Performance of Integrated Wired (Token Ring) Network and Wireless (PRMA) Network

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ABSTRACT: *Computer networks can be built using either wired or wireless technology. Although wired network has been the traditional choice, wireless technologies are becoming more popular. One of the most challenges is to have an existing wired network to which a wireless network extension could be added. Specifically the challenge is to connect a group of wireless networks through a wired backbone. The primary purpose of this study is to develop an integrated mathematical model by integrating Packet Reservation Multiple Access (PRMA) one of the most wireless LAN protocols and Token Ring wired network protocol. Performance parameters of an integrated PRMA-Token Ring model such as delay and throughput have be analyzed. The numerical analysis presented in this paper may help in studying the affect of some parameters on the system performance and stability.*

Categories and Subject Descriptors
C 2. 1[Network Architecture and design]; Wireless communication: C.2.5 [Local and Wide-Area Networks]; Token rings

General Terms
Wireless networks,Packet Reservation Multiple Access (PRMA), LAN Protocols.

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1. Introduction

Berry and Chandy (1983) defined the Token Ring as "Token Ring consists of a communication line configured as a closed loop. Data is transmitted in a single direction, bit serially, around this ring". Berry and Chandy further pointed out that when a station needs to send a message, packet has to wait for permission to be transmitted onto the ring, which takes the form of a special sequence of bits called the token or free token. Therefore, all waiting stations constantly monitor the ring and watch for this special sequence. When the station recognizes the free token sequence, it will be altered by changing the last bit of that sequence. This action removes the token from the ring and creates a new bit sequence called a connector token or a busy token. The station seizing the token may now start to send out the packets that are at the head of its queue. As the station has finished sending out all bits of the connector token sequence followed by the bits of the station's packet, the token must be given up [1].

Furthermore, Goodman et al. (1989) defined Packet Reservation Multiple Access (PRMA) as "allows a variety of information sources to share the same wireless access channel. Packets from all sources contend for access to channel time slots. When a periodic information terminal succeeds in gaining access, it reserves subsequent time slots for uncontested transmission" [2].

In this study, we have proposed an integrated Packet Reservation Multiple Access (PRMA) Protocol (wireless network) with Token Ring Protocol (wired network) through an access point. The impact of the proposed protocol on the overall system performance and stability has been investigated.

2. Integrating Token Ring and Packet Reservation Multiple Access (PRMA) Protocols

The proposed integrated protocol consists of two different data sources and two different data destinations (wired and wireless). In other words, a wired local area network (LAN) using Token Ring Protocol is connected to a wireless LAN network using PRMA. As a result, the two LANs are connected through an access point.

Since, PRMA is a centralized technique, the access point acts as a base station (BS) for the wireless LAN, and also it acts as a bridge between wired and wireless networks. The data source will be either wired or wireless workstation. Similarly, the data destination will be wired or wireless workstation. As a result, the following four scenarios for message transmission are considered:

1. Message transmitted from a wireless user to a wireless user.
2. Message transmitted from a wireless user to a wired user.
3. Message transmitted from a wired user to a wired user.
4. Message transmitted from a wired user to a wireless user.

Since the access point acts as a bridge, the message from a wired LAN will be passed to a wireless LAN only if its destination is in the wireless LAN, and the message from the wireless LAN will be passed to the wired LAN only if its destination is in the wired LAN.

The messages from a wired user to a wired user will be passed using Token Ring protocol only without queuing at the access point (scenario 3).

The messages from a wireless user to a wireless user will be passed using PRMA without queuing at the access point (scenario 1). In addition, for scenarios 2 and 4, the access point contains two separate message queues: the first queue holds the messages from wireless users to wired users until they served by the Token Ring Protocol, and the second queue holds the messages from wired users to wireless users until they served by PRMA using outbound channel.

2.1 Hybrid Protocol (PRMA-Token Ring)

The previous discussion indicates that their is a need for a Hybrid Protocol that integrates Token Ring and PRMA protocols in order to deal with the four scenarios.

The scenarios of the proposed PRMA-Token Ring protocol for message transmissions are:

The first scenario: the message is transmitted from a wireless user to a wireless user. In this scenario, the sender will not begin the transmission unless an information slot is reserved for message in both inbound and outbound channels. The sender uses ALOHA to send a reservation request to the access point. By using the destination address, the access point detects that the destination is a wireless user. Then the access point reserves information slot in both inbound and outbound channels. After the reservation has been done, the sender begins transmitting the message in both inbound and outbound channels until the end of the message.

The second scenario: the message is transmitted from a wireless user to a wired user. In this scenario, the sender begins the transmission only after an information slot is reserved for the message in the inbound channel only. By using the destination address, the access point detects that the destination is a wired user and hence there is no need for outbound channel. Then, the access point sends the request to the inbound reservation queue to request a slot in the inbound channel. As soon as the source station receives the reservation acceptance, it starts transmitting the packets of the message packet by packet. The message packets are queued at the access point until they get served by the Token Ring Protocol.

The third scenario: the message is transmitted from a wired user to a wired user using Token Ring protocol without any change in principle.

The fourth scenario: the message is transmitted from a wired user to a wireless user. In this scenario, the sender uses the Token Ring protocol to transmit the packet to the access point. As soon as the packets queued at the access point (wired to wireless queue), the access point assigns free slot in the outbound channel without the need for a slot reservation.

2.2 Hybrid PRMA-Token Ring Protocol Analysis Steps

Based on the four scenarios, an analytical model for the hybrid protocol has been developed. The model is based on the Token Ring analytical model which was suggested by Matthew and Ilyas (1994) [3] and PRMA analytical model which developed by Mitrou, Orinos, and Protonotarios (1990) [4]. The analysis of both Token Ring and PRMA models assumes loss-less systems, which means that the packets are retransmitted up to an infinite number of times until they reach the destination.

The delay and throughput performance parameters for the analytical model of the hybrid protocol are calculated and analyzed. The equation of the packet delay for each of the four scenarios was developed. Further, the total average of packet delay was calculated by multiplying each scenario-delay with the probability of that occurred scenario. Then the results of the four scenarios were added. The throughput was calculated by adding the four scenarios-throughputs without the probability.

The hybrid PRMA-Token Ring Protocol model is based on the following concepts:

First, the access point acts as a bridge, which means that: the wired-to-wired network traffic is isolated from the wireless-to-wireless traffic. Then the access point passes the packets from a token ring wired sub-network to a wireless LAN sub-network only if the destination station is in the wireless sub-network and passes the packets from a wireless LAN to a wired network only if the destination station is in the wired sub-network.

Second, each inbound and outbound channels are divided into two parts: one part is used for wireless-to-wireless traffic only and the second part is used for wireless-to-wired traffic in the inbound channel and for wired-to-wireless traffic in the outbound channel.

3. Hybrid PRMA-Token Ring Model

A mathematical model for the Hybrid PRMA-Token Ring protocol has been developed.

The model is based on the following assumptions:

1. There are two networks; the first one is a wired network using Token Ring protocol that has finite number of users U_{wd}. And the second one is a wireless network using PRMA protocol and has finite number of users U_{ws}.
2. There are two infinite length buffers at the access point; one is used for wireless to wired messages and the other one is used for wired-to-wireless messages.
3. All the arrival processes are Poisson arrivals.
4. In a wireless LAN sub-network, the inbound channel is divided into two parts: one part is used for wireless to wireless traffic with N slots and the other part is used for wireless to wired traffic with N_{ws_wd}.
5. In a wireless LAN sub-network, the outbound channel is divided into two parts: one part is used for wireless-to-wireless traffic with N slots and the other part is used for wired-to-wireless traffic with N_{wd_ws}.
6. The inbound frame length and the outbound frame length must be equal so we can keep the synchronization between them as $N_{ws-wd} = N_{wd-ws}$.
7. In a wired network the time slot equals one end-to-end propagation delay = τ.
8. In a wireless LAN network the time slot equals $F/(N.N_{MS})$, where F is the wireless-to-wireless channel length in seconds, while $N.N_{MS}$ is the number of mini-slots in wireless channel.
9. The time slot in a wired network is equal to the time slot in a wireless network.
10. The wireless traffic to wired traffic has a fixed ratio = R_{ws-wd}.
11. The wired traffic to wireless traffic has a fixed ratio = R_{wd-ws}.
12. At the idle wireless users the messages arrival rate $=\lambda_{ws}$.
13. The packets arrival rate at the wired users = λ_{wd}.
14. In a wireless network, the messages have exponentially distributed with average T_{av} seconds. Thus, the rate of reaching message end $\sigma = 1/T_{av}$.
15. An Extra traffic will be added to the wired network. This extra traffic is equal to the throughput of wireless-to-wired inbound channel which = λ_{ws-wd}.
16. An Extra traffic will be added to the wireless network. This extra traffic is equal to $U_{wd}*\lambda_{wd}*R_{wd-ws}$.

Based on the previous assumptions, the model consists of two sub-networks. The first network is a wired network using Token Ring protocol with U_{wd} users, each one of these users has an arrival rate equal λ_{wd} packets per second, and an extra traffic that is coming from the wireless network with an arrival rate equals λ_{ws-wd}. The second network is a wireless network using PRMA protocol with U_{ws} users, each one of these users has an arrival rate equals λ_{ws} messages per second, and an extra traffic that is coming from the wired network with an arrival rate equals $U_{wd}*\lambda_{wd}*R_{wd-ws}$.

4. The Model Performance Measurement: Delay and Throughput

In this section, we have analysed the performance of the hybrid model. This model consists of two networks: a wired network using Token Ring protocol with U_{wd} users that are connected to a wireless LAN with U_{ws} users using PRMA protocol. The wireless LAN has one base station which works although as a bridge connecting this two different types of networks.

The wireless sub-network contains two channels, inbound and outbound channels. The inbound channel is divided into two parts: one part is used for wireless-to-wireless traffic with N slots and the other part is used for wireless- to-wired traffic with N_{ws_wd} .

The outbound channel is divided also into two parts: one part is used for wireless-to-wireless traffic with N slots, while the other part is used for wired-to-wireless traffic with N_{wd_ws}. The inbound frame length and the outbound frame length must be equal so we can keep the synchronization between them $N_{ws\text{-}wd} = N_{wd\text{-}ws}$. Wireless-to-wireless traffic channel contains N slots with frame length equal to F seconds for each inbound and outbound channel. Adding $N_{ws\text{-}wd}$ for inbound channel which is used for wireless to wired traffic, the frame length will be equal to F_t seconds. Similarly, adding $N_{wd\text{-}ws}$ for outbound channel which is used for wired to wireless traffic, the frame length will be equal to F_t seconds. Therefore, inbound frame must be equal to outbound frame.

Likewise, wireless inbound channel contains N_R(K) slots as reservation slots, the remaining slots are information slots [4]. The wireless users who are using slotted ALOHA reservation process of PRMA during reservation slots of inbound channel. The wireless sender does not need to know whether its destination is a wired or a wireless node. So, the ALOHA contention and reservation slots for both wireless-to- wireless traffic and wireless-to-wired traffic must occur only during the N inbound wireless- to-wireless slots. This means that N_R(K) is always part of N. Outbound channel contains mirrors to N_R(K) slots. These mirrors are called acknowledgement slots which occur at the same time with one packet slot delay. The acknowledgement slots number is equal to N_R(K) slots number. The base station uses the acknowledgement slots to inform the wireless nodes that the results of their reservation requests are successful or not successful. N_R(K) slots has a minimum number that is equal to N_{RMIN} but it can be increased by using any one of the information slots depending on the wireless traffic.

The wireless sub-network consists of U_{ws} users as:

$U_{ws} = i + h + k$
- Idle users i.
- Contending users for Aloha reservation process h.
- Transmitting or waiting for information to be assigned by the base station to them; k.

Further, the analytical model of PRMA that was developed by Mitrou, Orinos, and Protonotarios (1990) [4], used closed queuing method. The system is a Markov model with fixed population $U_{ws.}$ The system states (i, h, and k) represented by 3-dimensional vectors. The vectors components are i, h and k. In order to calculate the performance parameters (throughput and delay), it is required to find P(h,i,k) which is the probability of being in state, where $U_{ws} = i + h + k$, k can be determined if i and h are calculated. As a result of this calculation, the system can be represented by 2-dimensional vectors by finding p(h,i) instead of P(h,i,k).

According to the analytical model of PRMA given in [4] :

$$P(h,i) = \begin{cases} \dfrac{1}{1+\sum_{h=1}^{U_{ws}}\prod_{j=1}^{h}\frac{b_{j-1}}{d_j}} \cdot \prod_{j=1}^{h}\frac{b_{j-1}}{d_j} \cdot \dfrac{\left(\frac{\sigma}{\lambda_{ws}}\right)^i \binom{U_{ws}}{i}}{\left(1+\frac{\sigma}{\lambda_{ws}}\right)^{U_{ws}}}, & 0 \le i \le U_{ws}, 1 \le h \le U_{ws}, i+h+k=U_{ws} \\ \dfrac{1}{1+\sum_{h=1}^{U_{ws}}\prod_{j=1}^{h}\frac{b_{j-1}}{d_j}} \cdot \dfrac{\left(\frac{\sigma}{\lambda_{ws}}\right)^i \binom{U_{ws}}{i}}{\left(1+\frac{\sigma}{\lambda_{ws}}\right)^{U_{ws}}}, & 0 \le i \le U_{ws}, h=0, i+h+k=U_{ws} \\ 0 & ,otherwise \end{cases}$$

Where

$$b_h = \left[1 - h \cdot p_t \cdot P_{nerr}(1-p_t)^{h-1}\frac{N_R(k)}{N}\right] \cdot i \cdot \lambda_{ws}$$

$$d_h = h \cdot p_t \cdot P_{nerr}(1-p_t)^{h-1}\frac{N_R(k)}{N}\left(\frac{N \cdot N_{MS}}{F} - i \cdot \lambda_{ws}\right)$$

$$\sigma = 1/T_{av}$$

P_t = the probability of deciding to transmit in the ALOHA

P_{nerr} = the probability of error free transmission

The performance analysis for the delay and the throughput are used for PRMA-Token Ring. The first step is to find the delay for each of the previous mentioned scenarios. Secondly, summing the multiplication of delay for each scenario with the probability of that scenario occurred. The throughput calculated by finding the throughput for each scenario then summing them without weighting.

4.1 First Scenario: Wireless-to-Wireless Delay

The first scenario is exactly the same of wireless PRMA protocol, in this scenario the PRMA analysis given by Mitrou, Orinos, and Protonotarios (1990) [4] will be used with one difference. In which the frame size will be F_t instead of F . Where $F_t = ((N+N_{ws\_wd})/N)*F$.

The wireless-to-wireless delay $D_{ws\text{-}ws}(h,i)$ consists of two parts: the access delay and the transmission delay as shown in the equation below:

$$D_{ws\_ws}(h,i) = D_{acc}(h,i) + D_{tr}$$

The transmission time is given by:

$$D_{tr} \cong F_t \cdot \frac{\left(1/\sigma\right)}{\left(F/N\right)} = \frac{N \cdot F_t}{\sigma \cdot F}$$

The access delay is given by:

$$D_{acc}(h,i) = D_{aloha}(h,i) + D_{queue}(h,i)$$

Where

$$D_{queue}(h,i)=\begin{cases}0.5F_t, & k(1-R_{ws\_wd})<N-N_{RMIN}\\ F_t+[k(1-R_{ws\_wd})-(N-N_{RMIN})]\dfrac{1}{\sigma(U_{ws}-i)(1-R_{ws\_wd})}, & otherwis\end{cases}$$

The average message delay expression is:

$$\overline{D_{ws\_ws}(h,i)}=\sum_{h=0}^{U_{ws}}\sum_{i=0}^{U_{ws}-h}D_{ws\_ws}(h,i)\cdot P(h,i)$$

Because, every message consists of N/(σ . F) packets, the average packet delay is:

$$D_{ws\_ws}=\overline{D_{ws\_ws}(h,i)}\frac{\sigma\cdot F}{N}$$

4.2 Second scenario: Wireless-to-Wired Delay

In this scenario the packet delay is the summation of two parts: The first part is the summation of inbound channel ALOHA reservation, reservation queue and transmission delay. The second part starts after the packet reaching the access point, in which the access point uses Token Ring Protocol to send the packet to its wired destination.

The summation of the inbound access delay and the transmission delay gives the inbound message delay as:

$$D^{in}_{ws\_wd}(h,i)=D^{in}_{acc}(h,i)+D_{tr}$$

Where:

$$D^{in}_{acc}(h,i)=D_{aloha}(h,i)+D^{in}_{queue}(h,i)$$

$D_{aloha}(h,i)$ is calculated as follows:

$$D^{in}_{queue}(h,i)=\begin{cases}0.5F_t, & k\cdot R_{ws\_wd}<N_{ws\_wd}\\ Ft+[k\cdot R_{ws\_wd}-N_{ws\_wd}]\dfrac{1}{\sigma(U_{ws}-i)\,R_{ws\_wd}}, & \text{otherwise}\end{cases}$$

The average inbound wireless-to-wired message delay is as shown below:

$$\overline{D^{in}_{ws\_wd}(h,i)}=\sum_{h=0}^{U_{ws}}\sum_{i=0}^{U_{ws}-h}D^{in}_{ws\_wd}(h,i)\cdot P(h,i)$$

After the packet reaches the access point, the access point will use the Token Ring Protocol to send the packet to its wired destination. In order to find wired-to-wired Token Ring delay, (D_{wd_wd}), and λ_{ws_wd} must be calculated first. This is the number of packets successfully transmitted from the access point to the Token Ring Network per second.

From Little's formula, the number of messages transmitted in the inbound wireless-to-wired channel can be found as:

$$S^{in}_{ws\_wd}(h,i)=\frac{(U_{ws}-i)R_{ws\_wd}}{D^{in}_{ws\_wd}(h,i)}$$

$$\lambda_{ws\_wd}\equiv\overline{S^{in}_{ws\_wd}(h,i)}\frac{N}{\sigma\cdot F}$$

Furthermore, the total traffic to the Token Ring channel (λ_{wd}^{tot}) is equal to the sum of that offered by the wired stations and the wireless-to- wired traffic. The Token Ring Model was suggested by Matthew and Ilyas (1994) [3] is used to find wired to wired delay as:

$$D_{wd\_wd}=\frac{\tau\left(1-\frac{\rho}{U_{wd}}\right)}{2(1-\rho)}+\frac{\rho\cdot m^2}{2\cdot m(1-\rho)}+m+\frac{\tau}{2}$$

Where :

$$m=\text{packet length in seconds}$$

$$m=F/N$$

$$\tau=\text{end to end propagation delay on the wire medium}$$

$$\tau=\frac{F}{N\cdot N_{MS}}$$

$$\lambda_{wd}^{tot}=U_{wd}\cdot\lambda_{wd}+\lambda_{ws\_wd}$$

$$\rho=\lambda_{wd}^{tot}\cdot m$$

The wireless to wired average packet delay is:

$$D_{ws-wd}=\overline{D^{in}_{ws-wd}(h,i)}\frac{\sigma\cdot F}{N}+D_{wd-wd}$$

4.3 Third Scenario: Wired-to-Wired Delay

This scenario is exactly the same as Token Ring wired protocol without any changes. Wired-to- wired delay D_{wd_wd} was calculated as in the second scenario.

4.4 Fourth Scenario: Wired-to-Wireless Delay

In this scenario, the sender uses Token Ring protocol to send the packets to the access point. So, packets will be influenced by the Token Ring delay till they reach the access point. This means that the packets will wait in the wired-to -wireless queue until they get served by the wired-to-wireless outbound channel. The base station doesn't need any reservation process. It uses the free wired-to-wireless outbound slots to serve the packets as shown below:

$$D_{wd\_ws}=D^{out}_{queue}+D_{wd\_wd}$$

Where:

D_{wd-ws} is calculated using M/M/n queuing model which is described in [5], this system has n servers which is the number of slots in the wired-to-wireless outbound sub-channel.

$$D^{out}_{queue}=\frac{1}{\mu_{MMn}}+\frac{p_0(n\cdot\rho_{MMn})^n}{n!(1-\rho_{MMn})}\cdot\frac{1}{n\cdot\mu_{MMn}-\lambda_{MMn}}$$

Where

$n = N_{ws-wd}$

$$\rho_{MMn} = \frac{\lambda_{MMn}}{n \cdot \mu_{MMn}}$$

$$p_0 = \frac{1}{\sum_{1=0}^{n-1} \frac{(n \cdot \rho_{MMn})^i}{i!} + \frac{(n \cdot \rho_{MMn})^n}{n!}}$$

the service rate of the server in packets per second.

$$\mu_{MMn} = 1 / F_t$$

λ_{MMn} = arrival rate at the input of the queue.

The wired to wireless traffic.

$$\lambda_{MMn} = U_{wd} \cdot \lambda_{wd} \cdot R_{wd-ws}$$

4.5 Total Average Delay

As the delay for each scenario of the four previous scenarios was calculated, the delay will be multiplied by the probability of that scenario. Finally, summing the multiplication results gives the total average delay D as follows:

$$D = D_{ws-ws}(1 - R_{ws-wd}) + D_{ws-wd} \cdot R_{ws-wd} + D_{ws-ws}(1 - R_{ws-wd}) + D_{ws-wd} \bullet R_{ws-wd}$$

4.6 Total Throughput

The following equation shows the total throughput (S) which is the summation of the four previous scenarios throughputs.

$$S = S_{wd-wd} + S_{wd-ws} + S_{ws-ws} + S_{ws-wd}$$

The following four equations show the results of each scenario individually.

First scenario: Wireless-to-wireless throughput from the Little's formula.

$$S_{ws-ws} = \frac{N}{\sigma \cdot F} \sum_{h=0}^{U_{ws}} \sum_{i=0}^{U_{ws}-h} \frac{(U_{ws}-i)(1-R_{ws-wd})}{D_{ws-ws}(h, i)} \cdot P(h,i)$$

Second Scenario: Wireless-to-wired throughput equals the total traffic from the wireless users to the token ring wired users.

$$S_{ws\_wd} = \lambda_{ws\_wd}$$

Third scenario: Wired-to-wired throughput equals the total traffic from the token ring wired users to token ring wired users.

$$S_{wd\_wd} = U_{wd} \cdot \lambda_{wd} (1 - R_{wd\_ws})$$

Fourth Scenario: Wired-to-wireless throughput equals the total traffic from the token ring wired users to wireless message queue.

$$S_{wd\_ws} = \lambda_{mmn}$$

5. Numerical Analysis Results

In light of the previous performance analysis results and previous equations, this section explores the affect of some parameters on the system performance and stability.

5.1 Throughput Numerical Analysis Results

Using, λ_{wd} = 1500 packets/sec, λ_{ws} = 1500 messages/sec, F= 0.0002 sec, N_{RMIN} = 2 slots, N_{MS} = 100 slots, N =6 slots, σ = 2, P_t = 0.5, P_{nerr} =1, Ack=3 packets, U_{ws} = U_{wd} =10 users. The results of the throughput analysis are shown in figures 1, 2, and 3.

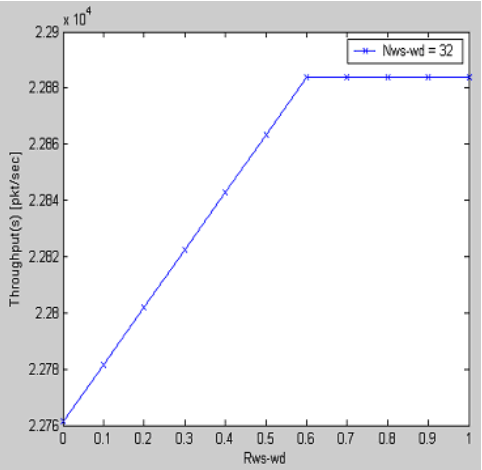

Figure 1.

In figure 1, the throughput is a function of R_{ws-wd}, and a wired-to-wireless ratio R_{wd-ws} = 0.5 is used. When wireless-to-wired ratio is increased, the throughput is also increased. This increase is caused by the more efficient use of wireless-to-wired inbound channel slots N_{ws-wd}. The throughput gets increased until all the available wireless-to-wired inbound slots are used. When this happens, the throughput reaches a saturation value, and at that point the increasing of the throughput stops.

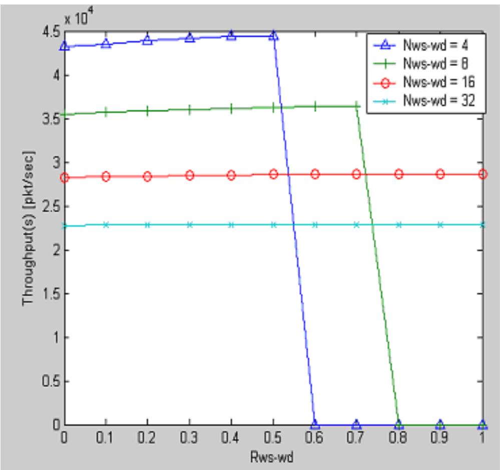

Figure 2.

In figure 2, the throughput is a function of R_{ws-wd}, and a wired-to-wireless ratio R_{wd-ws}= 0.5 is used and also different values of N_{ws-wd} are used. The increasing in wireless-to-wired inbound channel slots N_{ws-wd} increased the system stability. When the N_{ws-wd} is low, the throughput reaches instability point and reaches to zero. At N_{ws-wd} =16 instability do not occur. When N_{ws-wd} is more than 16, the throughput is decreased and this is because of the increase in the frame size. The most suitable wireless-to- wired inbound channel is when N_{ws-wd} =16. The question is how the access point can decide which the most efficient N_{ws-wd} number?

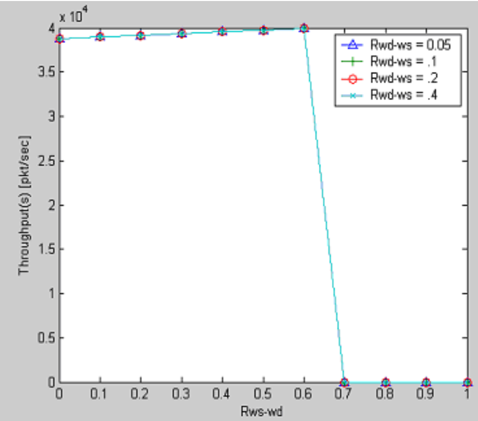

Figure 3.

In figure 3, the throughput is a function of $R_{ws\text{-}wd}$, using $N_{ws\text{-}wd}$ = 6 and different values of $R_{wd\text{-}ws}$. The deferent values of $R_{wd\text{-}ws}$ do not change the instability point, and this is because only the wireless-to-wired traffic causes the instability.

5.2 Delay Numerical Analysis Results

Using, $U_{ws} = U_{wd}$ =10 users, λ_{wd} = 1500 packets/sec, λ_{ws} = 1500 messages/sec, F= 0.0002 sec, N_{RMIN} = 2 slots, N_{MS} = 100 slots, N =6 slots, σ = 2, P_t = 0.5, P_{nerr} =1, Ack=3 packets. The results of the delay analysis are shown in figures 4, and 5.

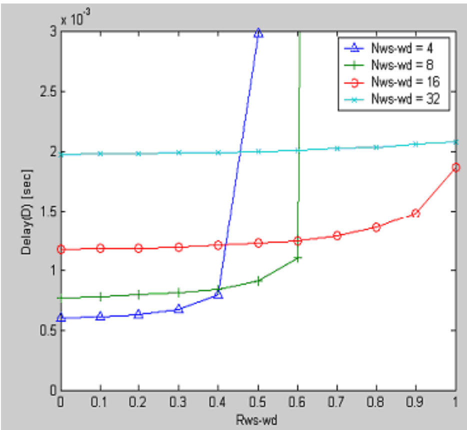

Figure 4.

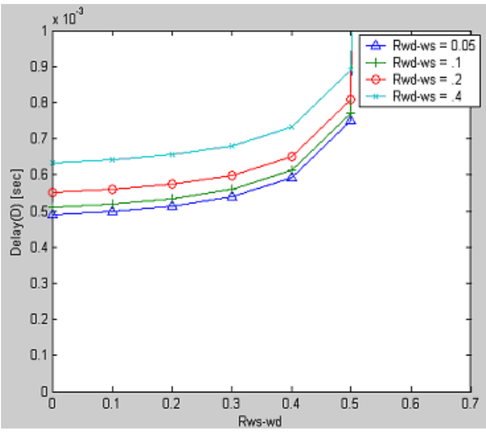

Figure 5.

In figure 4 the delay is a function of $R_{ws\text{-}wd}$, and a wired-to-wireless ratio $R_{wd\text{-}ws}$=0.5 is used and also different values of $N_{ws\text{-}wd}$. It could be noticed that the increasing in wireless-to-wired inbound channel slots $N_{ws\text{-}wd}$ leads to an increases in the system stability. While of a low $N_{ws\text{-}wd}$, the delay reaches instability point and reaches to infinity. As $N_{ws\text{-}wd}$ =16, instability do not occur.

Looking to the next figure, (figure 5) where the delay is a function of $R_{ws\text{-}wd}$, using $N_{ws\text{-}wd}$ = 6 and different values of $R_{wd\text{-}ws}$ are used, the deferent values of $R_{wd\text{-}ws}$ do not change the instability point. This is because the wireless-to-wired traffic causes the instability.

6. Conclusion and Future work

In this paper we have presented an analytical model for an integrated PRMA-Token Ring protocol. In order to test the system performance and stability, the throughput and the delay factors were considered. It is seen from the analysis that a wireless-to-wired traffic causes the system instability, while a wired-to- wireless traffic do not affect system stability.

The model derived for the PRMA and Token Ring can be tested against other models such as PRMA and Bus.

References

[1] Berry, Robert., Chandy, K.Mani (1983). Performance Models of Token Ring local Area Networks, *ACM*, 0-89791-112-1/83/ 008/0266.

[2] Goodman, D. J. Valenzuela,R. A . Gayllard K. Tand B. Amamurthi, B (1989). Packet Reservation Multiple Access for Local Wireless Communications, *IEEE Transactions on Communications,* 31 (8) August 1989.

[3] Matthew N.O.sadiku and Mohammad Ilyas, Simulation of Local Area Networks, Publisher CRC (December 27,1994).

[4] Mitrou,N. M., Orinos,TH. D., Protonotarios,E. N (1990). A Reservation Multiple Access Protocol for Microcellular Mobile-Communication Systems, *IEEE Transactions on Vehicular Technology,* 39 (4).

[5] Gallager, R.,Bertesekas, D (1987).Data Networks, Prentice-Hall.

[6] http://www.cisco.com, Introduction to LAN Protocols. Chapter 2.

[7] Ahmad, Aftab (2003). Data Communication Principles for Fixed and Wireless Networks, Kluwer Academic Publishers, 2003, eBook ISBN: 0-306-47793-9.

[8] Lam, S.S (1980). A carrier Sense Multiple Access Protocol for Local Networks, *Computer Networks*, 4 (1) 21-32.

[9] Iannello,Giulio Pescap'e, Antonio., Ventre, Giorgio., Vollero, Luca (2004).Experimental Analysis of Heterogeneous Wireless Networks. P. Langendoerfer et al. (Eds.): WWIC 2004, LNCS 2957, p. 153–164. Springer-Verlag Berlin Heidelberg.

[10] F´elix Hern´andez-Campos and Maria Papadopouli, Assessing The Real Impact of 802.11 WLANs: A Large-Scale Comparison of Wired and Wireless Traffic, Supported by the IBM Corporation under an IBM Faculty Award 2004/2005 grant.

[11] Yarvis, M.,Papagiannaki, K., Conner, W.S (2005). Characterization of 802.11 Wireless Networks in The Home. *In*: 1st workshop on Wireless Network Measurements (Winmee).

[12] Richards, Deryck. Setting up a Network — Wired or Wireless?. http://www.ezinearticles.com