Analytical Modeling and Performance Evaluation of the HIPERLAN CAC Layer Protocol for Real-Time Traffic

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Abstract

The growing interest in wireless systems and networks has led to the first Wireless LAN (WLAN) protocols. The Medium Access Control (MAC) layer protocols of such protocol suites are of key importance. The Radio Equipment and Systems (RES) Technical Committee of the European Telecommunications Standards Institute has proposed the High PErformance Radio LAN (HIPERLAN) protocol suite. In this paper we present, study, analyze and evaluate the performance of the Channel Access Control layer (lower sublayer of the MAC layer) of the HIPERLAN protocol suite for real-time traffic. Numerical results from both analysis and simulation are presented, so that the issues involved are better understood.

1 Introduction

In recent years there has been an increasing trend towards personal computers and workstations becoming "portable" and "mobile." This ever increasing group of mobile users have been demanding access to network services similar to their "tethered" counterparts. The desire to provide universal connectivity for these portable mobile computers and communication devices is fueling a growing interest in wireless packet networks. To meet these and other future communication needs it is expected that tomorrow's communication networks will employ wireless media in the local area and utilize high capacity wired media in the metropolitan and wide-area environment. Wireless systems and networks will provide communication capability, not only between mobile terminals, but also permit these mobile devices to have access to "wired" networks.

In order to achieve the goal of offering broadband communication services and providing universal connectivity to mobile users it is important that (i) a suitable standard for *Wireless Local Area Networks* (WLANs) be designed and (ii) an approach to interconnect these WLANs to the existing wired LANs and broadband networks be developed. A key design requirement for WLANs is that mobile hosts be able to communicate with other mobile and "wired" hosts (on other LANs and/or networks) in a transparent manner, i.e., (i) a WLAN should appear to the *Logic Link Control* (LLC) layer and those above as just another LAN (for example, Ethernet and Token ring), and (ii) the response times should not be so large that the productivity of end-users is compromised. To be able to achieve the above objectives it is imperative that mobility be handled at or below the Media Access Control (MAC) layer (note that in wireless networks an "address" does not correspond to a fixed physical location as in wired networks). Furthermore, it is important that the performance available to mobile users be comparable to the performance available to the wired hosts.

So far two protocol suites have been proposed for WLANs. The first is the result of the work done by IEEE committee 802.11 and has recently become an official standard. Studies of the protocol for asynchronous data traffic can be found in [5] and [4], while studies of time-bounded data traffic can be found in [6]. The second protocol is currently under development by the European Telecommunications Standards Institute (ETSI) and is named High PErformance Radio Local Area Network (HIPERLAN). The HIPERLAN protocol functionality is presented in [9]. Other sources of information and analysis of the HIPERLAN protocol can be found in [1], [3], [10], [11], [12], [16] and [15]. No analytical models that take into account the phenomena of hidden nodes and capture are presented in these papers, although a first attempt to gather simulation results considering only the possibility of hidden nodes can be found in [10] and [16]. Detailed analysis of the HIPERLAN protocol for asynchronous traffic, taking into account

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both the phenomena of hidden nodes and capture can be found in [7] and [8]. In this paper we examine the ability of the HIPERLAN standard to support time-bounded services. Analytical and simulation results are presented.

2 Overview of the HIPERLAN CAC Layer Protocol

The HIPERLAN Draft Standard reflects the desire for a WLAN protocol suite with performance similar to wired LAN protocols, under both asynchronous and time-bounded data traffic. In this section we will present the basic functionality of the protocol under asynchronous data traffic, since we are only interested in that type of traffic.

The RES technical committee has identified two frequency bands of operation, 5.15 – 5.30 GHz and 17.1 – 17.2 GHz. The standard currently mainly addresses the 5.15 – 5.30 GHz frequency band (HIPERLAN type 1). The frequency band is divided into five channels. The upper two are restricted for use by only some countries, while the lower three can be used all over Europe. The HIPERLAN WLAN will operate at 23.529 Mbits/sec with support for multihop routing and power saving. At the Physical layer, transmission shifts between a high bit rate transmission scheme that uses Gaussian Minimum Shift Keying (GMSK) as the modulation scheme and a low bit rate transmission scheme that uses Frequency Shift Keying (FSK) as the modulation scheme. Bose-Chaudhuri-Hocquenghem (BCH) encoding is used. Each encoded block consists of 496 bits, of which 416 are used for data. The maximum length of a packet is 47 blocks.

The HIPERLAN MAC layer is actually a MAC layer that does not include a channel access mechanism. The channel access mechanism is the main part of the Channel Access Control (CAC) layer. The basic functionality of the HIPERLAN MAC layer protocol is: HIPERLAN differentiation, HIPERLAN identification scheme, communication confidentiality, MAC layer priority assignment, relaying (multihoping) and power conservation. For the purpose of our study, we do not need to deal with the MAC layer functionality and we can assume that whatever priority a packet is assigned initially will remain until it is transmitted. It is the CAC layer protocol that interests our study.

The CAC layer is actually the "lower sublayer" of the MAC layer that basically deals with channel access. The mechanism used for channel access is the Elimination Yielding Non Pre-emptive Multiple Access (EY-NPMA) mechanism.

The EY-NPMA mechanism is an access mechanism with three phases. The three phases of the EY-NPMA mechanism constitute the contention phase of the *Synchronized Channel Access Cycle*.

In Figure 1 we see a renewal interval, its components, and their components as well. Transmission is denoted by black color, while its absence is denoted by white color, and a different shade filling is used for the synchronization slot. All three phases of the EY-NPMA mechanism are divided into time slots, which are shown as rectangular boxes.

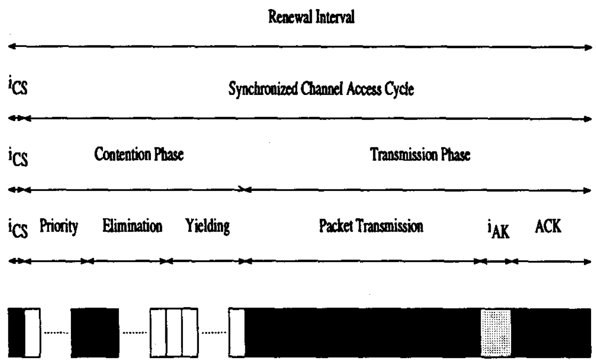

Figure 1. The EY-NPMA mechanism.

We will refer to a node that wishes to access the channel as an active node and A_n and I_n will denote the sets of active and inactive nodes of priority n respectively.

In the prioritization phase, an active node of priority n must signal its intention to access the channel by transmitting a burst during the nth time slot, provided that no active nodes of higher priority have already signaled their intention to access the channel. As soon as active nodes of a given priority n have transmitted a burst, all nodes of lower priority will discontinue their effort to access the channel, and the prioritization phase is over, allowing only active nodes of priority n to continue pursuing channel access. We are assuming a total of m_{CP} priority levels, from 0 to $m_{\mathrm{CP}} - 1$.

In the elimination phase, each active node bursts a signal for a random number of time slots and then listens to the channel; if another active node is still bursting this active node has to stop pursuing channel access, otherwise it may continue into the yielding phase. In the elimination phase we have a maximum of m_{ES} elimination slots. The probability of bursting in an elimination slot is p_{E} . The maximum burst allowed is $m_{\mathrm{ES}} - 1$ time slots.

In the yielding phase each active node listens for a random number of time slots and then, if the channel is still free, starts a packet transmission. In the yielding phase we have a maximum of m_{YS} yielding slots. The probability of yielding in a yielding slot is p_{Y} . An active node can listen for a maximum of $m_{\mathrm{YS}} - 1$ time slots.

3 Channel Access

Let C_n be the random variable that represents the number of active stations of priority n that are competing for the channel. Let $X_{\rm E}$ be the random variable that represents the number of elimination slots that a station will be bursting in during the elimination phase and $X_{\rm Y}$ be the random variable that represents the number of yielding slots that a station will be listening in during the yielding phase. Since the random variables follow the truncated geometric distribution, we have

$$P\{X_{\rm E}=x\}=\begin{cases} p_{\rm E}^x(1-p_{\rm E}) & if\ x<m_{\rm ES}-1 \\ p_{\rm E}^x & if\ x=m_{\rm ES}-1 \end{cases} \quad (1)$$

$$P\{X_{\rm Y}=x\}=\begin{cases} p_{\rm Y}^x(1-p_{\rm Y}) & if\ x<m_{\rm YS}-1 \\ p_{\rm Y}^x & if\ x=m_{\rm YS}-1 \end{cases} \quad (2)$$

Let E be the random variable that represents the number of station that survive the elimination phase and Y be the random variable that represents the number of stations that survive the yielding phase. The probability of t stations accessing the channel after the contention phase is over is

$$P\{Y=t\mid C_n=c\}= \sum_{j=t}^{c} P\{E=j\mid C_n=c\}P\{Y=t\mid E=j\}, \quad (3)$$

where

$$P\{E=j\mid C_n=c\}= \begin{cases} \binom{c}{j}\sum_{k=1}^{m_{ES}-1} P\{X_{\rm E}=k\}^j P\{X_{\rm E}<k\}^{(c-j)} & if\ j\neq c \\ \sum_{k=0}^{m_{ES}-1} P\{X_{\rm E}=k\}^j & if\ j=c, \end{cases} \quad (4)$$

and

$$P\{Y=t\mid E=j\}= \begin{cases} \binom{j}{t}\sum_{w=0}^{m_{YS}-2} P\{X_{\rm Y}=w\}^t P\{X_{\rm Y}>w\}^{(j-t)} & if\ t\neq j \\ \sum_{w=0}^{m_{YS}-1} P\{X_{\rm Y}=w\}^t & if\ t=j. \end{cases} \quad (5)$$

4 Calculating the Average Delay

Due to the strict performance guarantees that real-time traffic demands from the network, real-time traffic should only be admitted into the network as traffic of the highest priority. If it is also admitted in lower priorities, the contracts that stations with real-time traffic negotiate will be affected by changes in higher priorities causing them to be violated. Our proposal is to admit asynchronous traffic in all other priorities. The priority assignment for asynchronous traffic can be based on other criteria.

We now analyze the performance of the protocol for real-time traffic following our proposal to assume that all traffic sources are of the highest priority. Consider stations that generate packets following the Poisson distribution. The arrival rate of packets at station i is λ_i, with the total arrival rate of packets from all real-time sources being λ. The average service time that a packet receives depends on the average number of contenders that it finds competing with it for the channel. The overall average service time for a packet coming from any station is $\bar{X}$, and the average service time for a packet specifically from station i is $\bar{X}_i$. The average queueing time is $\bar{W}$, and the average waiting time for a packet from station i is $\bar{W}_i$. The probability that any station will successfully utilize the channel and there will not be a collision is a, and a_i is the probability that a station will successfully utilize the channel and there will not be a collision given that station i is a contender. Finally N is the total number of stations with real-time traffic.

In order to calculate the queueing delay for HIPERLAN, we need to examine what happens from the moment that a packet enters the queue to the moment that the packet enters the server for service. To calculate the average waiting time $\bar{W}_n$ for a packet generated by station n, we proceed following a similar methodology as the one used to prove the P-K formula in [2] , taking into account the probability of collisions and HIPERLAN's peculiarities.

Lets observe the queue at the moment that a new packet enters the queue. It finds other waiting in the queue and at least another packet accessing the channel seeking to be served by the server. The remaining service time for that packet is the residual time R. If a collision happens, then the packet that was seeking service is reintroduced into the contention phase to retry for channel access. If it is from the same station it's retransmission efforts will add to the queueing delay. The average number of attempts needed to successfully access the channel is d_n. If at the moment of arrival of packet i there are already $N_n(i)$ packets in the queue, then the waiting time for the ith packet from station n is

$$W_n(i)=\frac{\lambda-\lambda_n}{\lambda}R(i)+\frac{\lambda_n}{\lambda}a_nR(i)+\frac{\lambda_n}{\lambda}(1-a_n)X_nd_n + \sum_{j=i-N_n(i)}^{i-1} X_n(j)d_n(j)+X_n(i)(d_n(i)-1). \quad (6)$$

By taking expectations and using the independence of the random variables $N_n(i)$ and $X_{i-1}...X_{i-N_n(i)}$, and taking

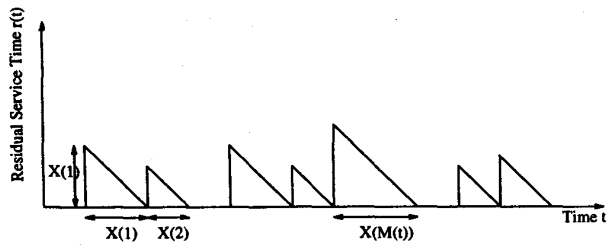

Figure 2. Graphical Calculation of Residual Time

the limit as $i \to \infty$, we obtain

$$\begin{aligned}\bar{W}_n &= \frac{\lambda - \lambda_n}{\lambda} R + \frac{\lambda_n}{\lambda} a_n R + \frac{\lambda_n}{\lambda}(1-a_n) X_n d_n \\ &\quad + \bar{X}_n N_n d_n + \bar{X}_n (d_n - 1) \\ &= \frac{\lambda - \lambda_n}{\lambda} R + \frac{\lambda_n}{\lambda} a_n R + \frac{\lambda_n}{\lambda}(1-a_n) X_n d_n \\ &\quad + \bar{X}_n \lambda_n W_n d_n + \bar{X}_n (d_n - 1),\end{aligned} \tag{7}$$

and finally

$$\bar{W}_n = \frac{\frac{\lambda-\lambda_n}{\lambda} R + \frac{\lambda_n}{\lambda} a_n R + \frac{\lambda_n}{\lambda}(1-a_n) X_n d_n + \bar{X}_n (d_n - 1)}{1 - \bar{X}_n \lambda_n d_n}, \tag{8}$$

We can calculate R by a graphical argument. In figure 2 we plot the residual service time $r(t)$ (i.e., the remaining time for completion of the packet transmission of the packet in service at time t) as a function of t. Note that when a new service of duration X begins, $r(t)$ starts at X and decays linearly for X time units. Consider a time for which $r(t) = 0$. The time average of $r(t)$ in the interval $[0, t]$ is

$$\frac{1}{t}\int_0^t r(t)dt = \frac{1}{t}\sum_{i=1}^{M(t)} \frac{1}{2}(X(i))^2, \tag{9}$$

where $M(t)$ is the number of service completions within $[0, t]$, and $X(i)$ is the service time of the i^{th} customer. We can also write this equation as

$$\frac{1}{t}\int_0^t r(t)dt = \frac{M(t)}{t} \frac{\sum_{i=1}^{M(t)} \frac{1}{2}(X(i))^2}{M(t)}, \tag{10}$$

and for $t \to \infty$, we obtain

$$R = \frac{1}{2}\lambda \bar{X}^2. \tag{11}$$

Now we calculate $\bar{X}$, $\bar{X}_n$, a, a_n and $\bar{X}^2$. For a constant packet length, $\bar{X}$ and $\bar{X}_n$ only depend on the number of stations competing for the channel, and we have

$$\bar{X} = \sum_{c=1}^{N} P\{C = c\} f(c), \tag{12}$$

and

$$\bar{X}_n = \sum_{c=1}^{N} P\{C = c \mid i_n \ is \ active\} f(c), \tag{13}$$

where C is the random variable that represents the number of stations that are active. Since the overall system has a service time that is not highly stochastic, but rather deterministic we will approximate the number of packets in the system with the number of packets in a M/M/1 or M/D/1 queue (they are the same), and by defining

$$G(c,k) = \sum_{(i_1,i_2,\dots,i_c)} \sum_{(j_1+j_2+\dots j_c = k \mid j_1,j_2,\dots j_c \neq 0)} \binom{k}{j_1,j_2,\dots,j_c} \left(\frac{\lambda_{i_1}}{\lambda}\right)^{j_1} \left(\frac{\lambda_{i_2}}{\lambda}\right)^{j_2} \cdots \left(\frac{\lambda_{i_c}}{\lambda}\right)^{j_c}, \tag{14}$$

the probability of c contenders in the queue becomes

$$P\{C = c\} = \sum_{k=c}^{\infty} (1-\rho)\rho^k G(c,k), \tag{15}$$

and

$$P\{C = c \mid i_n \ is \ active\} = \sum_{k=c}^{\infty} (1-\rho)\rho^k G_n(c,k), \tag{16}$$

where $G_n(c,k)$ is a relative term that includes only the summation terms with $j_n > 0$. Previously, $f_n(c)$ denotes the service time when c contenders are competing and is equal to

$$\begin{aligned} f(c) =& PT + T_{\text{TRANS}} + T_{\text{ACK}} \\ &+ ET \sum_{r=0}^{(m_{\text{ES}}-1)} (r+1) P\{max(X_{\text{E}}) = r \mid C_n = c\} \\ &+ YT \sum_{s=0}^{(m_{\text{YS}}-1)} s \sum_{j=1}^{c} P\{E = j \mid C_n = c\} \\ &\quad P\{min(X_{\text{Y}}) = s \mid E = j\},\end{aligned} \tag{17}$$

where PT, ET and YT represent the time intervals of a priority, elimination and yielding slot, T_{TRANS} is the time to transmit a packet and T_{ACK} is the time to transmit an acknowledgment,

$$P\{max(X_{\mathrm{E}}) = r \mid C = c\} = \sum_{m=1}^{c} \binom{c}{m} P\{X_{\mathrm{E}} = r\}^m P\{X_{\mathrm{E}} < r\}^{(c-m)}, \quad (18)$$

and

$$P\{min(X_{\mathrm{Y}}) = s \mid C = c\} = \sum_{m=1}^{c} \binom{c}{m} P\{X_{\mathrm{Y}} = s\}^m P\{X_{\mathrm{Y}} > s\}^{(c-m)}. \quad (19)$$

From equations 12, 15 and 14, we have:

$$\bar{X} = \sum_{c=1}^{N_n} \sum_{k=c}^{\infty} (1 - \lambda\bar{X})(\lambda\bar{X})^k G(c,k) f(c). \quad (20)$$

In order to solve the above non-linear equation we first need to limit the infinite summation. The above equation is approximated to

$$\begin{aligned} \bar{X} &= \frac{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (1 - \lambda\bar{X})(\lambda\bar{X})^k G(c,k) f(c)}{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (1 - \lambda\bar{X})(\lambda\bar{X})^k G(c,k)} \\ &= \frac{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (\lambda\bar{X})^k G(c,k) f(c)}{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (\lambda\bar{X})^k G(c,k)}, \end{aligned} \quad (21)$$

and by further manipulation we get:

$$\sum_{c=1}^{N_n} \sum_{k=c}^{M} \lambda^k \bar{X}^{(k+1)} G(c,k) - \sum_{c=1}^{N_n} \sum_{k=c}^{M} \lambda^k \bar{X}^k G(c,k) f(c) = 0. \quad (22)$$

In order to solve the equation we need to choose a packet size such that $\lambda < 1$, and for accuracy we need to choose a very big M. This makes solving the above equation not practical. To find a solution without the above limitations, we instead solve the system of non-linear equations (although one equation is linear) below using Newton's Method for solving a system of non-linear equations,

$$\rho - \lambda\bar{X} = 0, \quad (23)$$

$$\sum_{c=1}^{N_n} \sum_{k=c}^{M} \bar{X} \rho^k G(c,k) - \sum_{c=1}^{N_n} \sum_{k=c}^{M} \rho^k G(c,k) f(c) = 0. \quad (24)$$

The probability of a successful transmission a is

$$a = \frac{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (1 - \lambda\bar{X})(\lambda\bar{X})^k G(c,k) P\{Y = 1 \mid C_n = c\}}{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (1 - \lambda\bar{X})(\lambda\bar{X})^k G(c,k)}. \quad (25)$$

Calculating $\bar{X}_n$ and a_n we have

$$\bar{X}_n = \frac{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (1 - \lambda\bar{X})(\lambda\bar{X})^k G_n(c,k) f(c)}{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (1 - \lambda\bar{X})(\lambda\bar{X})^k G_n(c,k)}, \quad (26)$$

and

$$a_n = \frac{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (1 - \lambda\bar{X})(\lambda\bar{X})^k G_n(c,k) P\{Y = 1 \mid C_n = c\}}{\sum_{c=1}^{N_n} \sum_{k=c}^{M} (1 - \lambda\bar{X})(\lambda\bar{X})^k G_n(c,k)}. \quad (27)$$

For d and d_n we have:

$$d = \sum_{c=1}^{N_n} \sum_{k=c}^{\infty} (1 - \lambda\bar{X})(\lambda\bar{X})^k G(c,k) \frac{c}{P\{Y = 1 \mid C_n = c\}}, \quad (28)$$

and

$$d_n = \sum_{c=1}^{N_n} \sum_{k=c}^{\infty} (1 - \lambda\bar{X})(\lambda\bar{X})^k G_n(c,k) \frac{c}{P\{Y = 1 \mid C_n = c\}}. \quad (29)$$

Finally, in order to calculate $\bar{X}^2$, we use: $\bar{X}^2 = (\bar{X})^2 + Var(X)$, since both $(\bar{X})^2$ and $Var(X)$, can easily be calculated after the calculation of $\bar{X}$.

The total time spend in the system will be:

$$\bar{T} = \bar{W} + \bar{X}, \quad (30)$$

and

$$\bar{T}_n = \bar{W}_n + \bar{X}_n. \quad (31)$$

5 Connection Admission

In real-time traffic, admission control is very critical. Because of the extreme burstiness of some real-time traffic (e.g. video), accepting a new session in a network close to congestion may be dramatic. On the other hand, rejecting too many users may be very costly. Whenever a new potential connection is requesting admission we need to determine if the quality of service requirements can be met. Two typical requirements posed by the new station i are: $W < d$ and $P\{W \geq b\} \leq q$. The first requirement can easily be checked by using the information provided in the previous section. We will now calculate a decision rule for satisfying the second requirement.

Due to [14], we can calculate an exponential bound for a G/G/1 queue as follow. Let r be the random variable describing the interarrival times of packets and s be the random variable describing the service times. Let $\theta > 0$ be such that $\phi(\theta) \leq 1$, where $\phi(\theta)$ is the Laplace transform of the random variable ($r_i - s_i$).

Then,

$$P\{W \geq b\} \leq e^{-\theta b} \ \forall b > 0. \quad (32)$$

From the above it is deduced that

$$P\{W \geq b\} \leq q \ \text{ if } \ \phi(-(\ln q)/b) \leq 1. \quad (33)$$

Since this holds for a G/G/1 queue it will also hold for a M/G/1 queue, which in general is our case. By denoting the c.d.f. of $\bar{X}_k$ as $F_k(y)$, for $\phi(\theta)$ we obtain as in [13]

$$\begin{aligned} \phi(\theta) &= E(e^{\theta(s_i - r_i)}) \\ &= E(e^{\theta s_i})E(e^{-\theta r_i}) \\ &= \frac{\lambda}{\lambda+\theta}\sum_{k=1}^{N}\frac{\lambda_k}{\lambda}\int_0^\infty e^{\theta y}dF_k(y) \\ &= \sum_{k=1}^{N}\frac{\lambda_k}{\lambda+\theta}\int_0^\infty e^{\theta y}dF_k(y) \quad (34) \end{aligned}$$

Thus from above, a new connection can be admitted into the system when there are already k other connections, if

$$\sum_{k=1}^{K} a_k + a_i \leq 1, \quad (35)$$

with

$$a_i = \frac{\lambda_i b(1 - \phi(-(\ln q)/b))}{\ln q} \quad (36)$$

6 Numerical Results

The numerical results are now presented. We are interested in the probability of overflow for various maximum delay times. This will determine the system's performance. In order to conduct performance evaluation, two programs were developed, a simulation program, and a program for calculating the theoretical data.

The protocol parameters used are: priority slot duration $i_{\text{PS}} = 256$ bits, $p_{\text{E}} = 0.5$, elimination slot duration $i_{\text{ES}} = 256$ bits, $p_{\text{Y}} = 0.9$, yield slot duration $i_{\text{YS}} = 64$ bits, constant packet size 14880 bits (30 blocks) and acknowledgment packet size 512 bits. The channel bandwidth is 23529 bits/sec .

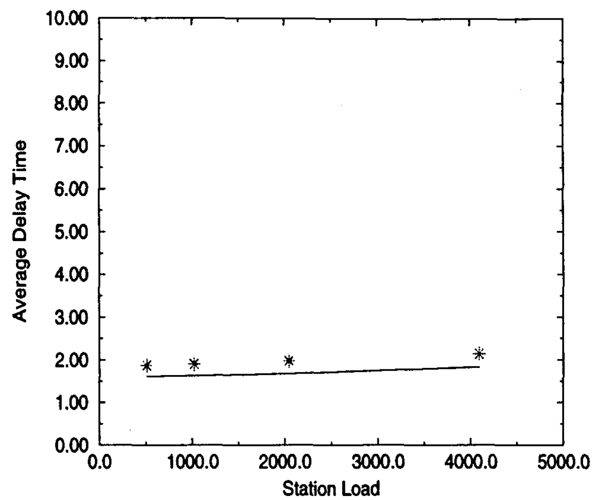

Figure 3. Average Delay, Total Load = 14.336 Mbps

We present plots of the average time in the system, and plots of the probability of overflow for a specific maximum delay.

In figures 3, 4 and 5 we plot the average time in the system. We have chosen a lightly loaded, a moderately loaded and a heavily loaded example for our calculations. The analytical results are presented with a solid line, while simulation results are shown through the star symbol.

As expected, as the total load increases, so does the average time in the system. Also we can see that stations with higher bit rates are experiencing higher average times in the system. This is becoming more dramatic as the overall load gets heavy. The reason for this is that the individual queues at each station are not all experiencing the same delays. A station of higher data rate introduces much more packets into the contention phase than stations of lower load.

In figures 6, 7 and 8 we plot the probability of overflow for specific maximum delay times. As we can see the HIPERLAN protocol has excellent performance. Only under heavy load the stations of high bit rates experience significant increases of the probability of overflow, but still the performance is very good. This of course is due to the very high channel rate that HIPERLAN is using.

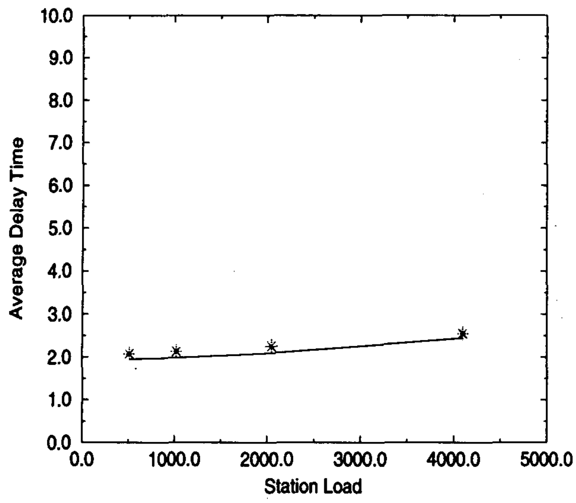

Figure 4. Average Delay, Total Load = 15.360 Mbps

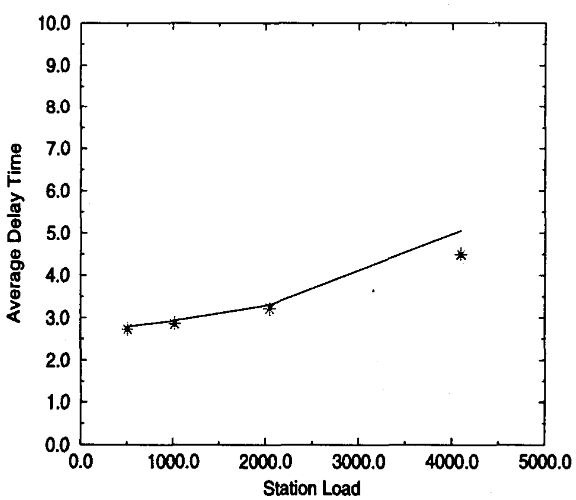

Figure 5. Average Delay, Total Load = 17.408 Mbps

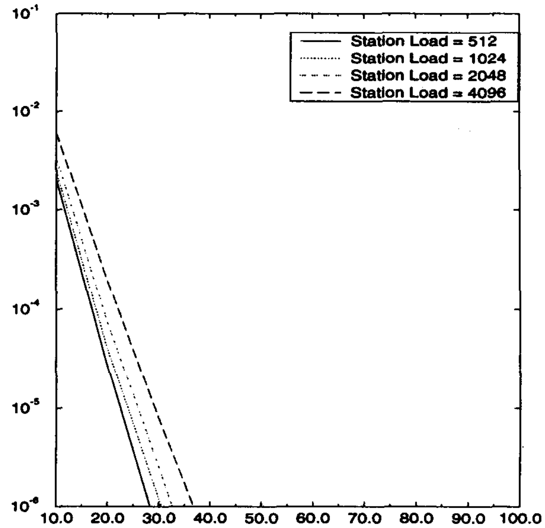

Figure 6. Overflow Probability, Total Load = 14.336 Mbps

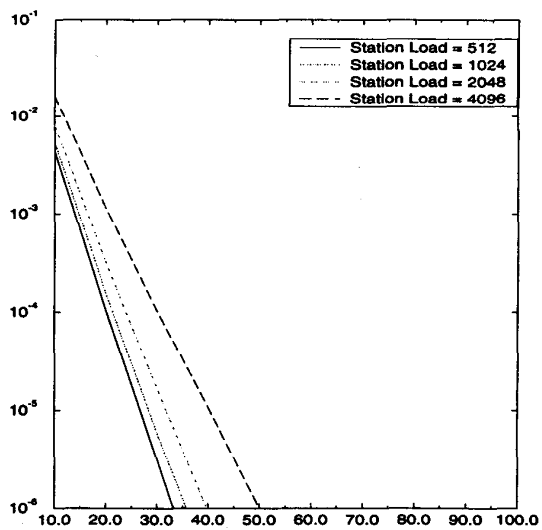

Figure 7. Overflow Probability, Total Load = 15.360 Mbps

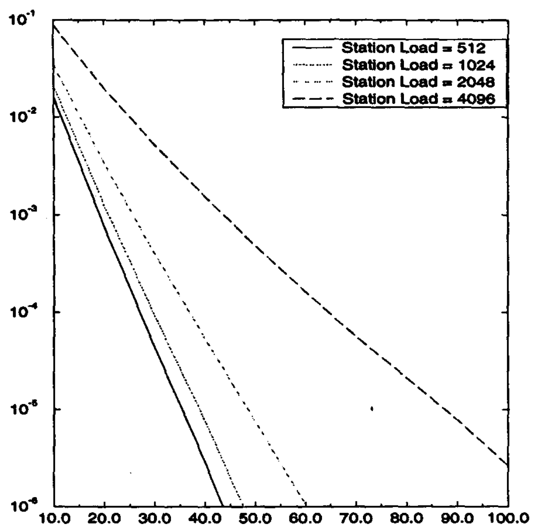

Figure 8. Overflow Probability, Total Load = 17.408 Mbps

7 Conclusion

We have presented a brief outline of the HIPERLAN CAC layer protocol and discussed the procedures required for supporting real time traffic. We have analysed performance through the calculation of the average mean time that a packet spends in the system and presented the probability of overflow for specific maximum delay times. We have also suggested a technique for call admission/rejection. Finally we presented the numerical results of both simulation and analysis. Our future work involves studying the HIPERLAN CAC Layer performance under time-bounded traffic with dynamic adjustment of packet priority.

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