-homogeneous Poisson process. Hence the system task of estimating the load becomes easier. In this way we can make the arrival function piecewise linear. This traffic pattern handles many cases but is not suitable for the actual traffic in the cell that is bursty, which essentially characterizes traffic with large variance.

### 3.2 BURSTY TRAFFIC

The uncertainty in call generation time and due to the randomness of the interval in which more number of calls made, leads to bursty [2, 11] traffic. Typically the arbitrary number of packets to be transmitted is separated by inter-arrival intervals of random duration. These idle intervals are often much longer than the periods of transmission. Hence the peak traffic is always much higher than the average traffic. The following figure clearly interprets this. Here the average load is 0.25 but the peak traffic is around 2.8. This figure clearly depicts burstiness, with some high load slots with large low data rate periods.

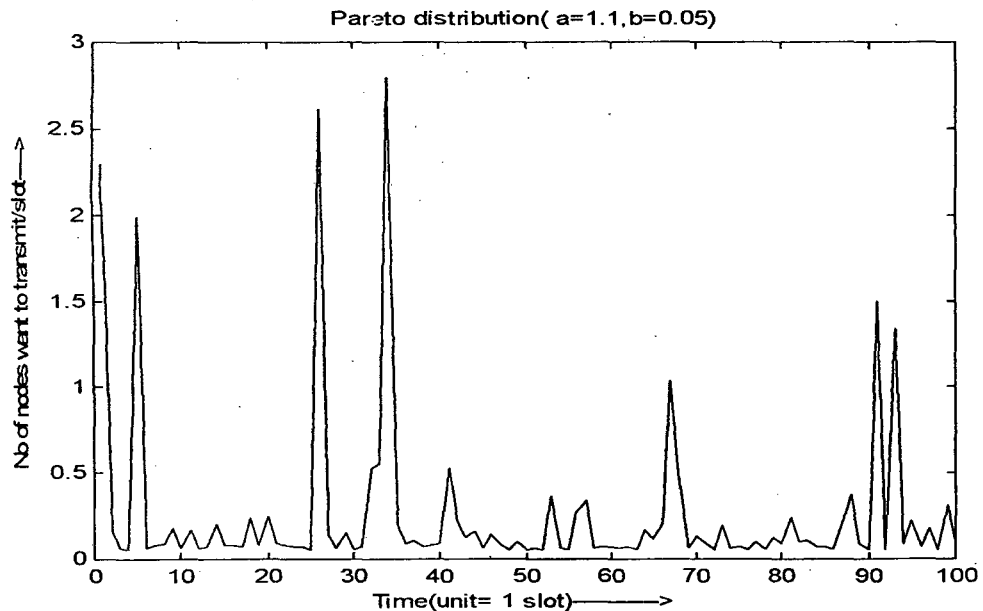


Figure 3.1 Bursty Traffic

It may be noted that the traffic modeled as Poisson shows burstiness for small time scales. But this pattern smoothes out for a large time interval. But in actual case the traffic remains similar for different time scales and can be modeled as a self-similar



### 3.2.1 Self-similar Traffic

If the traffic pattern of the network at different time scales regenerates the same pattern, then the traffic pattern is self-similar [9]. A self-similar traffic has similar statistical properties for different time scales and is in vogue for characterizing internet traffic. A self-similar traffic process is a stochastic process  $X(t)$ , with parameter  $H$  ( $0.5 \leq H \leq 1$ ) if for any constant  $a > 0$ , the process  $a^{-H}X(at)$  has the same statistical properties as  $X(t)$ . i.e. mean, variance and autocorrelation of both the processes are same.

The parameter  $H$ , known as the Hurst parameter, or the self-similarity parameter, is a key measure of self-similarity. Also  $H$  is the measure of the persistence of the statistical properties and is a measure of the length of the long-range dependence [2, 9] of the stochastic process. When  $H$  approaches to 1 the degree of persistence or long-range dependence increases and hence the self-similarity appears in full.

Long range dependence is defined in terms of the behavior of the auto covariance  $C(\tau)$  [9] of a stationary process as  $\tau$  increases. In case of short-range dependent processes the auto covariance decays exponentially. A long range dependent process has a hyperbolically decaying auto covariance.

The network traffic patterns such as the packet inter-arrival times and burst lengths can well be characterized by heavy tailed distributions. For heavy-Tailed the distribution of the random variable is,

$$1-F(x)=\Pr[X>x] \sim 1/x^\alpha \text{ as } x \rightarrow \infty, 0<\alpha<1$$

The above equation shows that the random variable with heavy-tailed distribution will include very large values with non negligible probability. Hence this model can be applied for the traffic pattern in cellular networks, where the number of nodes want to transmit at the same time are small but for few slots the number is relatively very large. Pareto distribution is a heavy tailed distribution [9].

### 3.2.2 Pareto Distribution

Pareto distribution [9] is an example of heavy-tailed distribution. Pareto distribution can be used to generate bursty traffic patterns. It can generate a large number of low load intervals with short inter-arrival gap and also a few heavy loaded intervals with large gap.

Pareto distribution with parameters  $a$  and  $b$ , has density and distribution functions,

$$f(x) = F(x) = 0, \quad (x \leq b)$$

$$f(x) = \frac{a}{b} \left( \frac{b}{x} \right)^{a+1} \quad (3.3)$$

$$F(x) = 1 - \left( \frac{b}{x} \right)^a \quad (x > b, a > 0), \quad (3.4)$$

where  $a$ : specifies the shape parameter for ( $1 < a < 2$ ) the distribution is self-similar then the distribution have infinite variance with finite mean,  $b$ : specifies the minimum value of the random variable.

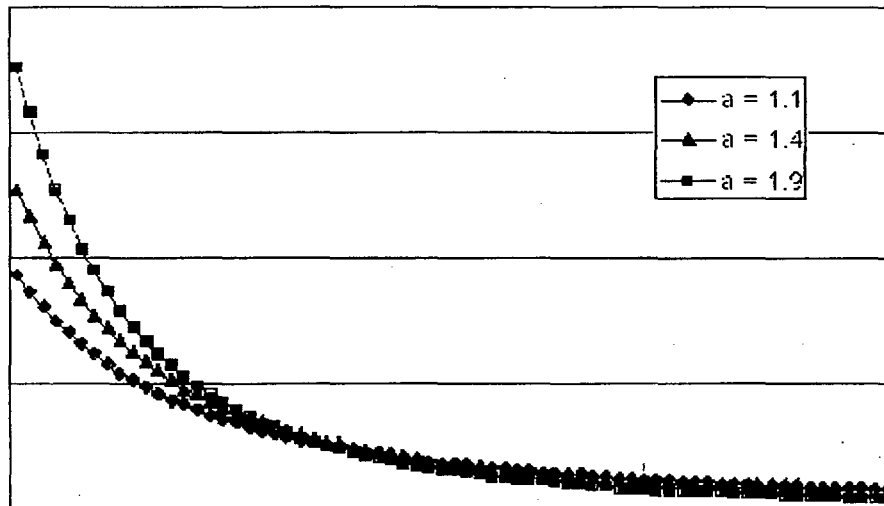


Figure 3.2 Probability density function of Pareto distribution with  $a = 1.1, 1.4, 1.9$ .

Fig. 3.2 shows the graph of Pareto distribution for different values of  $a$ . For the values of  $a$  approaching 1, the probability of a very large value for  $x$  is more. Hence self-similarity increases for lesser values of  $a$ .

Hurst parameter is related with the shape parameter or self-similarity parameter of the Pareto distribution as, the lower the value of  $a$ , the higher the probability of an extremely large  $x$ .

Mean value of the Pareto distribution is,

$$E(x) = \frac{ab}{a-1} \quad (3.5)$$

Generation of random variables distributed as Pareto Variation,

$$X_{\text{pareto}} = \frac{b}{U^{1/a}}, \quad (3.6)$$

where  $U$  is a uniformly distributed value in the range  $(0, 1]$

If  $s$  is the minimum value that may be produced from the uniformly distributed values. Then, the generated Pareto-distributed values will not exceed  $q$ . Using equation (3.6),

$$q = \frac{b}{s^{1/a}} \quad (3.7)$$

Now, the mean value of the Pareto distribution can be calculated as shown below:

$$E(x) = \int_b^q xf(x)dx \quad (3.8)$$

$$= \int_b^q x \frac{ab^a}{x^{a+1}} dx = ab^a \int_b^q \frac{1}{x^a} dx = \frac{ab}{a-1} \left[ 1 - \left( \frac{b}{q} \right)^{a-1} \right] \quad (3.9)$$

Using equation 3.6 and 3.8

$$E(x) = \frac{ab}{a-1} \left[ 1 - s^{\frac{a-1}{a}} \right] \quad (3.10)$$

In the proposed work, we have generated Pareto traffic. For different cases of Pareto parameters the traffic is generated, and ranges of the parameters have been tested for getting better self-similar pattern. The assumptions for the network are already

specified. Here also the load is calculated for some number of slots known as estimation interval. The  $p_{\text{access}}$  is calculated depending on the load and  $p_{\text{access}}$  for the previous interval. Then this  $p_{\text{access}}$  is applied for the same interval. The length of the interval for calculating the load and announcing the  $p_{\text{access}}$  are kept same in this without loss of generality. The interval length also should be varied according to the estimated load to get better results. The mean traffic generated by the protocol is compared with the mean of Pareto distribution. Based on the difference the interval length varied to get an optimal estimation interval.

The expected mean is calculated from equation (3.10), where the values of  $a$  and  $b$  are taken constant for the whole simulation period. By finding the value of  $s$ , the mean can be calculated. If the average load differs largely from the expected load, then the period of estimation interval is varied. After getting an optimal estimation interval for the initial process, then the interval is optimized by the estimated load. If the load decreases then the estimation period is increased.

## **Chapter 4**

### **PERFORMANCE OF DAP FOR SELF-SIMILAR TRAFFIC**

---

The simulation of different ALOHA versions and DAP protocol for Pareto traffic is done using MATLAB. MATLAB (Matrix Laboratory) is an excellent programming tool for simulation of mathematical functions and simplifying matrix operations.

#### **4.1 Generating Different Traffic**

In my work I have not used any real time traffic from web. But many types of traffic are generated using simulation. By varying the parameters of the traffic generating functions, many cases of traffic are examined. Traffic is generated in a large scale of 10000 intervals. Assuming each interval consists of 100 slots. And each slot is assumed to occupy, the time required for one packet transmission. In the following figures, 100 slots i.e. 1 interval is taken as 1 sec.

### 4.1.1 Generating Pareto Traffic

Self-similar pattern can be produced using Pareto traffic, for the values of the shape parameter in the range [1,2]. As introduced in chapter 3, Pareto traffic is an example of heavy-tailed distribution, which exhibits long-range dependence [9]. As discussed earlier Pareto traffic has two parameters a, b. By varying the values of a or b different traffic patterns are obtained. For all these case of traffic the protocol is examined and the protocol is quite stable for different traffic. The parameters are varied in accordance with the expected arrival rate in the real cases. The Pareto traffic is generated as:

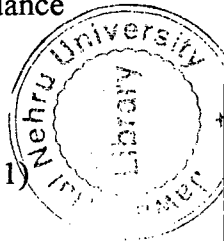
$$X_{\text{pareto}} = \frac{b}{U^{1/a}},$$

(4.1)

where b: the minimum value of the possible arrival rate, and a: Shape parameter, for self-similar traffic:  $[1 < a < 2]$ , and U is a uniformly distributed random number  $[0, 1)$ .

U is generated randomly and applied for the Pareto traffic generation. The maximum load is obtained for the minimum probable value that can be produced for U. For different values of a and b the traffic is generated.

In the following figures the parameters of the Pareto distribution are ( a = 1.5, b = 0.2)



TH - 11279

FIGURE 4.1. load vs time

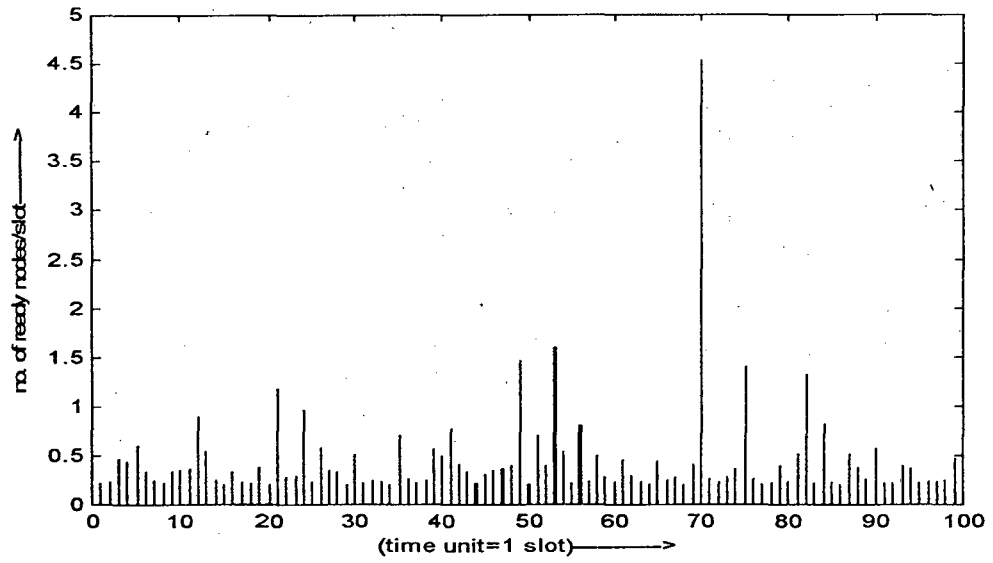
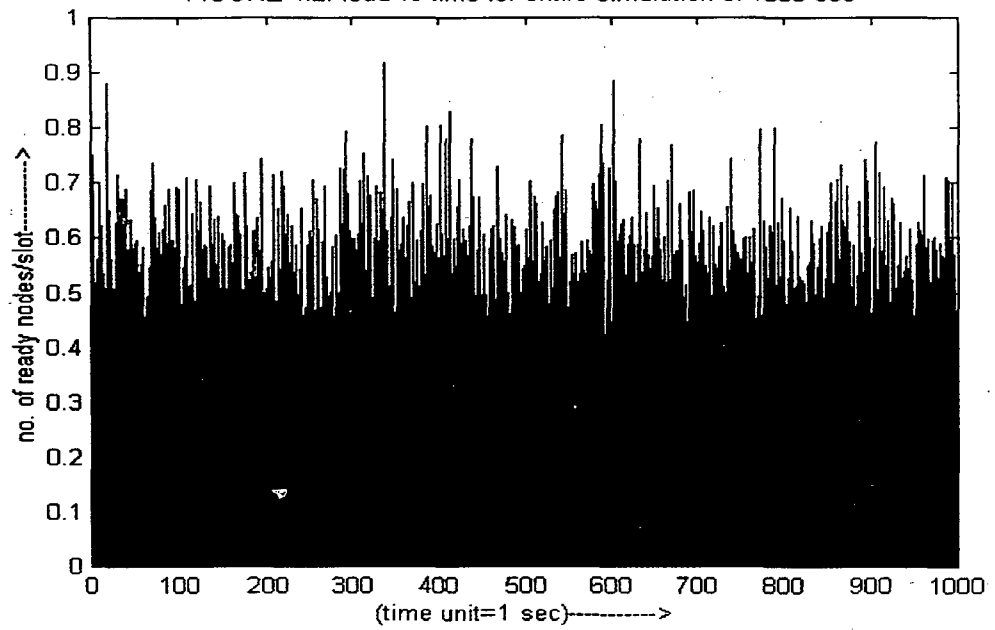
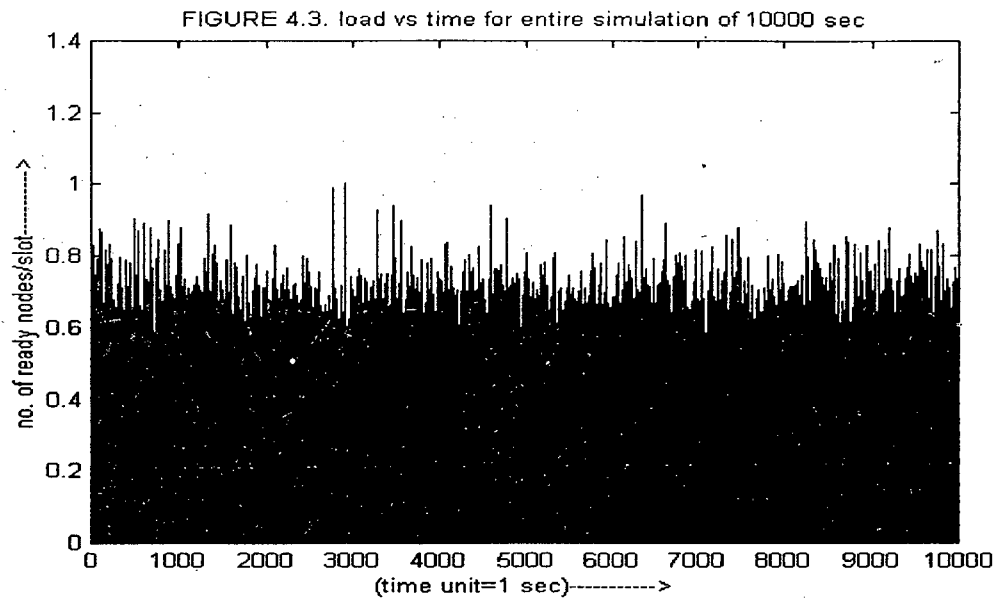


FIGURE 4.2. load vs time for entire simulation of 1000 sec





In figure 4.1 the Pareto distribution is plotted for the time interval of 100 slots.

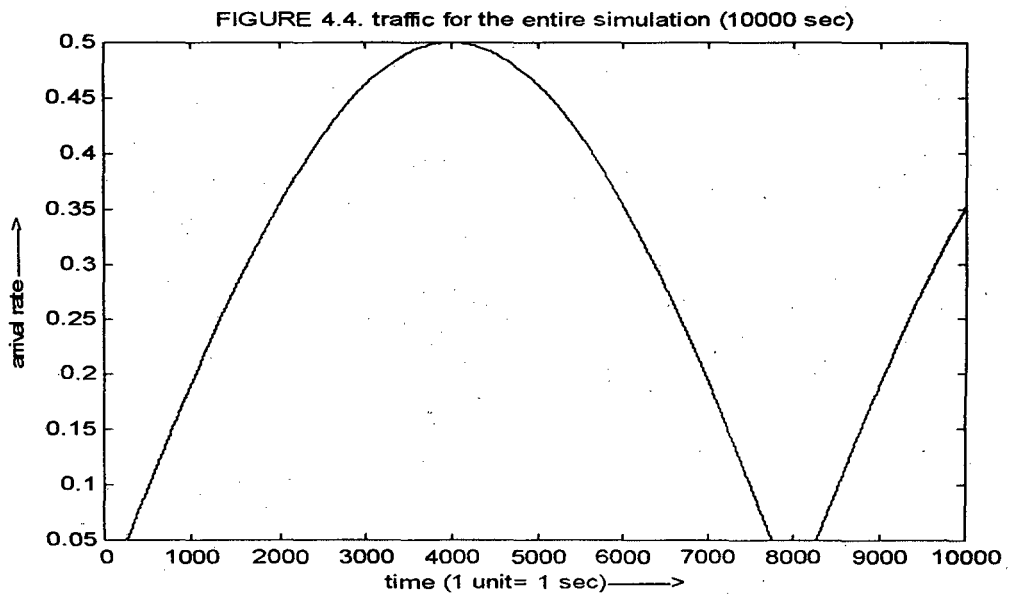
In figure 4.2 the mean load /slot is plotted against a time period of 1000 sec (1 sec= 100 slots) and in figure 4.3 the mean load per slot is calculated and is plotted for the entire simulation time of 10000 sec.

For all these above three figures the traffic pattern is similar, which shows the self-similar property of Pareto distribution. Hence, this traffic is applied for the performance analysis of DAP protocol.



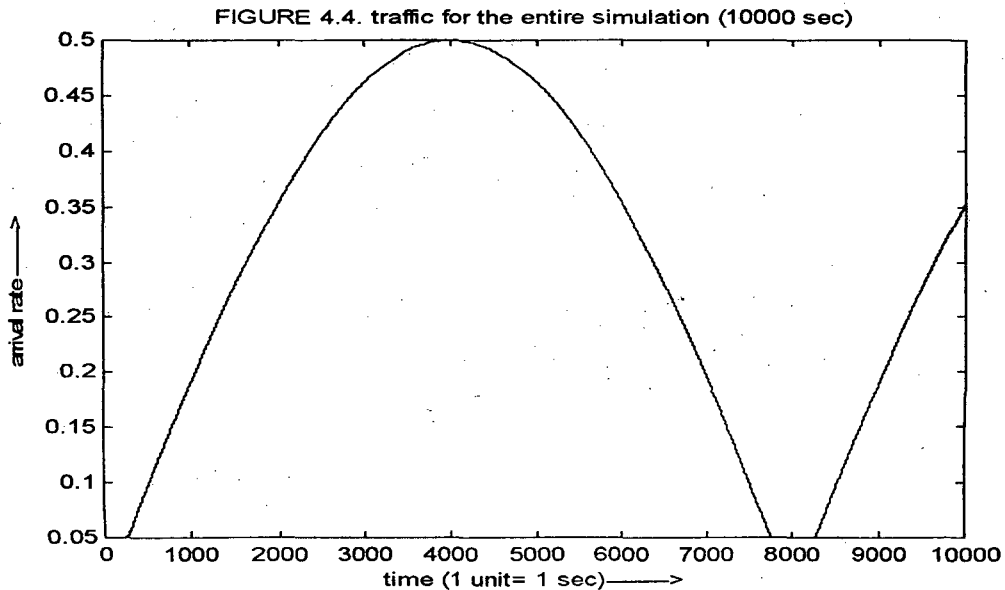
### 4.1.2 Generating Non-Stationary Arrival Rate

As discussed in chapter 3, upon specific requirement of some cell, non-stationary traffic can also be simulated for the MAC protocol using DAP. Here one specific case of non-stationary traffic is examined. If the arrival rate of the cell can be predicted for different times, with some mathematical function. Then the function can be applied for Poisson traffic generation. The main advantage of this is that if the arrival pattern is known for some cell which repeats after some period of time, then the arrival rate can be applied for load estimation for that time instant. Moreover the expected arrival rate for some intervals can be pieced into straight line. Then for these linear intervals the traffic can be considered to be Poisson, with parameter equivalent to the slope of the interval. Here some cases of sinusoidal arrival rates are generated.



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Here in the above figure (4.4) Non-stationary traffic is generated for a total simulation interval of 10000 sec. The average load per slot is plotted against each interval. The maximum arrival rate is 0.5.

### 4.1.3 Generating Poisson Traffic

Poisson traffic is the simplest case for networks to simulate. In appendix a model of Poisson traffic generation is given for different input parameters ( $\lambda$ ).

Poisson traffic can be generated using Poisson process. If  $\lambda$  be the arrival rate, then the probability density function of Poisson process is,

$$P(k) = \frac{\lambda^k}{k!} e^{-\lambda} \quad (4.2)$$

Where  $P(k)$  is the probability of  $k$  transmission attempts.

$$P(0) = \frac{1}{e} \quad (4.3)$$

Using the PDF of Poisson process (equ. 4.2). Recursively it can be calculated as

$$P(k) = \frac{\lambda}{k} * p(k-1) \quad (4.4)$$

Here in my simulation I have generated Poisson traffic by first generating a uniform random variable  $[0, 1)$ . And by calculating the probability of  $k$  transmissions, if it

exceeds the uniform random number then the generated Poisson number is  $k$ . The simulation of Poisson distribution for parameter  $\lambda$  is given in the Appendix.

## **4.2 Simulation of DAP using Pareto Traffic**

First the Pareto traffic for different parameters is generated. And these traffic patterns are compared with the self-similar traffic pattern. Then some suitable range of the Pareto parameters was determined. For different input parameters the DAP protocol is simulated. Here some results discussed for a fixed set of parameters. Simulation is carried out for a range of 10000 sec. Where 1 sec = 100 slots. The intervals are fixed for simplification of implementation. Better results can be expected for dynamically changing the interval length after calculating the load for each interval. The interval length also can be varied according to the estimated load. That will work as, when the estimated load increases, then the interval length should be shortened for next interval and if the average traffic is very low, then the interval length should be increased.

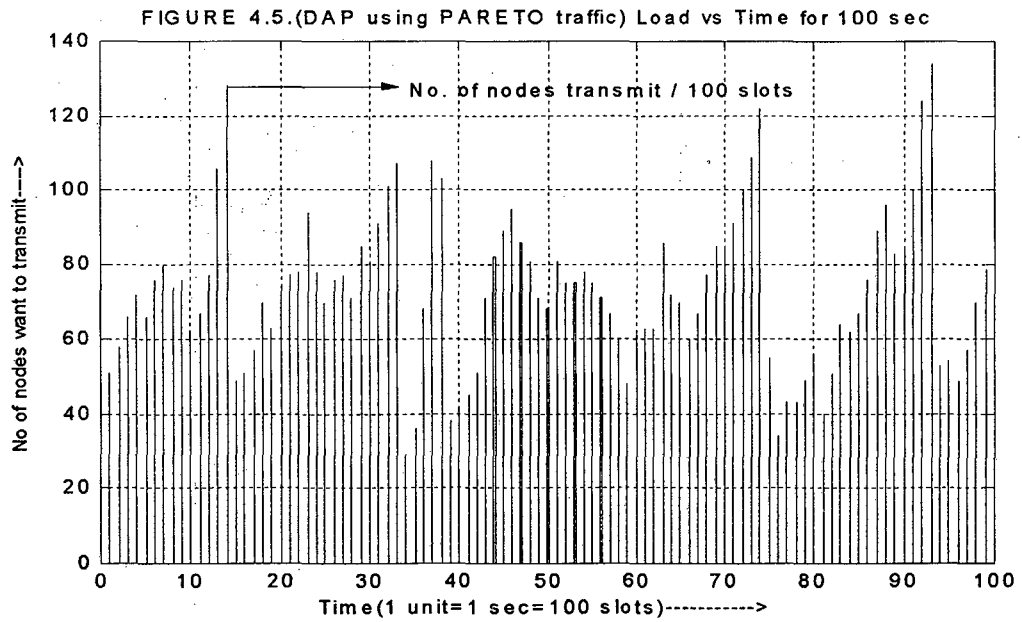


Figure 4.5 shows the bursty nature of the generated Pareto traffic. Here the load for 1 interval is plotted for duration of 100 intervals. The figure shows that the difference between the average traffic and the peak traffic is high. Due to some rounding of the actual generated traffic, the result is less bursty.

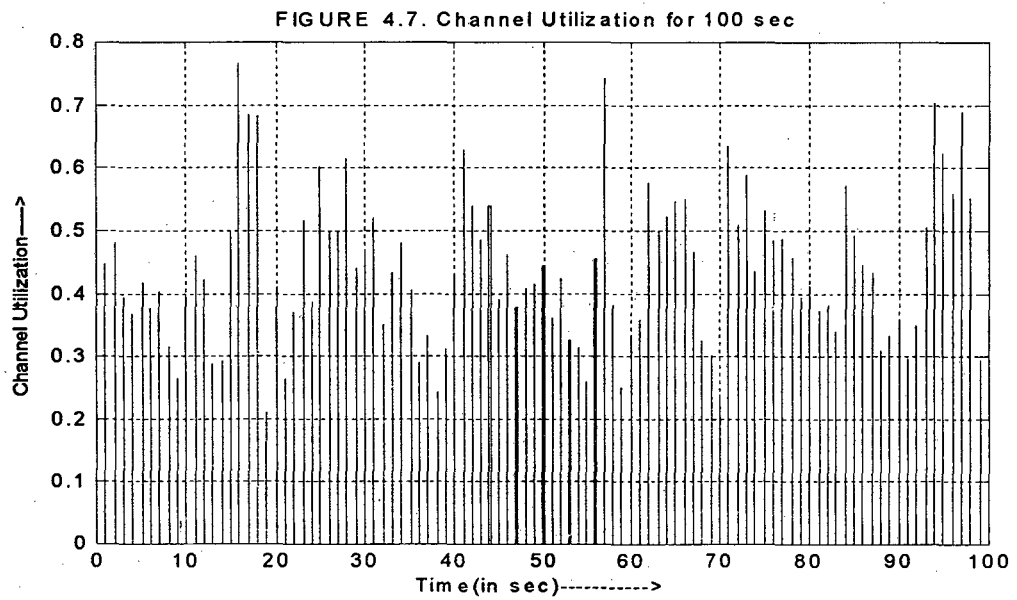
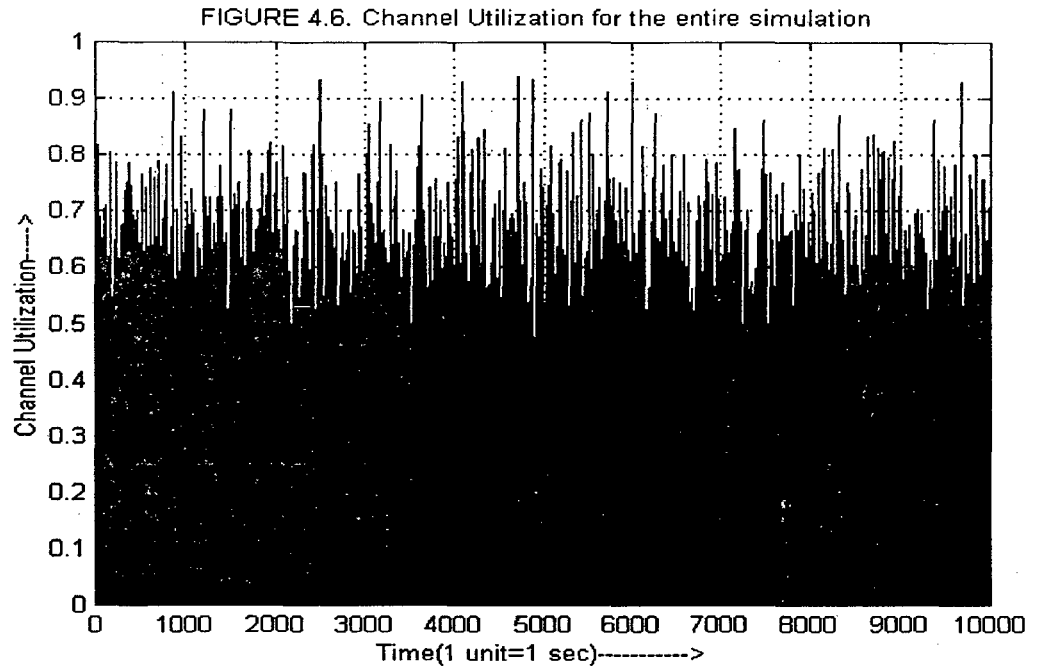


Fig. 4.6 and 4.7 shows the channel utilization for some intervals exceeds 0.8. This suggests that the protocol is very efficient and the average utilization is also approaches to the mean arrival.

This efficiency is achieved by the application of  $p_{\text{access}}$  to all ready nodes. Both the retransmission probability and the fresh packet is to be transmitted with  $p_{\text{access}}$ . And this probability of accessing the channel is varied with respect to average traffic and  $p_{\text{access}}$  for the previous interval. The values of  $p_{\text{access}}$  for each interval are plotted for the entire simulation period. Figure 4.8 and 4.9 depicts the optimal values of  $p_{\text{access}}$  for each interval is calculated.

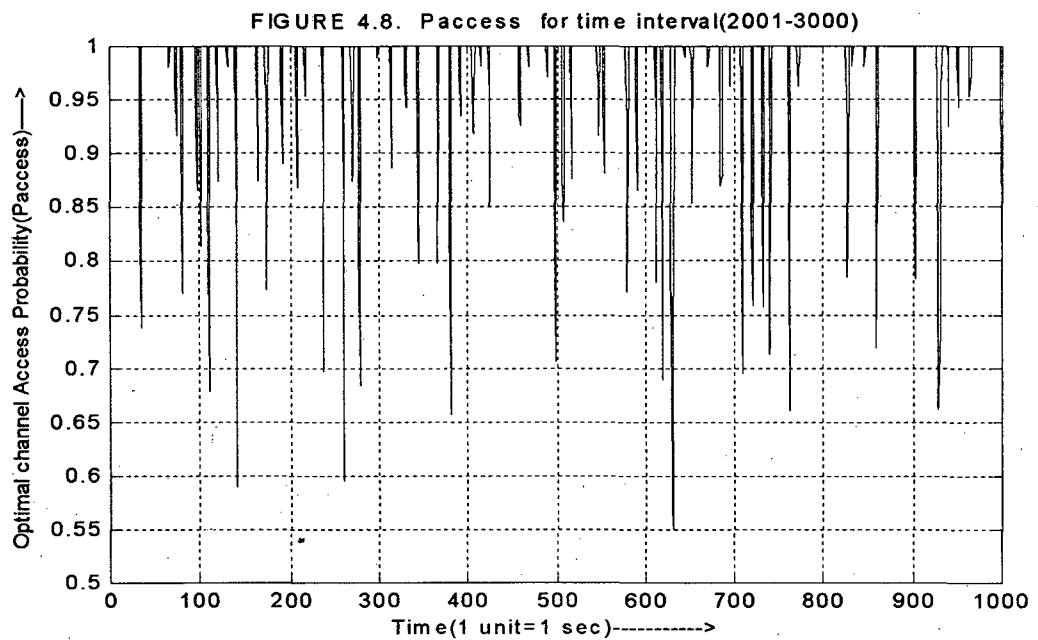
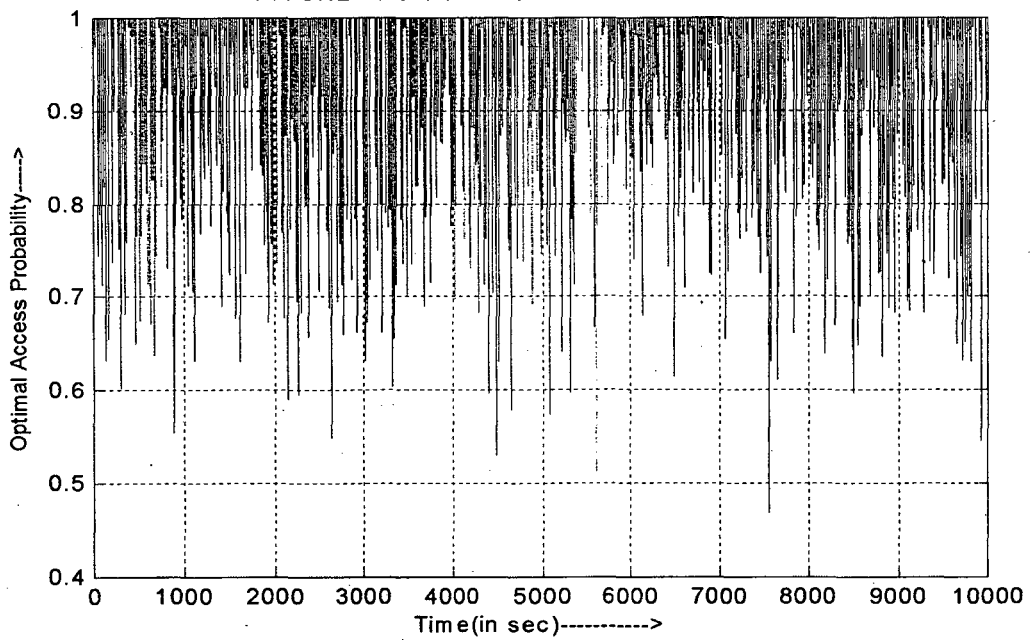


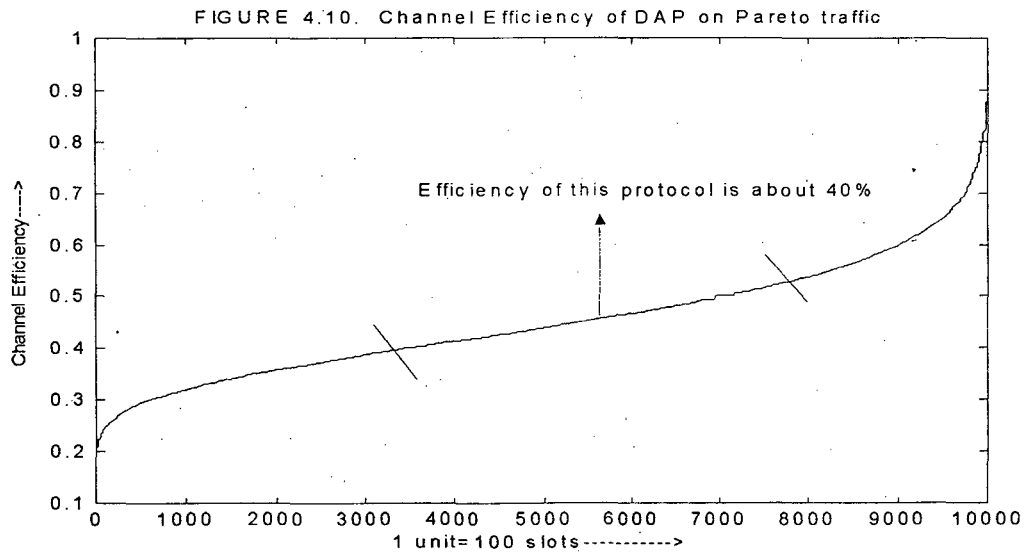
FIGURE 4.9. Paccess for the entire simulation



After the entire simulation is finished the efficiency of this protocol is calculated.

In our simulation the average load per slot is kept less than 2. This protocol works very stable for any load. But the simulation time becomes very time consuming for the entire simulation period. And the efficiency is plotted for various load patterns. Fig. 4.10 clearly shows that the efficiency of this protocol as compared to other protocol is very impressive which is almost equal to 45%.

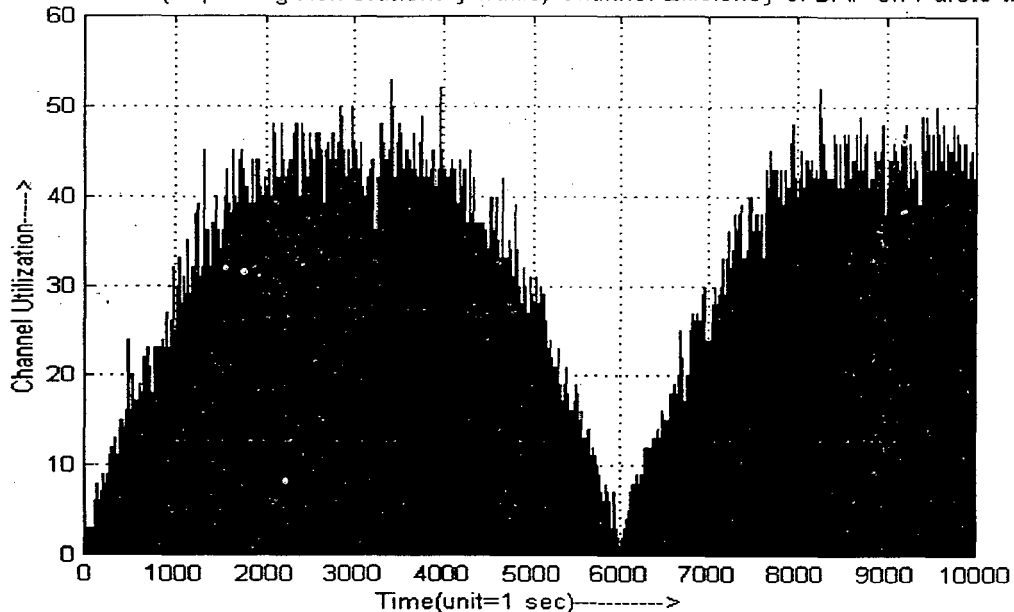




### 4.3 Simulation of DAP using non-stationary arrival

One specific case of the non-stationary arrival is designed in my work. This can be an example of the traffic pattern of some cell that changes accordingly a mathematical function. The designed traffic is based on the arrival function and generated by Poisson process. The burstiness can be incorporated in this by changing the Pareto parameters according to the mathematical function. Here in my simulation, the traffic is generated for a sinusoidal arrival rate. This case occurs in many cases. In come cell if the traffic is very high at peak hours and becomes very low at odd hours. The arrival rate is given in the Appendix. This rate is applied as the parameter to the Poisson distribution. And the this load is used for the analysis of DAP protocol. Here are some results.

FIGURE 4.11. (Dap using Non-stationary traffic) Channel Efficiency of DAP on Pareto traffic



Under this traffic, channel utilization become very high, it approaches to the arrival rate as shown in the figure 4.11 and 4.12.

FIGURE 4.12. Load vs Time for 100 sec

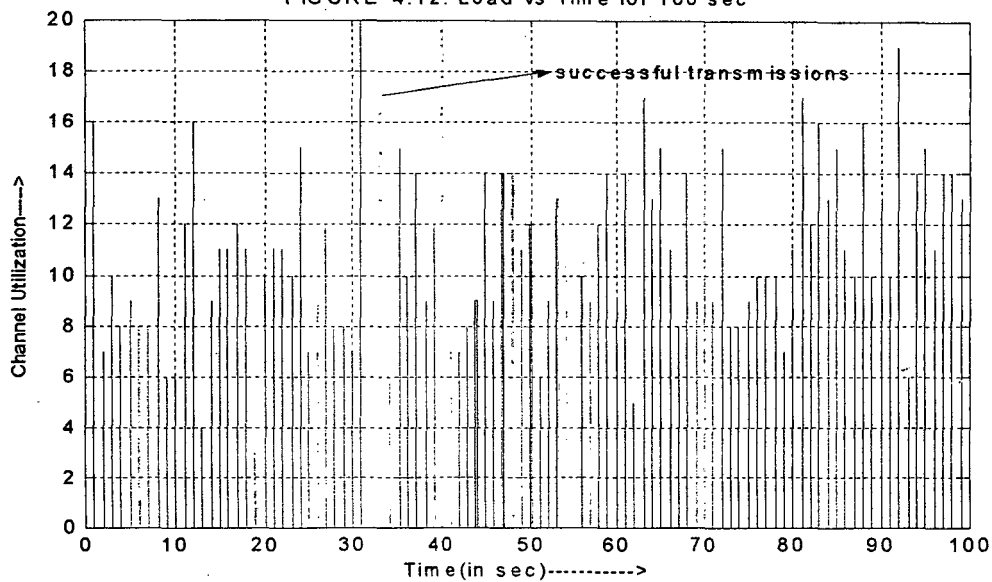
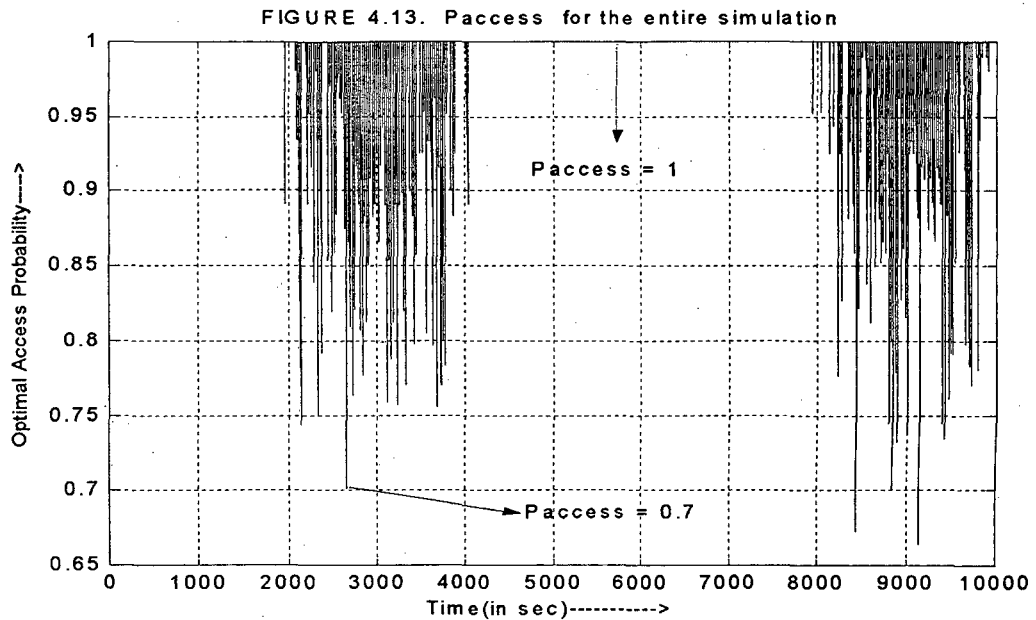


Fig. 4.13 shows how optimal access probability is changed in this case. Initially the value of  $p_{\text{access}}$  is 1 for a long time as the arrival rate is very less. When the arrival rate increases and approaches to peak, the  $p_{\text{access}}$  is optimized accordingly. Again, when the load decreases then  $p_{\text{access}}$  increases.



#### 4.4 Simulation of Slotted ALOHA protocols Using Pareto Traffic

The simulation work of slotted ALOHA protocol is carried with the same input Pareto traffic as applied for DAP (in section 4.2). Slotted ALOHA protocol designed here, is slightly modified to cope with the more number of backlogged users. In case of slotted ALOHA a ready node (fresh arrival/backlogged), transmits its packet at the beginning of the next slot. But by this strategy the network becomes unstable because the collisions occur frequently. Hence here also the total time is divided into slots and the protocol is applied for some slots. At the end of the interval all the backlogged users

are scheduled in the next interval randomly. This is an improvement over the simple slotted ALOHA protocol. Some results are given in the following figures.

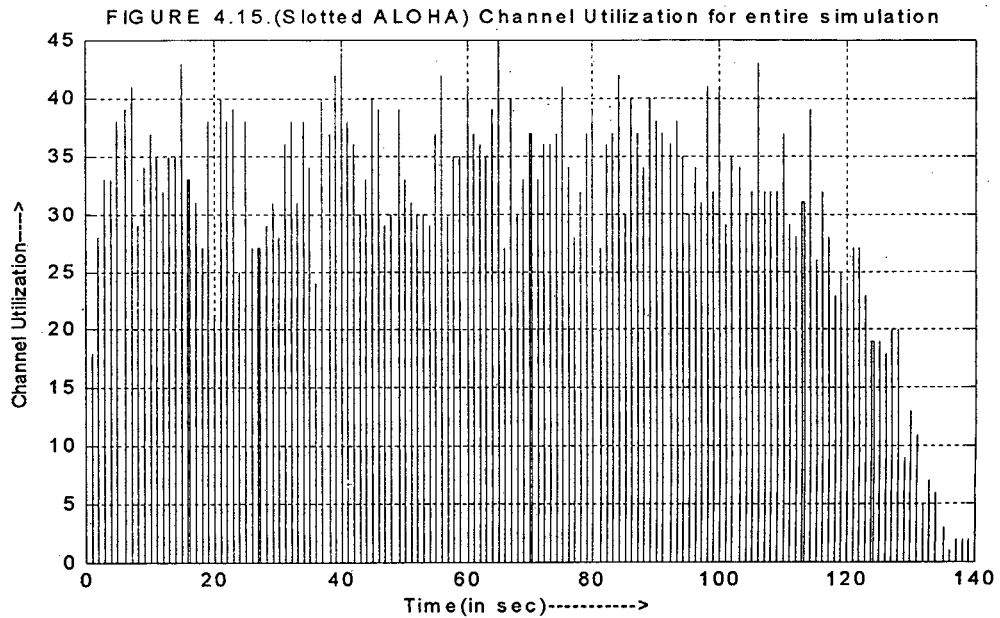


Fig. 4.15 shows the channel utilization decreases after some time. After 140 sec the channel utilization approximately becomes zero. This happens because, after some time the system cannot handle the collisions.

Number of collision increases with time. Hence, the system cannot recover after some period. So the number of ready users, competing for the channel becomes very high as shown in the figure 4.16. So this protocol cannot handle the traffic when the number of users per slot becomes more than 7, for the particular input.

FIGURE 4.16. (Slotted ALOHA using PARETO traffic) Average Traffic/slot for the entire simulation

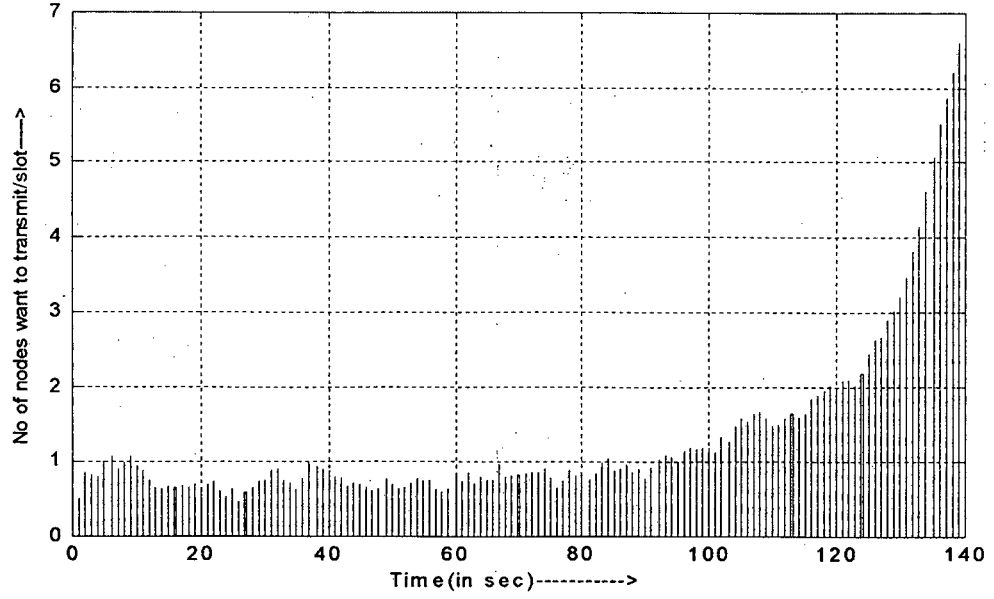


FIGURE 4.17. Channel Efficiency of Slotted ALOHA on Pareto traffic

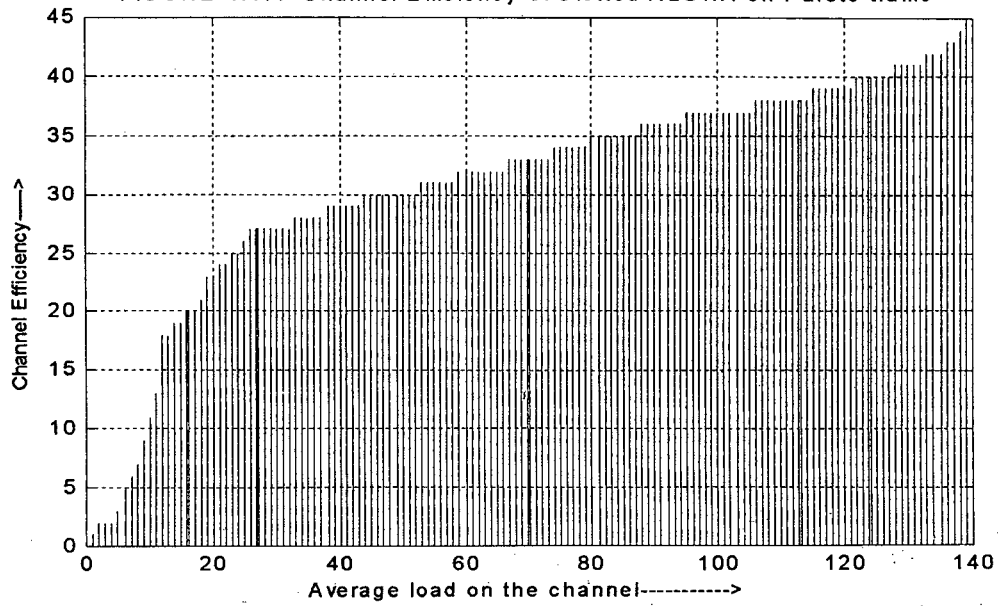
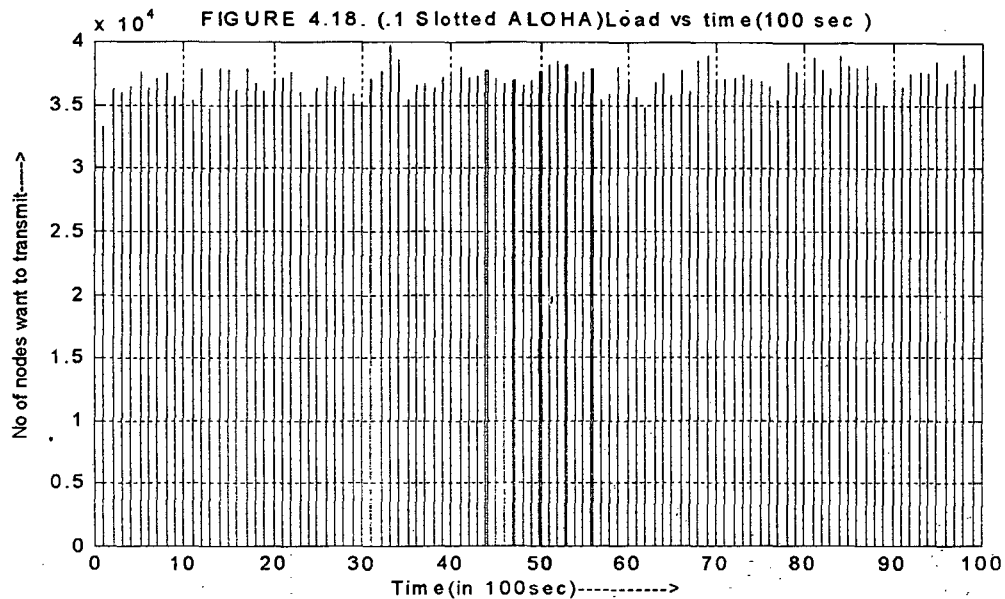
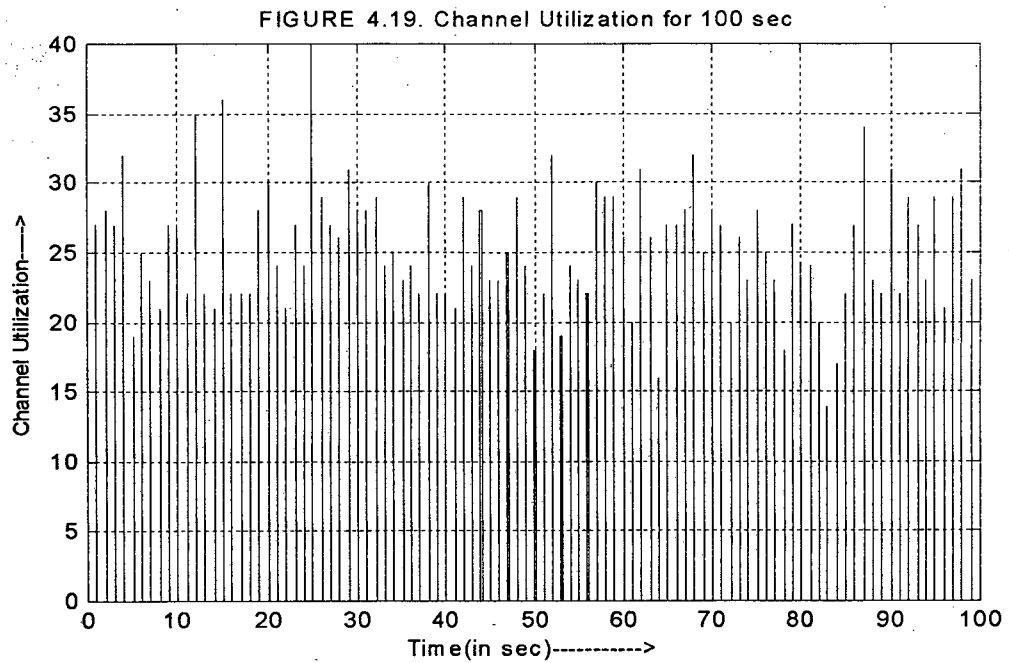


Figure 4.17 shows the channel efficiency of this protocol under Pareto traffic. As compared with the DAP, this protocol is very inefficient. DAP protocol is stable for any type of traffic pattern. But slotted ALOHA protocol becomes useless after some time.

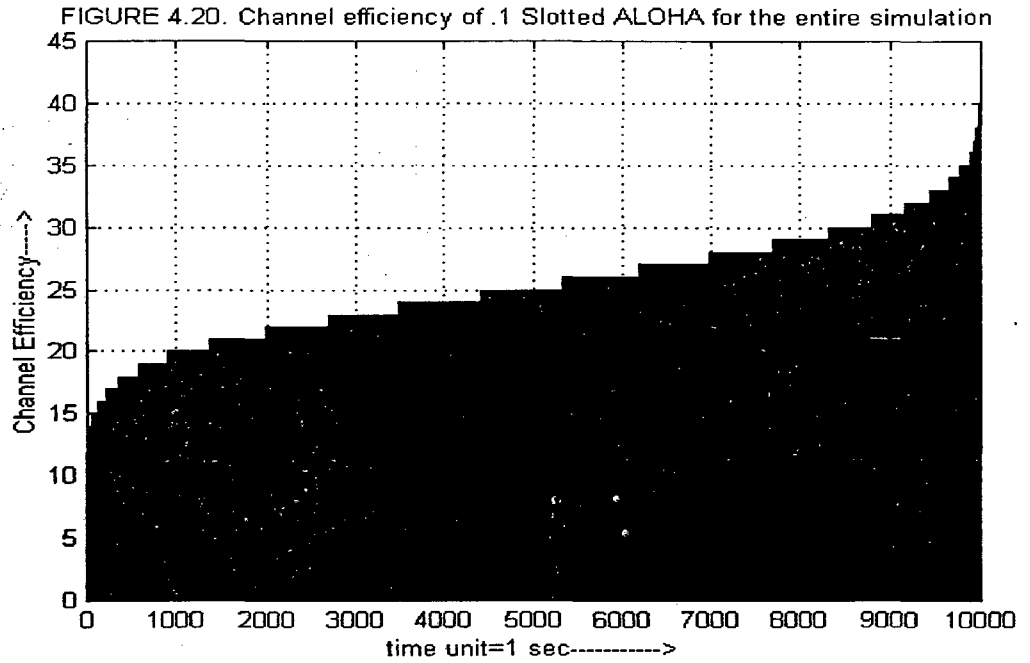
Different versions of slotted ALOHA that can be used in wireless networks are designed. One such protocol is 0.1 persistent slotted ALOHA. Some results for this protocol are also discussed here. Here in this protocol the probability of accessing the channel is kept constant ( $p_{\text{access}} = 0.1$ ). This is designed exactly same as DAP protocol, with only one difference  $p_{\text{access}}$ . This protocol works very well, if the expected number of transmission attempts is very high. But at low load periods this protocol gives unnecessary delay. Fig. 4.18 tells about the inefficiency of this protocol, because the traffic used in the simulation is not high. Here in many cases the users are backlogged. This decreases the efficiency.





The channel utilization using this protocol becomes very less around 20 nodes per interval. The channel utilization of this protocol is given in figure 4.19.

Fig. 4.20 depicts the channel efficiency under this protocol. The efficiency of this protocol is very less compared to the DAP protocol as shown in fig. 4.9.



All the above results show that the efficiency of DAP protocol is very high as compared to other protocols and moreover this protocol is very stable for different load consideration.



## Chapter 5

### DISCUSSION AND CONCLUSION

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Because of limited bandwidth, wireless medium is a shared resource and the channel access becomes crucial. Various Access Protocols are designed for the same. One of popular protocol is DAP and in this case the traffic load is assumed to be Poisson. This assumption is not valid if the traffic exhibit bursty phenomena. In this case DAP with Poisson assumption may not fully characterize the load.

We have attempted to simulate DAP multiple access for non-stationary as well as self-similar traffic. And also simulated slotted ALOHA protocol specifically taking the case of cellular networks. This can also be efficiently applied in any wireless networks where channel sensing is not possible and network with poor collision detection capability. As opposed to earlier works, we have considered the self-similar traffic which gives more realism to our work. We have carried out the comparison between previous models which used Poisson traffic with our model with Non-Stationary (NHPP) traffic and also with Self-Similar traffic. Here the Self-Similar traffic is simulated using Pareto distribution and generated all kinds of load that would be possible by changing the parameters. This protocol is stable for all kind of load variations. We have carried out the performance and analysis of these protocols.

Results indicate that the DAP protocol with self-similar load characterization can handle bursty traffic in cellular networks.

The extension of this study can be for media access control with different message length. That would support the Multimedia applications consisting both of Real-Time and non Real-Time traffic.

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## APPENDIX A

```
%FUNCTION FOR GENERATING POISSON DISTRIBUTION
%THIS FUNCTION GENERATES N POISSON NO.S WITH PARAMETER
LAMBDA
function p=posson(n, lambda)
r=rand(1,n);
  for j=1:n
    prob=exp(-lambda);
    s=prob;
    i=0;
    while r(j)>= s
      i=i+1;
      prob=lambda*prob/i;
      s=s+prob;
    end
    p(j)=i;
  end
p;%Return array to the calling function.
```

```

%FUNCTION GENERATING THE NON STATIONRY POISSON PARAMETER
FOR PREDICTABLE ARIVABILITY
%GIVEN BY SOME MATHEMATICAL FUNTION
function l=non_staionay(time) %time is in sec
a_rate=abs(40*sin(pi*time/4000));
l=a_rate/100;
l;

```

```

%FUNCTION FOR GENERATING PARETO DISTRIBUTION
%N PARETO NO.S WITH PARAMETERS A,B
function p=pareto(n)
%n=100
a=1.5;
%SHAPE PARAMETER OF PARETO DISTRIBUTION VALUE IN[1,2] FOR
SELF-SIMILAR
b=0.2;
%b IS THE MINIMUM VALUE OF x :  $P(x)=a*b^a/x^{(a+1)}$ 
uni=rand(1,n);
% N UNIFORMLY DISTRIBUTED RANDOM NO.S
p=round(b./power(uni,1./a));
%N PARETO DISTRIBUTED NO.S
p;

```

## APPENDIX B

```
%*****%
%*****DAP PROTOCOL FOR SELF SIMILAR TRAFFIC*****%
%*****%
%GENERATING SELF-SIMILAR TRAFFIC USING PARETO DISTRIBUTION
AND USING THE TRAFFIC
%FOR PERFORMANCE ANALYSIS OF DAP PROTOCOL
n=100;
% N IS THE NUMBER OF TIME SLOTS TAKEN FOR ESTIMATION
%INTERVAL(ANNOUNCEMENT INTERVAL)

%LET 1 ESTIMATION INTERVAL(LET 1 TIME UNIT) N = 100 TIME
%SLOTS(1 SEC)

for m=1:n,
    par_backx(m)=0;
    %BACKLOGGED PACKETS TO BE SCHEDULED IN THE FOLLOWING
    %TIME INTERVALS
    par_x(m)=0;
    %TOTAL NO OF PACKETS (BACKLOGGED + FRESH) IN MTH SLOT
    n_backlogged(m)=0;
    % NO OF BACKLOGGED NODES IN MTH SLOT
end

time=1;

while time<=10000
```

```

% SIMILUTION PERIOD OF 10000 SEC (TAKE 1 SEC=N SLOTS)

c_uti=0;
% CHANNEL UTILIZATION i.e NO. OF SLOTS WITH SINGLE
%TRANSMISSION
par=pareto(n);
for m=1:n,
    n_backlogged(m)=0;
    if par(m) > 10
        par(m)=10 ;
    end %END OF IF CONDITION
end %END OF FOR LOOP

par_x=par_backx+par;
    par_backx(1:n)=0;
%TOTAL NODES WISHING TO TRANSMIT (BACKLOGGED + FRESH
%NODES)
tot_load(time)=sum(par_x);
%TOT_LOAD IS THE TOTAL LOAD IN THE 100 SLOTS
avg_load(time)=mean(par_x);
%AVG_LOAD IS THE AVERAGE NO OF NODES WISHING TO
TRANSMIT

    if avg_load(time) < 0.01
        P-access(time)=1;
    end

    if time==1
        P-access(time)=1;
%INITIAL PROBABILITY FOR ACCESSING THE CHANNEL IS SET TO
1
    end %END OF IF CONDITION

```



%DAP PROTOCOL IF  $P_{\text{ACCESS}}$  IS OTHER THAN 1 THAN EACH NODE  
WILL TRANSMIT WITH A PROBABILITY  $P_{\text{ACCESS}}$

%IF THE CALCULATED ACCESS PROBABILITY FOR THE ANNOUNCED  
INTERVAL IS LESS THAN 1

if  $P_{\text{access}}(\text{time}) < 1$

for  $k=1:n$ ,

for  $j=1:\text{par}_x(k)$ , %FOR EACH NODE WANT TO TRANSMIT  
IN THE KTH SLOT

rnd=rand ; %RND IS A UNIFORM  
DISTRIBUTED[0,1] NO

if  $\text{rnd} > P_{\text{access}}(\text{time})$

n\_backlogged(k)=n\_backlogged(k)+1 ;

end %END OF IF CONDITION

end %end of inner for loop

$\text{par}_x(k) = \text{par}_x(k) - \text{n\_backlogged}(k)$ ;

%NOW  $\text{PAR}_X(K)$  IS THE ACTUAL NO OF NODES WANT TO  
%TRANSMIT IN THE KTH SLOT AND

%ALL OTHER NODES (BACKLOGGED) ARE SCHEDULED FOR  
%NEXT INTERVAL

end %END OF OUTER FOR LOOP

end %END OF OUTER IF LOOP

if  $P_{\text{access}}(\text{time}) == 1$

for  $k=1:n$ , %each user can access the channel when  
%they have data

if  $\text{par}_x(k) > 1$

n\_backlogged(k)=n\_backlogged(k)+ $\text{par}_x(k)$ ;

$\text{par}_x(k) = 0$ ;

end

```

    end
end

tot_backlogged=sum(n_backlogged);
%TOTAL NO. OF BACKLOGGED NODES IN N SLOTS
%ALL BACKLOGGED NODES ARE RANDOMLY SCHEDULED IN THE NEXT N
%SLOTS
for j=1:tot_backlogged
    s=ceil(rand*99);
    par_backx(s)=par_backx(s)+1;
end %IND OF FOR LOOP

%OPTIMAL ACCESS PROBABILITY IS CALCULATED BASED ON THE
%FOLLOWING EQUATION
if avg_load(time)< 0.01
    P-access(time+1)=1;
else
    P-access(time+1)=min(P-access(time)/avg_load(time),1);
end

if P-access(time+1)<0.01
    P-access(time+1)=0.01
end

%NO OF SLOTS WITH SINGLE TRANSMISSION i.e THE CHANNEL
%UTILIZATION
for l=1:n
    if par_x(l)==1
        c_uti=c_uti+1;
    end
end
end

```

```

disp(c_uti);
throughput (time)=c_uti/tot_load(time);
time=time+1;

end %END OF THE WHILE LOOP
figure
bar(par(1:99),.01)
grid
title('FIGURE 1. (DAP using PARETO traffic) Load vs Time
(1 slot) for 100 slots ')
xlabel('Time(in slots)----->')
ylabel('No of nodes want to transmit----->')

figure
bar(tot_load(201:299),.01)
grid
title('FIGURE 1. (DAP using PARETO traffic) Load vs
Time(100 slots) for 100 sec ')
xlabel('Time(in sec)----->')
ylabel('No of nodes want to transmit----->')
for i=1:100
    y=(i-1)*100+1 ;
    load(i)=sum(tot_load(y : y+99));
end

figure
bar(load(1:99),.01)
grid
title('FIGURE 2. Channel utilization for the entire
simulation')
xlabel('Time(in 100 sec=10000 slots)----->')

```

```
ylabel('No of nodes want to transmit----->')
```

```
figure
```

```
bar(throughput(1:9999),.01)
```

```
grid
```

```
title('FIGURE 3. Channel Utilization for the entire  
simulation ')
```

```
xlabel('Time(in sec)----->')
```

```
ylabel('Channel Utilization----->')
```

```
figure
```

```
bar(throughput(501:599),.01)
```

```
grid
```

```
title('FIGURE 4. Load vs Time(100 slots) for 100 sec ')
```

```
xlabel('Time(in sec)----->')
```

```
ylabel('Channel Utilization----->')
```

```
figure
```

```
plot(p-access(2001:3000))
```

```
grid
```

```
title('FIGURE 5. p-access for time interval(2001-3000)')
```

```
xlabel('Time(in sec)----->')
```

```
ylabel('Optima channel Access Probability(p-access)----->')
```

```
figure
```

```
plot(p-access(1:10000))
```

```
grid
```

```
title('FIGURE 6. p-access for the entire simulation ')
```

```
xlabel('Time(in sec)----->')
```

```
ylabel('Optimal Access Probability----->')
```

```
figure
```

```

bar(avg_load(1:9999),.01)
grid
title('(FIGURE 7. Average Traffic/slot for the entire
simulation ')
xlabel('Time(in sec)----->')
ylabel('No of nodes want to transmit/slot----->')

t=sort(throughput);
figure
plot(t)
grid
title('FIGURE 8. Channel efficiency of DAP for the entire
simulation ')
xlabel('time unit = 1 sec----->')
ylabel('Channel Efficiency----->')

disp('average load for first 10 intervals');
mean(avg_load(1:10))
disp('average access for the interval 101-200');mean(p-
access(101:200))
disp('average load for the entire simulation');
mean(avg_load)
disp('average P-access for the entire simulation');mean(p-
access)
disp('average throughput for first 10 intervals');
mean(throughput(1:10))
disp('average throughput for the entire simulation');
mean(throughput)

```

