OPTIMAL BANDWIDTH UTILIZATION IN WIRELESS TOKEN RING NETWORKS

By

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TOKEN RING NETWORKS

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PREFACE

The Internet world is rapidly progressing from a wired era to a wireless era. New protocols are designed for this transition. Wireless Token Ring protocol (WTRP) is one such protocol that is based on a token scheme. Performance in WTRP is limited by the channel bandwidth as the channel is shared among many stations. Under normal operating conditions, MAC protocol must provide guarantees to achieve Quality of Service (QOS). To improve the performance of WTRP, three different improvements to the protocol are proposed. These are: 1) a token reverse mechanism; 2) a farthest-hop mechanism and finally 3) a secondary communication mechanism. Simulation results show that proposed approach uses the bandwidth effectively and minimizes the token rotation time. Furthermore, results show that this further reduces the message delay in each node and increases the number of messages passed.

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Chapter 1

Introduction

1.1 Networks

Computer Networking has brought people across the globe much closer to each other and the speed at which it brings people closer keeps increasing day by day. The days of twisted pairs and cables are changing and a world obsessed with wireless communications is emerging. Businesses that churn out billions are dependent on networks and every minute is worth millions.

Wireless networks are essential to people who are always on the move. Wireless communication is not entirely done in a wireless medium. A wired station is required in order for the wireless user to send and receive messages. The term wireless networking refers to technology that enables two or more computers to communicate using standard network protocols, but without network cabling.

1.2 Wireless Token Ring Protocol

An ad-hoc (or "spontaneous") network is a local area network or other small network, with wireless or temporary plug-in connections. In such a network some or all of the mobile network devices are part of the network only for the duration of a communications session. [2]

WTRP (Wireless Token Ring Protocol) is a MAC (Medium Access Control) protocol for applications running on wireless ad-hoc networks that provide QoS (Quality of Service). In ad-hoc networks, participating stations can join or leave at any moment in time. This implies a dynamic topology. The MAC protocol through which mobile stations can share a common broadcast channel is essential in an ad-hoc network. Due to the existence of hidden terminals and partially connected topology, contention among stations in an ad-hoc network is not homogeneous. Some stations can suffer severe throughput degradation in access to the shared channel when load of the channel is high, which also results in unbounded medium access time for the stations. This challenge is addressed as QoS in a communication network. [1] [3].

The advantages of WTRP are robustness against single node failure, and support for flexible topologies, in which nodes can be partially connected and not all nodes need to have a connection with a master. Current wireless distributed MAC protocols such as the IEEE 802.11 do not provide QoS guarantees that are required by some applications. In particular medium is not shared fairly among stations and medium access time can be arbitrarily long. [1] [3].

WTRP is designed to recover from multiple simultaneous failures. One of the biggest challenges that the WTRP overcomes is partial connectivity. To overcome the problem of partial connectivity, management, special tokens, additional fields in the tokens, and new timers are added to WTRP. When a node joins a ring, it is required that the joining node be connected to the prospective predecessor and successor. The joining node obtains this information by looking up its connectivity table. When a node leaves a ring, the predecessor of the leaving node finds the next available node to close the ring by looking up its connectivity table. A priority assignment scheme for tokens is used, which in this case is the order of the nodes in the ring. Stations only accept a token that has greater priority than the token last accepted. The WTRP also has algorithms for keeping each ring address unique to enable the operation of multiple rings in proximity. [3][4]

The wireless ad hoc network has many applications: Military, rescue missions, national security, commercial use, education, sensor networks, in which there is a need for rapid establishment of a communication infrastructure. WTRP overcomes the challenges introduced by ad hoc wireless medium through procedures for joining, leaving and failure recovery. [10]

The limitation of the existing WTR protocol is that in a large ring network, most of the nodes stay idle and this results in the wastage of the wireless bandwidth. When a node communicates with another node which is not far away from its position in the ring, then the rest of the nodes, in the downstream of the destination node are idle and they simply transmit the packet. Also it takes more time for a node to get its right to communicate, or simply, to get its token, if the ring is large. These are the few limitations in the existing WTR protocol.[18][22].

In the proposed extension, we devise a mechanism where nodes get their chance much earlier than expected to communicate. The token reaches the node much earlier. Also a novel token management system is proposed to enable a second concurrent communication to take place in the same ring without any collisions. We also propose a method where a packet 'hops' as far as it can until it reaches the destination. These proposed mechanisms bring down the token rotation time, the idle time of the station and the average message delay significantly.[23]

In chapter 2, the Wireless Token Ring Protocol is outlined. In chapter 3, a detailed description of the protocol is given along with the communication setup, the packet set up and other components that control the functioning of the network. In chapter 4, extensions to the existing WTRP are proposed. The proposed extensions are: secondary communication in the ring, reducing the token rotation time by Fly fast mechanism and reduce the token idle time by doing a Token Reverse.

Chapter 5 deals with the results, findings and conclusions is reported in chapter 6

Chapter 2

Architecture of WTRP

2.1 Overall System Architecture

To put WTRP into a context in terms its placement in the communication system, we describe the overall system architecture. In addition to the communication stack including the Datalink layer where WTRP will be located, we need Moblity Manager, Channel Allocator, Management Information Base (MIB), and Admission Control Manager. We assume that multiple channels are available, and that different rings are on different channels. Different rings are assigned to different channels by a channel allocator. [5]

In a Wireless Token Ring Network, the token is held by a node determined by the priority list. In this case, the priority is the order of the nodes in the ring. Whichever node holds the token has the right to communicate. The node that has the token therefore starts transmitting the packet. When the packet reaches the destination, the destination node starts processing the packet and removes the data from the packet and passes the packet to the successor and the packet rotation continues. Once the packet reaches the original source node, it puts the token inside the empty packet and passes it on to the successor. [19]

2.2 Medium Access Control

MAC enables multiple nodes to transmit on the same medium. This is where WTRP is located. The main function of MAC is to control the timing of the transmissions by different nodes to increase the chance of successful transmission. In this architecture, the MAC layer performs ring management and timing of the transmissions. The ring management involves: [6][9][20]

1. Ensuring that each ring has unique ring address.
2. Ensuring that one and only token exists in a ring.
3. Ensuring that the rings are proper with all nodes having a predecessor and successor in the ring. This means that in case if a node leaves the ring, then the ring will re-adjust properly and will now be a new ring.
4. Managing the joining and leaving operations.

2.3 Channel Allocator

The channel allocator chooses the channel on which the station should transmit. If a large number of token rings exist in proximity, efficiency can be achieved by using spatial reuse through sensible channel allocation. The idea of spatial reuse is one of the core ideas in wireless cellular communications. The same channel (or a set of channels) can be reused in region A and B, if the two regions are separated by sufficient distance measured in terms of the signal to interference ratio. One way to increase spatial reuse is to reduce the cell size. Reducing the cell size (thus reducing the transmission power) has the following benefits:

1. Increase in capacity

2. Increase in battery life

3. Decrease in equipment costs

In addition, dividing the nodes into multiple rings would reduce the number of nodes in a ring. This would decrease the token rotation time which results in decreased maximum medium access time.[8]

Finding a global optimal solution for the channel allocation in many mobile nodes is a challenging problem. Collecting and maintaining channel allocation information can be a difficult task. The collection and maintenance of information may involve frequent packet transmission. The problem of finding an optimal channel allocation is further complicated by factors such as the limited transmission ranges of the nodes, absence of a stationary base station and the fluidity of the boundary of each channel. A greedy algorithm is therefore a solution for channel allocation, so that each station can access the network topology through MIB. Each node decides on which channel to join in a distributed manner using the information collected. [2][7]

2.4 Mobility Manager

The Mobility Manager decides when a station should join or leave the ring. The problem that the Mobility Manager has to solve is similar to the mobile hand-off problem. When a mobile node is drifting away from a ring and into the vicinity of another ring, at some threshold the Mobility Manager decides to move to the next ring. The level of connection of a node to a ring can be found from the connectivity table described in a later section. [2]

2.5 Admission Control

The Admission Control Manager limits the number of stations that can transmit on the medium. This is to ensure that a level of quality of service in terms of bounded latency and reserved bandwidth is maintained for stations already granted permission to transmit on the medium. There is an Admission Control Manager in each ring. The Admission Control Manager may move with the token but does not have to move every time the token moves. The Admission Control Manager periodically solicits other stations to join if there are "resources" available in the ring. The "resource" of the token ring can be defined in the following way. The MAX MTRT is the minimum of the maximum latency that each station in the ring can tolerate. RESV MTRT is the sum of token holding times (THT) of each station. MAX NoN is the maximum number of node (NoN) that is allowed in the ring. [2]

The Admission Control Manager has to ensure the inequality:
RESV MTRT < *MAX MTRT* and *NoN* < *MAX NoN*. Only if these inequalities are satisfied, may the Admission Control Manager solicit another station to join. During the solicitation, the Admission Control Manager also advertises the available resources. Only stations that require less resource than available in the ring may join.

2.6 Policer

The policer monitors the traffic generated by the application. It throttles the application when more traffic than reserved is produced. In the WTRP, because the token holding timer polices the traffic generated by a station, no special policer module is necessary. [2][9]

2.7 Management Information Base (MIB)

The Management Information Base holds all the information that each management module needs to manage the MAC module. The majority of this information is collected by the MAC module and stored there. [9][11]

Chapter 3

WTRP: Protocol Description

3.1 Definitions

In this chapter the describe the WTRP protocol (Wireless Token Ring Protocol).

- The term “frame” refers to what is passed to the physical layer interface. A “frame” does not include the preambles, the start delimiter, the CRC check, and the end delimiter.
- The terms “station” and “node” are used interchangeably to describe the communication entities on the shared medium.
- The predecessor and the successor of station X describe the station that X receives the token from and the station that the X passes the token to respectively.
- “Incorrect state” means that a node’s view of the topology is wrong. For example node X may believe that node Y is its predecessor, but node Y is not its predecessor.
- “Stable environment” refers to a state in which the topology of the network is fixed and there are no transmission errors. [2]

3.2 Observations

- Not all stations need to be involved in token passing. Only those stations which desire to initiate data transmission need to be involved.
- Any station may detect multiple tokens and lost tokens. There is no special “monitor” station required to perform token recovery functions.
- Due to errors, stations may not have a consistent view of the ring.

3.3 Frame Format

In WTRP, the successor and the predecessor fields of each node in the ring define the ring and the transmission order. A station receives the token from its predecessor, transmits data, and passes the token to its successor. Here is an illustration of the token frame. [2]

FC	RA	DA	SA	NoN	GenSeq	Seq	
1	6	6	6	2	4	4	bytes

Figure 3.1: Frame Format

FC stands for Frame Control and it identifies the type of packet, such as Token, Solicit Successor, Set Predecessor, etc. In addition, the source address (SA), destination addresses (DA), ring address (RA), sequence number (Seq) and generation sequence (GenSeq) number are included in the token frame. The ring address refers to the ring to which the token belongs.

The sequence number is initialized to zero and incremented by every station that passes the token. The generation sequence number is initialized to zero and incremented at every rotation of the token by the creator of the token. The number of nodes (NoN) in the ring is represented in the token frame and calculated by taking the difference of sequence numbers in one rotation.

3.4 Connectivity Manager

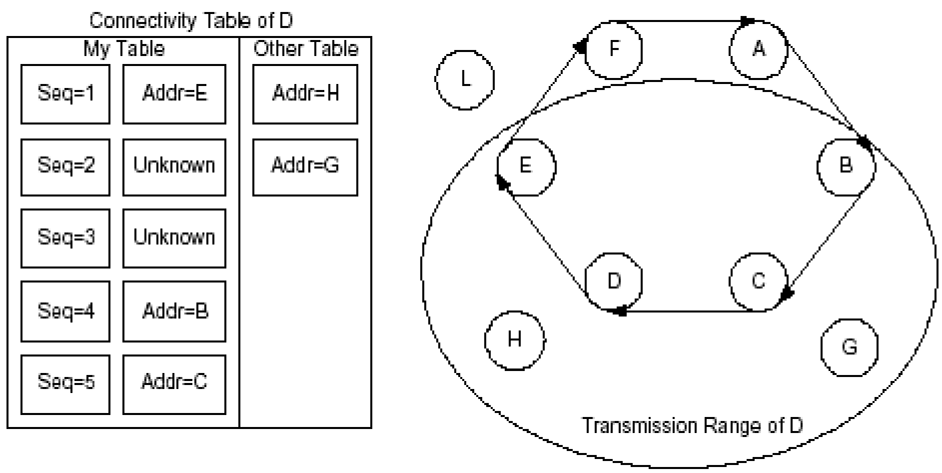


Figure 3.2: Connectivity Table

The Connectivity manager resident on each node tracks transmissions from its own ring and those from other nearby rings. By monitoring the sequence number of the transmitted tokens, the Connectivity Manager builds an ordered local list of stations in its own ring and an unordered global list of stations outside its ring. Station D monitors the successive token transmission from E to F before the token comes back to D. At time 0, D transmits the token with sequence number 0, at time 1; E transmits the token with the sequence number 1, and so on. D will not hear the transmission from F and A, but when it hears transmission from B, D will notice that the sequence number has been increased by 3 instead of 1. This indicates to E that there were two stations that it could not hear between E and B. [2]

The Ring Owner is the station that has the same MAC address as the ring address. A station can claim to be the ring owner by changing the ring address of the token that is being passed around. Stations rely on implicit acknowledgements to monitor the success of their token transmissions.

An implicit acknowledgement is any packet heard after token transmission that has the same ring address as the station. Another acceptable implicit acknowledgement is any transmission from a successive node regardless of the ring address in the transmission. A successive node is a station that was in the ring during the last token rotation. In other words, the successive stations are those present in the local connectivity table.

Each station resets its IDLE TIMER whenever it receives an implicit acknowledgement. If the token is lost in the ring, then no implicit acknowledgement will be heard in the ring, and the IDLE TIMER will expire. When the IDLE TIMER expires, the station generates a new token, thereby becoming the owner of the ring.

To resolve multiple tokens (to delete all tokens but one), the concept of priority is used. The generation sequence number and the ring address define the priority of a token.

A token with a higher generation sequence number has higher priority. When the generation sequence numbers of tokens are the same, ring addresses of each token are used to break the tie. The priority of a station is the priority of the token that the station accepted or generated. When a station receives a token with a lower priority than itself, it deletes the token and notifies its predecessor without accepting the token. With this scheme, it can be shown that the protocol deletes all multiple tokens in a single token rotation provided no more tokens are being generated.

3.5 Joining the Ring

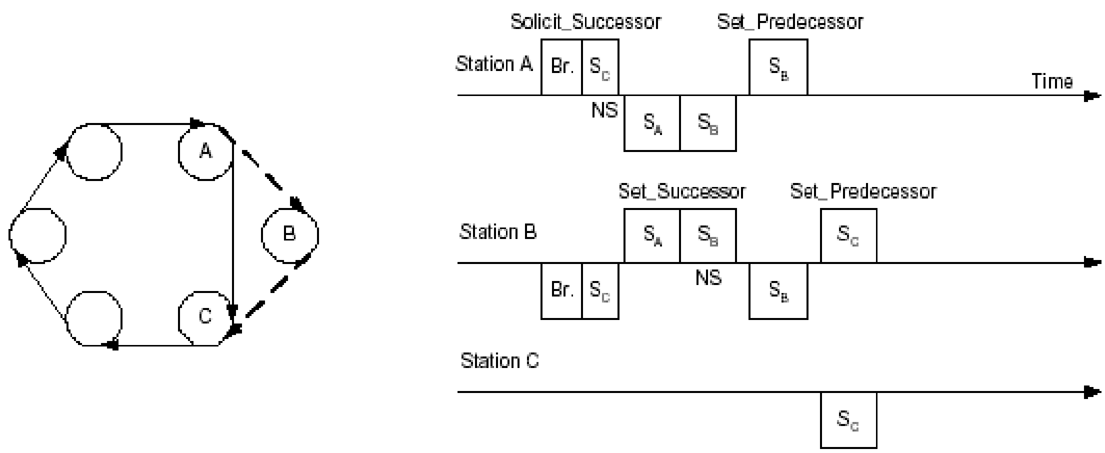


Figure 3.3: Joining

The ring recovery mechanism is invoked when the monitoring node decides that its successor is unreachable. In this case, the station tries to recover from the failure by forming the ring again. The strategy taken by the WTRP is to try to reform the ring by excluding as few stations as possible. Using the Connectivity Manager, the monitoring station is able to quickly find the next connected node in the transmission order. The monitoring station then sends the SET PREDECESSOR token to the next connected node to close the ring.[2][12]

WTRP allows nodes to join a ring dynamically, one at a time, if the token rotation time (sum of token holding times per node, plus overhead such as token transmission times) would not grow unacceptably with the addition of the new node. As illustrated in Figure 4, suppose station B wants to join the ring. Let us also say that the admission control manager on station A broadcasts (Br.) other nodes to join the ring by sending out a SOLICIT SUCCESSOR that includes successor(C) of A. The Admission Control Manager waits for the duration of the response window for interested nodes to respond. The response window represents the window of opportunity for a new node to join the ring. S_i stands for a solicit token and the subscript indicates if it's a solicit successor or a solicit predecessor token to a node i..

3.6 Exiting the Ring

The response window is divided into slots of the duration of the SET SUCCESSOR transmission time. When a node, such as B that wants to join the ring, hears a SOLICIT SUCCESSOR token, it picks a random slot and transmits a SET SUCCESSOR token. When the response window passes, the host node, A can decide among the slot winners. Suppose that B wins the contention, then the host node passes the SET PREDECESSOR token to B, and B sends the SET PREDECESSOR to node C, the successor of the host node A. The joining process concludes.[2][13]

As shown in Figure 3.4, suppose station B wants to leave the ring. First, B waits for the right to transmit. Upon receipt of the right to transmit, B sends the SET SUCCESSOR packet to its predecessor A with the MAC address of its successor, C. If A can hear C, A tries to connect with C by sending a SET PREDECESSOR token. If A cannot hear C, A will find the next connected node, in the transmission order, and send it the SET PREDECESSOR token. [2]

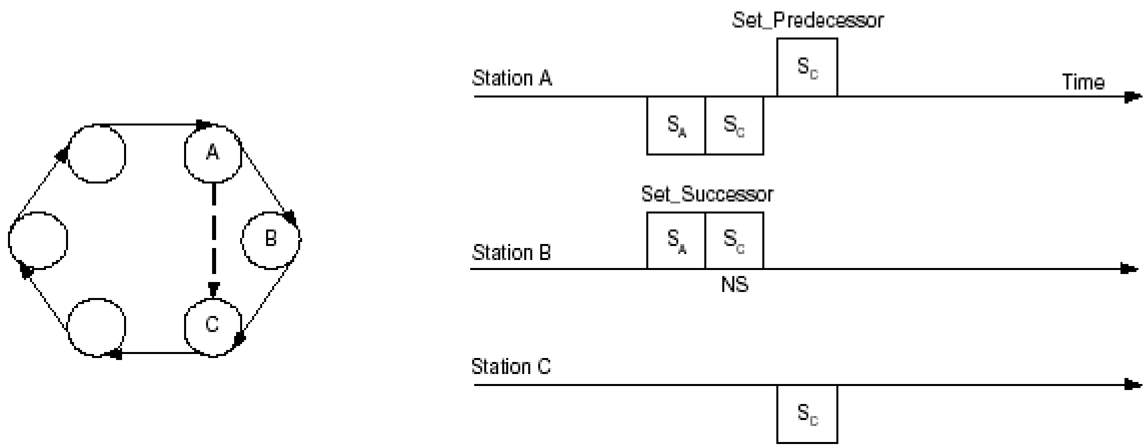


Figure 3.4: Exiting

Interference is eliminated by including NoN in the token packet. When a station detects a ring, it examines the NoN value in the token. If NoN is set to maximum, the station changes its channel and searches for another ring. Otherwise, the station either waits to become a ring member or changes its channel to search for another ring. If the station waits, it suspends transmission and waits for a SOLICIT SUCCESSOR token. As a result, a newcomer station never interferes with the ring.

3.7 Multiple Rings

In Figure 3.5, we can see that the ring address of a ring is the address of one of the stations in the ring, which is called the owner of the ring. In the example, the owner of ring A is station A. Because we assume that the MAC address of each station is unique the ring address is also unique. The uniqueness of the address is important, since it allows the stations to distinguish between messages coming from different rings. Multiple ring management is curial area for the out-of-band message transmission and it is discussed in detail in further chapters.[21][22]

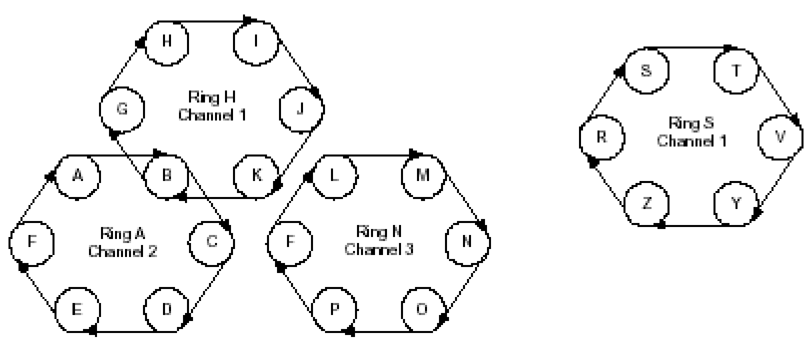


Figure 3.5: Multiple Rings

In Figure 3.5, we can see that the ring address of a ring is the address of one of the stations in the ring, which is called the owner of the ring. In the example, the owner of ring A is station A. Because we assume that the MAC address of each station is unique the ring address is also unique. The uniqueness of the address is important, since it allows the stations to distinguish between messages coming from different rings. Multiple ring

management is curial area for the out-of-band message transmission and it is discussed in detail in further chapters. There are possible schemes where a station can belong to more than one ring or a station may listen to more than one ring. To ensure that the ring owner is present in the ring, when the ring owner leaves the ring, the successor of the owner claims the ring address and becomes the ring owner. The protocol deals with the case where the ring owner leaves the ring without notifying the rest of the stations in the ring as follows. The ring owner updates the generation sequence number of the token every time it receives a valid token. If a station receives a token without its generation sequence number updated, it assumes that the ring owner is unreachable and it elects itself to be the ring owner.

Chapter 4

Proposed Extension to WTRP

4.1 Limitations of WTRP:

As we discussed in the previous chapter on WTRP if the subset (number of station participating in transmission) of the channel is busy for most of time, this leads to most of the nodes to wait until their idle time expires. The probability of a node getting any messages is low if the node has just sent a packet. This is a potential problem in Wireless Token Ring Network. Each station starts its idle timer as soon as it releases the token to the successor. This is similar to the Wired Token Ring Protocol. One of the techniques discussed is early token release, but this may not be the feasible for wireless ad-hoc networks because some of the nodes may be used as a communication path for the nodes to communicate. Moreover in Wireless Token Ring Protocol there is no explicit acknowledgement so the probability of many numbers of stations engaged in transmission is reduced.

WTRP is proposed to support mobility of nodes. This implies the following:

- Bandwidth is limited
- The channel is shared among many stations

Under normal operating conditions, the MAC protocol must provide the following guarantees to achieve Quality of Service (QOS) through

- Minimum throughput for each station
- Medium access time for each station is bounded.

One significant point that has to be noted is that in WTRP, the packets go to the successor and then they are forwarded to the destination taking a successor-to-successor route. This is similar to the packet transmissions in a wired token ring network.

Moreover in Wireless Token Ring Protocol there is no explicit acknowledgement so the probability of many number of station's engaged in transmission is reduced. For this work we assume that although the communication is wireless, all the nodes are static and not mobile.

The word cluster means the number of nodes lying within the transmission range of any give node. The basic assumption we make is that the cluster size is same.

The proposed extensions apply to data packets only. The token is assumed to be transmitted as in the standard WTRP.

4.2 Fast Routing

In this thesis we propose a novel approach to reduce the packet propagation time to reach its destination. Instead of a hop-by-hop packet transmission approach, a much faster packet transmission mechanism can be achieved if the packet can be transmitted between nodes that are at the boundary of the transmission range of the transmitting node.

Let us assume that D is the farthest node within the transmission range of A. Now, if A wants to communicate to I, then instead of communicating hop-by-hop, D can be responsible for forwarding the packet received directly from A. In the forward direction, F can be made responsible to transmit the packet from D to I (Figure 4.1).

This is achieved by checking the connectivity table. The connectivity table will say whether the destination node is within the transmission range. For example, as we see in Figure 3.1, the connectivity manager has the given information and with our proposed extension, we add more information to the connectivity manager. One important information that will be included in the connectivity manager is that every node will have an additional data, which gives the farthest node in its upstream and in its downstream. For example, for node A, FND will be D. FND stands for Farthest Neighbor Downstream and FNU stands for Farthest Neighbor Upstream. Also if A's FND is D, then D's FNU is A. This is true for all nodes as we make the assumption that the transmission ranges for all the nodes are the same.. If the destination node is not within the transmission range, then the packet is transmitted to the farthest node from the node that is in possession of the packet. If the destination node is within the transmission range of the source node, then the packet is directly transmitted to the destination node, similar to the communication between F and I, as in figure 4.1

<u>For Fast Routing (Fly Fast Communication)</u>

1. Source Node – ***Transmit packet***

2. All nodes in transmission range ***receive packet***

- All nodes ***decode address***
- If address = self address, then ***process packet.***
- If address not equal to self address and address is of a node within the cluster define cluster before writing this algorithm of the source node, stay idle – ***ignore packet.***
- If address not equal to self address
  - i. and address is not equal to a node within the cluster of the source node
  - ii. and if SELF is FND of source node,

    then forward packet.

- If address not equal to self address
  - i. and address is <> a node within the cluster of the source node
  - ii. and if SELF is not the FND of source node,

    then stay idle.

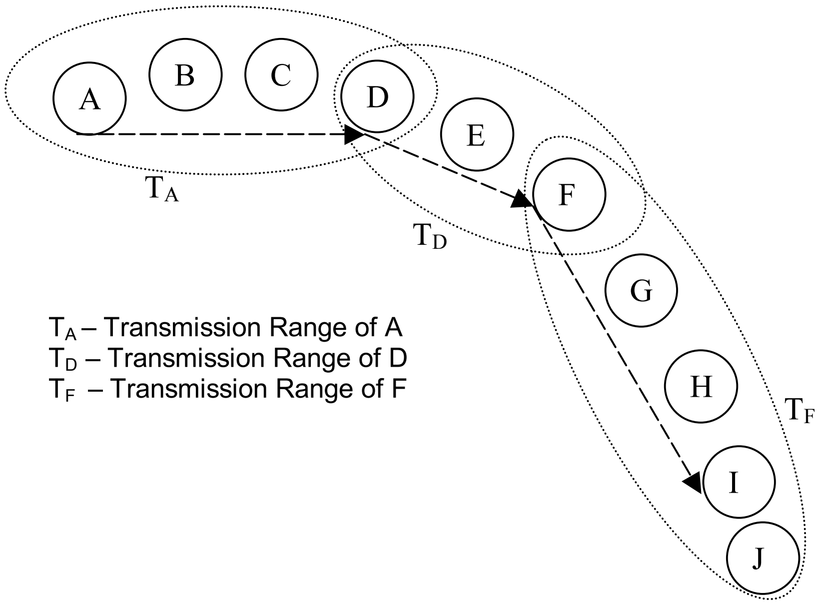


FIGURE 4.1 Fly Fast Communication

This will significantly reduce the number of times the token is handled by intermediate nodes and thereby considerably reduces the propagation time. Also there will be no change in the policy of implicit acknowledgement. All the nodes that receive the packet will know who the sender is. Every receiving node will also know whether it is the farthest neighbor. So only if it is the farthest node it will forward the packet. Otherwise it will simply ignore the packets. Also the node knows if it's the destination node. So in this case when node J receives the packet it knows that node I is within its transmission range in the upstream and also that it had received the packet. So J will simply ignore the packets.

The basic assumption for this is that the ring is large and the clusters are small. 'Clusters' in this context means the number of nodes lying within the transmission range of each other is less. As we see in the figure 4.1, only a part of the ring is shown.

4.3 Token Return

When the ring is too big and if the nodes that want to communicate with each other are considerably closer to each other when compared to the size of the ring, then instead of moving downstream to return the token to the owner, a shorter path can be taken and that is to return the token to the owner taking the path through which the token reached the destination, that is, in a reverse direction. This can only be done when the source and destination nodes are fairly close to each other, that is, the distance between the Source and destination is considerable less in a clockwise direction than it is in an anti-clockwise direction. By comparing the sequence number and the number of nodes we can find whether the destination is closer to the source on the upstream or downstream. If the sequence number is less than half the number of nodes, then the token can be returned instead of being rotated. Passing the packet to the predecessor instead to the successor, with a bit in the token indicating that the packet should be passed on to the successor does this. Thus the token is returned to the owner considerably fast paving way for the next station to claim the token and start a communication without having to wait for a long time.

<u>For Token Reverse Mechanism</u>

1. Source node – ***Transmit packet***
2. On Reaching Destination, ***compute relative position to source node RP position,***

   where RP = number of hops the packet has made.
3. If RP < N/2, where N is the total number of nodes in the ring,

   then ***pass packet to predecessor***

   else ***pass packet to successor***

4. If packet comes from successor

    And if NO TOKEN at SELF

        Then ***pass packet to predecessor***

5. If packet comes from predecessor

    And if NO TOKEN at SELF

        Then ***pass packet to successor***

6. If packet comes from predecessor

    And if TOKEN at SELF

        Then ***ignore packet, release token to successor***

7. If packet comes from successor

    And if TOKEN at SELF

        Then ***ignore packet, release token to successor.***

4.4 Secondary Communication

Based on the assumption that the Ring is large, there is a very good chance that the stations will be idle most of the time. So there is a high potential to make use of the resources when they are idle.

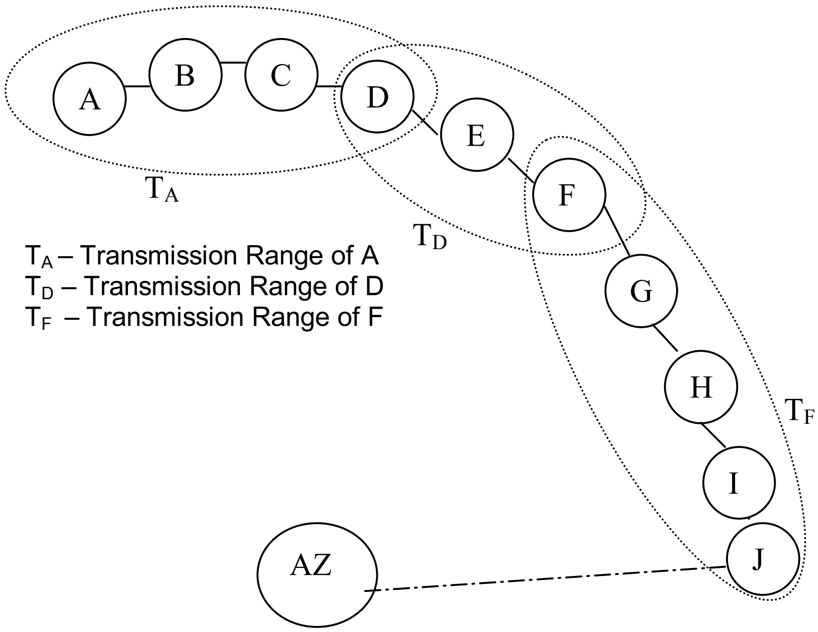


Fig. 4.2 Secondary Communication

As we see in figure 4.2 if A wants to communicate to AZ, then once A transmits the packet and also once the successor nodes are done with transmitting the packets, they will be idle. In such a situation, a secondary communication can be done among idle nodes, but under certain constraints. For example, when A wants to communicate with AZ, once A sends the packet and receives a 'ticket' from its farthest neighbor (D), then it can start a communication again, which is called secondary communication. D can send a ticket when it gets an implicit acknowledgement from its farthest neighbor (F).

This means that the transmission range of A is free. But we have to make sure that D's transmission range is also free in order to avoid collisions at D. That is why we wait for an implicit acknowledgement from F to make sure that D's transmission range is also free when A starts the secondary communication. The implicit acknowledgement from F will be the ticket to D and once D receives a ticket it will pass the ticket to A. This is how A comes to know that its transmission range in the downstream is free.. Is this correct – write a line or two on this. Thus collision is avoided initially. This policy of transmitting packets has to be followed by all the nodes. Only on getting their ticket, the nodes can transmit. Thus collisions are avoided.

The question of when to stop the secondary communication is as important as when to start it. Care should be taken that it doesn't interfere with the primary communication. For example, lets assume that there are 3 nodes in A's downstream and 4 nodes in the downstream of A's farthest neighbor. If t is the average time taken by a packet to move from one node to another, then it would take $7t$ for the secondary communication to start. Also lets assume that there are 3 nodes in A's upstream and 3 nodes in the upstream of A's farthest neighbor in A's upstream, then the secondary communication has to stop $(Nt - 6t)$, where N is the number of nodes in the ring. So the secondary communication can start at $7t$ and end at $(Nt - 6t)$. The secondary communication can take place for $(Nt - 6t) - 7t$.

It is necessary to stop the secondary communication at $(Nt - 6t)$ because at $(Nt - 6t) + 1$, the packet of the primary communication will enter A's transmission range. So stopping the secondary communication at $(Nt - 6t)$ will avoid collisions.

For Secondary Communication

1. Source Node – ***Transmit packet***

2. If SELF is farthest node of source and is SELF receives implicit acknowledgement from FND of SELF, then ***send ticket to source node.***

3. When source node receives ticket, then ***start secondary communication*** within transmission range

4. When FNU may receive a packet, then it tells the source node to s***top secondary communication***. This signal is called as ***terminate ticket.***

5. Source node receives terminate ticket, and then stops secondary communication.

The explanation for the terms used above is as follows.

SELF – node that has the packet.

FND – Farthest neighbor in downstream

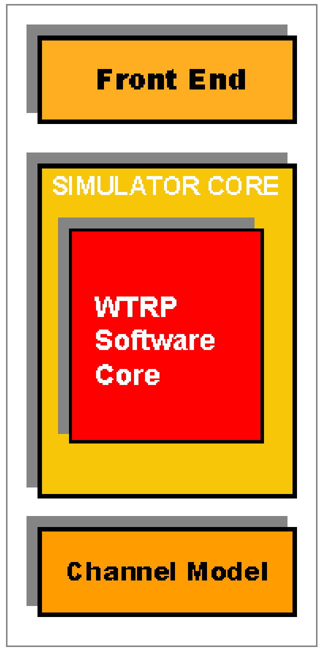
FNU – farthest neighbor is upstream

4.5 Simulation using NS

NS is a discrete event simulator targeted at networking research. Ns provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks. NS is primarily useful for simulating local and wide area networks.

4.6 WTRP Simulator

Depending on the usage scenarios of NS –2, it can be said that NS – 2 has its own set of limitations. Though it's an extensive tool, its not exhaustive. Wireless Token Ring protocol Simulator was developed at University of California at Berkeley to ease the simulation of WTRP protocols [14][15][16][17]



SIMULATOR Implementation

This simulator deals only with WTRP network implementation and parameters such as the node ids and the ids of successor nodes and predecessor nodes. are entered in a GUI window and the WTRS starts simulating the given scenario.

4.7 Why Simulation

By using any simulation tool we can predict the network performance and

- users needs
- applications needs
- network bottleneck
- Capacity Planning
- Ok for now, but *"what if"?*
- Network Performance Tuning
- Examining new network systems

- Examining new network protocols

Chapter 5

Simulation, Results & Performance Analysis

5.1 Performance Measures

To investigate the performance of the Secondary communication over the Wireless Token Ring Protocol, both protocols are studied with the growing network size. The WTRP simulator was used for this work. We simulated a list of nodes in the Wireless Token Ring Protocol with a random number of messages in their message queues. We compared the performance of the protocol with and without secondary message passing.

The performance is measured by comparing the results of the following measures

- Total cycle rotation time.
- Average Idle time by the ring
- Maximum token rotation time
- Simultaneous message passing between the stations

5.2 Steps involved in simulation

1) Add message queues in a Poisson distribution with varying length of messages.

2) Start the simulation with the base case and record the sensitive parameters for performance measure.
3) With the same input test case, start WTRP with secondary communication and record the parameters.
    a. Start the idle timer of each station when a node releases token.
    b. Once a station receives a ticket, it starts another communication. The basic assumption here is that the rings are large with the transmissions ranges being the same with same number of nodes and that every node would definitely like to communicate given a second chance.
    c. Any node doing a secondary communication should stop once it receives a terminate ticket from its farthest neighbor in its upstream. Upon completion of token rotation, the primary communication resumes.

Simulations were done for all the nodes 30 times and the average was taken for plotting the graphs.

5.3 Charts

Chart 1: Message delay for each node is calculated for secondary communication in WTRP and compared with standard WTRP without secondary communication.

Chart 2: Avg. station idle time for each node is calculated for secondary communication in WTR and compared with standard WTRP.

Chart 3: Token cycle time for each node is studied for secondary communication in WTR and is compared with standard WTRP.

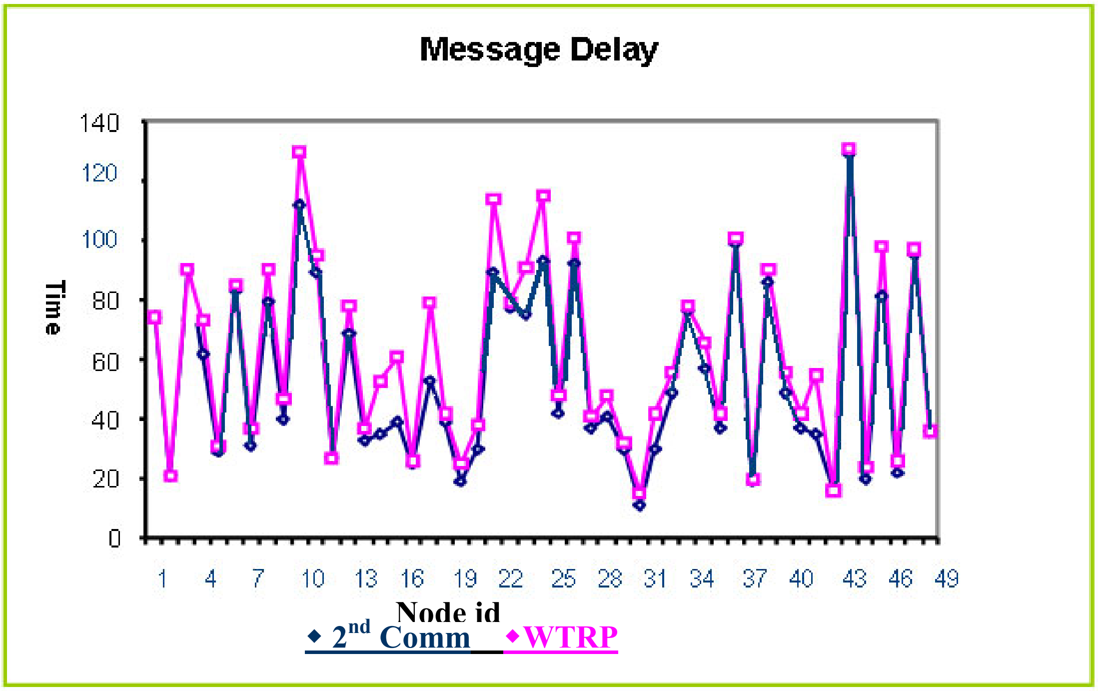


Figure 5.1: Message Delay in a station

The X axis is the node id, and the Y axis is the time unit. The blue graph is for WTRP with secondary communications whereas the pink graph is for standard WTRP without secondary communications.

From the above graph, the average message delay, which is a very important factor to measure the performance of the token ring protocol, the average message delay is slightly less in WTRP with secondary communication than in WTRP without secondary communication. This is because the nodes are more busy in WTRP and in the case where a secondary communication is introduced, a time-controlled algorithm controls the message and token passing. Although there is not a wide gap between the two measured parameters, the difference is significant.

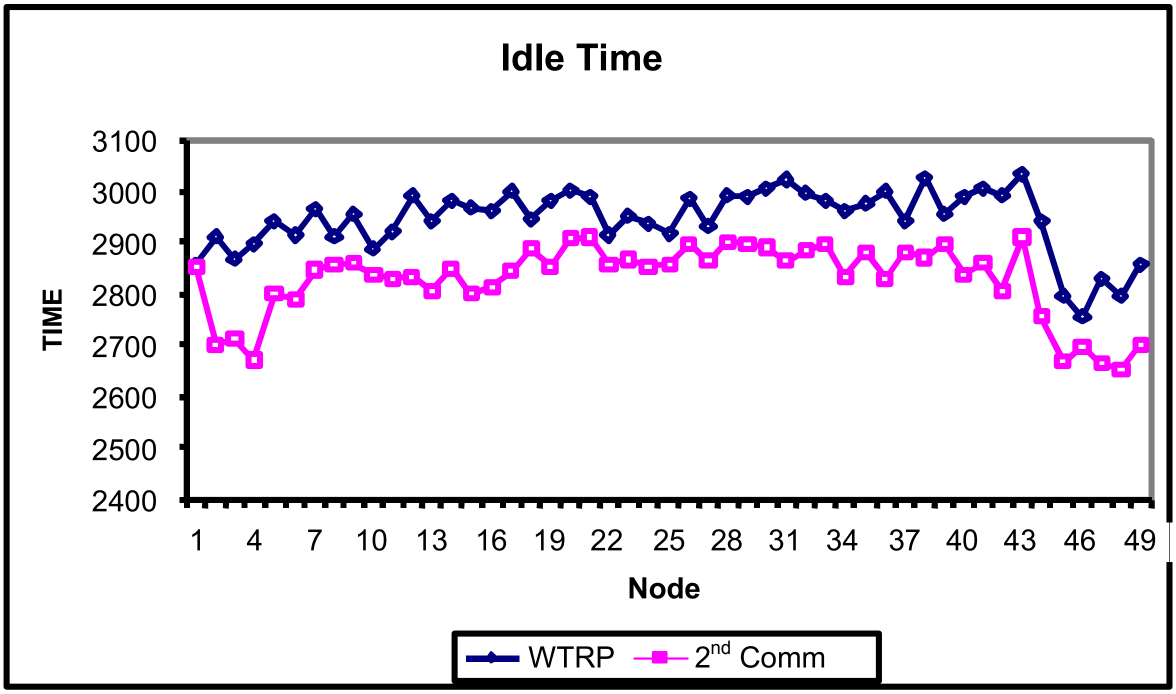


Figure 5.2: Average Idle time of Station

. Here the blue graph is the standard WTRP whereas the pink graph is for WTRP with secondary communications We can definitely see a marked change in the average idle time of each station. This is because; the probability that a node is involved in another communication process is slightly high than what we see under normal circumstances (WTRP without secondary communications). The nodes are more busy involved in some communication, thus bringing down the idle time. So this graph shows that when secondary communication takes place the nodes are more busy than the nodes that are in the standard WTRP.

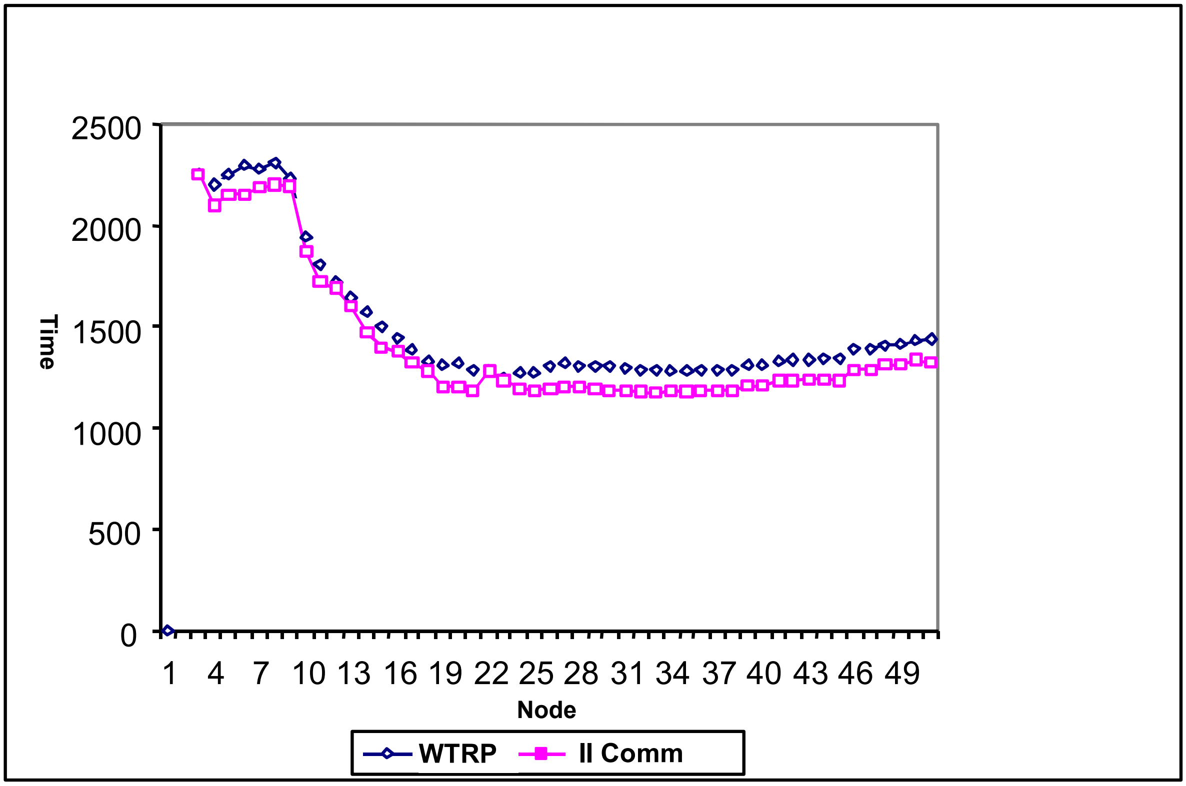


Figure 5.3: Token Holding Time

Token holding time is another important factor with which the performance of a token ring network can be measured. As part of the study, the token holding time of WTRP and the WTRP with Secondary communication is studied. As we see in the graph, there is a significant decrease in the token holding time of nodes in the wireless token ring network with our extension than in the standard WTRP. This gives us another reason to employ wireless token ring networks with secondary communications wherever possible.

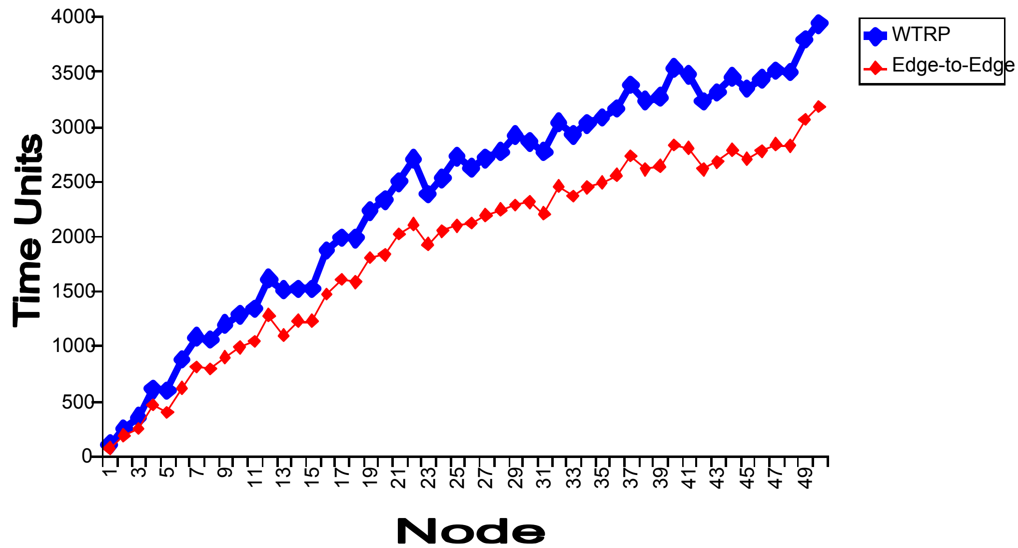


Figure 5.4: Fly Fast Communication (Edge-to-Edge)

As we see in the above graph, the (Fly Fast) Fast Routing mechanism is definitely much superior to the normal WTRP. Though theoretically the Fly Fast mechanism should cut down the time by N where N is the cluster size, there are other factors like node processing and token identification in a node that leads to a time reduction little less than N. This is assuming that the cluster size is same and the transmission power of all the nodes is the same. Fly Fast mechanism effectively works for rings that are large. In this case the ring has 50 nodes with a cluster size of 6. Edge-to-Edge refers to communication form a node at one end of the cluster to the other end of the cluster. The more the number of nodes, more time is saved with this mechanism. That is the reason why the gap widens between the lines as the number of nodes keeps increasing.

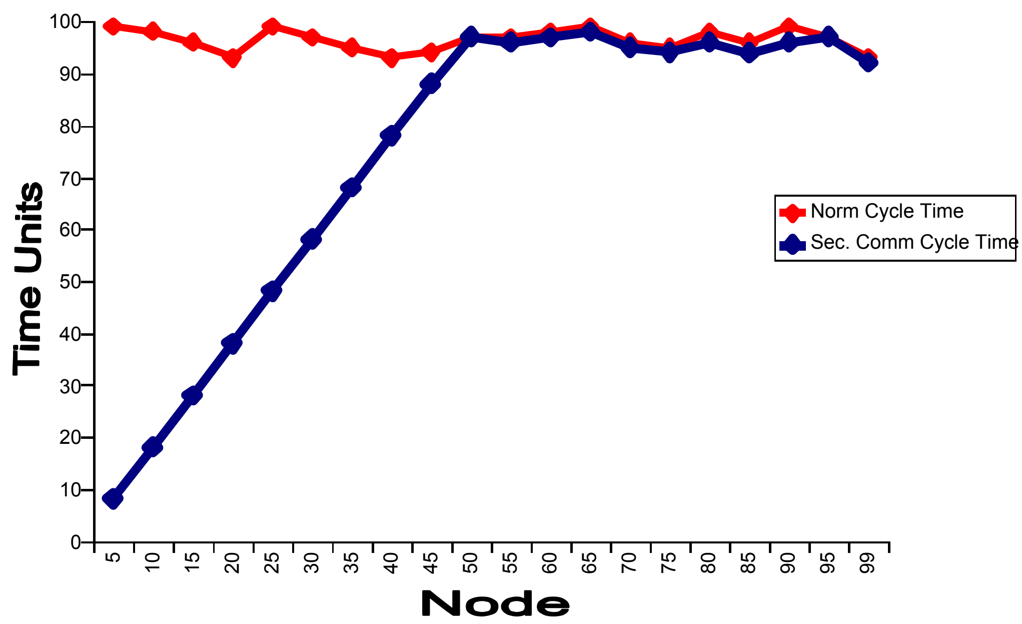


Figure 5.5: Cycle time of token

The above graph shows the time taken for a data packet to complete one cycle. When we employ a reverse return approach, then depending on where the destination node is, the token return time either decreases or remains the same. When the distance between the source node and the destination node is less than N/2; where N is the number of nodes in the ring, the token cycle time decreases as it takes a relatively less-distant path to return the empty data packet The decision whether to pass the token in the upstream or the downstream is made by the destination node by performing some simple computations such as finding the Relative Position of the SELF node as described in chapter 4.

In this case, the communication is clockwise and the return is anti-clockwise. Therefore as we see in the above graph, after node 49, the algorithm function as a normal Wireless Token Ring network and passes the packet to the successor. Before node 49, the packet is reversed thus enabling an early release of the token.

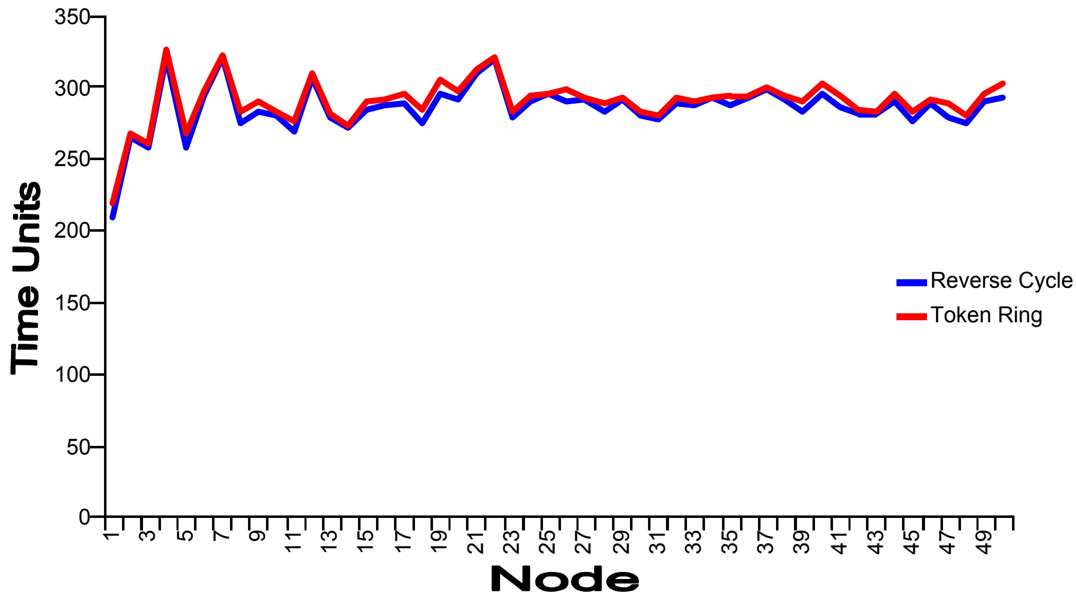


Figure 5.6: Average Idle time in Token Reverse

In the above graph, as we see the average idle time of a station is slightly less when the token takes a reverse path. When the token takes a reverse path, it means that the node that is next in the “right-to-transmit” list, can start a communication a little earlier than it could start a transmission originally. Though, once again, we don’t see a marked difference, we definitely can see that the idle time comes down by a fraction. This is assuming that the destination node is always a little less than or equal the ($^N/_2$-1)th node.

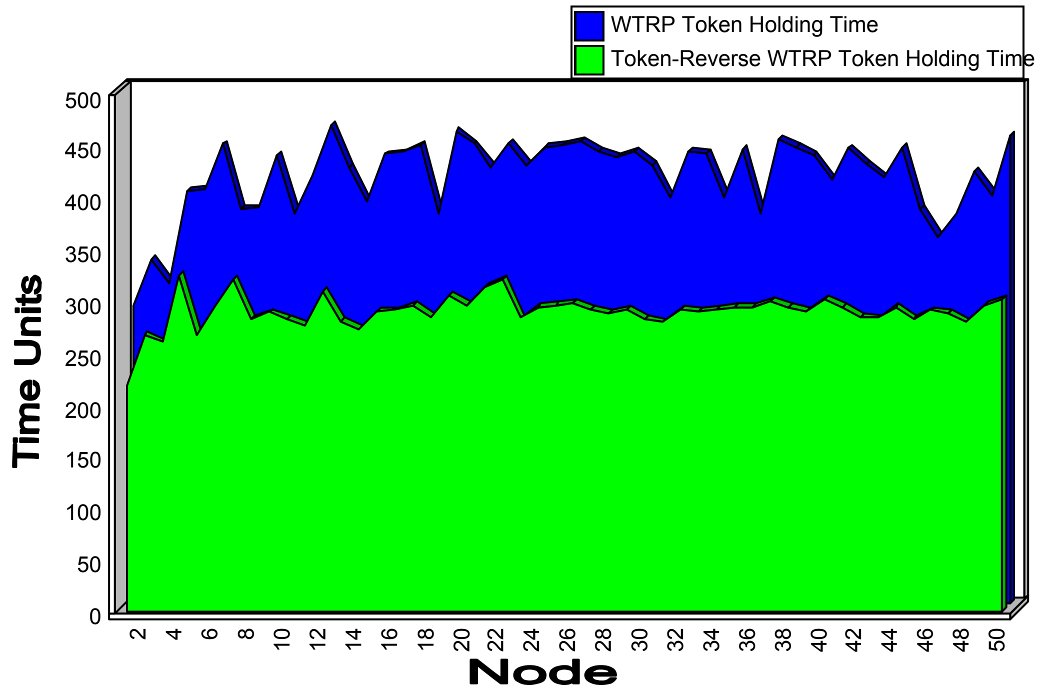


Figure 5.7: Token Holding Time on Token Reverse

As we see in the above graph, the idle time of a station is even better when we try to do a secondary communication when the token is reversed. This is definitely a step forward in optimally utilizing the bandwidth. In this case, the nodes tend to get their token earlier than expected and this results in the nodes being busy for more time than expected. Also they get more chances to communicate because there is a provision to do secondary communication once the token reversed in received at the end point (source node). This significantly brings down the token holding time leading to a decreased message delay.

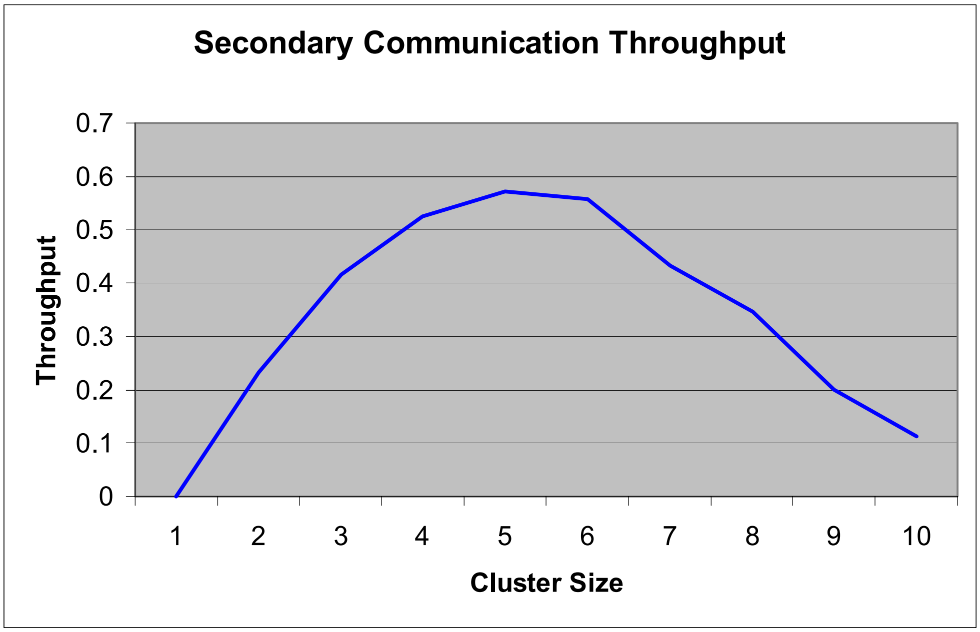


Figure 5.8: Secondary Communication Throughput

As we see in the above graph, a ring with 200 nodes is divided in to clusters which have a node strength of n={1,2,3,4,5,6,7,8,910}. For example, if n = 10, there are 20 clusters with 10 nodes in each cluster. The graph shows that the throughput of the secondary communication depends on the cluster size. When the cluster size is 1, meaning when there is one node in the cluster, then it's nothing but a normal wireless token ring. As the cluster size keeps increasing, there is an optimal break point, where the bandwidth can be more efficiently and optimally utilized. The bigger the cluster, the more time it takes for the source node to get a ticket from its farthest neighbor. Hence it takes more time to start the secondary communication. Also by the time the ticket is received, the token may also follow suit immediately. In this particular test case, the optimal number of nodes to have in a cluster ranges between 4 and 6. The cluster size can be fixed depending on the application and design constraints.

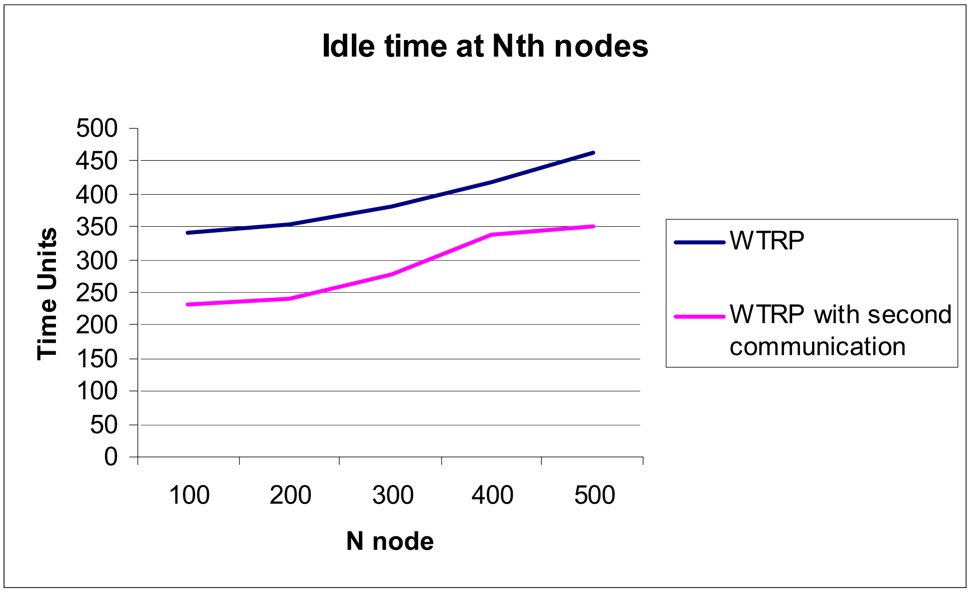


Figure 5.9: Average Idle time of Nth station

From the above graph, we observe that the average token idle time is always less in a Extended WTRP than the Standard WTRP. As the ring size tends to increase, so does the Average idle time of the nodes. But in the above graph, the line indicating the Second communication in WTRP starts flattening at around 420, indicating that the difference in the average idle time between the two schemes starts increasing around a network of size 400. The gap widens indicating that from this point superior performance could be extracted from this network setup when secondary communication is used.. As expected the more nodes in the network, the idle time increases. Moreover, when the cluster size varies, the optimal performance can be found in a ring of different size... This simulation shows that although the extended WTRP is superior at all network sizes, at a size of more than 350-450 nodes in a ring, the extended Wireless Token Ring Network gives even more superior performance. The simulations were based on a cluster size of 6.

5.4 Results

As we see from the above graphs, the message delay while using secondary communication is considerably less than what is observed in normal communication in a Wireless Token Ring Network.

From the simulation the following observations were made on Secondary Message passing in Wireless Token Ring Network. When a secondary communication takes place, the channel bandwidth is utilized more effectively. The time a station remains idle, comes down drastically as it gets involved in secondary communication. Moreover, the token rotation time comes reduces significantly. A significant improvement is simultaneous message passing is achieved. The throughput is better in a WTR with secondary communication than in a normal WTRP. This is due to effective channel bandwidth usage. To sum up, WTR with secondary communication,

- Utilizes more Channel Bandwidth
- Reduces Total Idle time for each station.
- Minimizes the Maximum Token Rotation time
- Simultaneous message passing is achieved

5.5 Performance Analysis

a. Fast Routing:

In Fast routing (Fly Fast)mechanism, the way the token is passed on from the source node to destination node is different from the normal packet passing mechanism of a token ring protocol. In a token ring protocol, a packet or a token moves from one node to another. In other words, all the intermediary nodes between the start and destination node are responsible for passing the packet from one node to the other. But in the proposed modified mechanism, as explained earlier, the farthest neighbor of each node is responsible for passing on the packet.

The significant difference here is that the token cycle time is reduced drastically and this results in an increase in the number of communications for a given interval of time. As a result the bandwidth is utilized more effectively. Though some nodes may lie idle for more time than their usual idle time, the mechanism solely concentrates on speeding up the communication process. Perhaps, the slight increase in idle time might be the compromise here.

For the farthest neighbor to forward the message to the destination a simple logic as explained earlier is implemented. But the ultimate goal of speeding up the communication process is achieved. In a normal wired token ring protocol, this may not be possible. But a wireless medium gives us more freedom to regulate the way the communication should take place.

The bigger the ring, it takes relatively less time for one communication. The speed up can be noticed when the ring is relatively large. For smaller rings, there will be a slight increase in the speed up. This is obvious because the difference in the number of hops made in WTRP and the WTRP with Fast Routing mechanism is not a significant number. The difference between this numbers widens, as the ring gets bigger.

b. Token Return

In the token return mechanism, the token takes the same route to return to the source node. This is effective when the “arc” between the source node and destination node, in the downstream of the source node, is smaller than the “arc” between the source node and destination node in the upstream of the source node (or vice-versa). The advantage is that, if the ring is relatively big and the distance between the source node and the destination node is small, then the token can be reversed. The decision whether the token route is reversed or not is made by the destination node which knows if its upstream or downstream route is shorter to the source node.

The advantage of returning the token to the source node via the same route is that its saves a lot of time. This is a deviation from the original mechanism where the token is passed all across the ring. This enables the next waiting token to start its communication sooner . The effective throughput of the system therefore increases as the frequency of number of messages being communicated increases significantly. This means the number of communications that can be done at a given interval of time increases, depending on the position of the source node and the destination node. Once again this may increase the idle time of the node on the downstream of the destination node, but the nodes may get their chance to communicate earlier. .

c. Secondary Communication

The mechanism suggested for doing a second(ary) communication while the first (primary) communication is still on is a complex mechanism. The communication process is both 'time' controlled and token controlled. The token holder (primary node) has the right to start a communication and once the primary node receives the ticket it starts a secondary communication. Though, the second communication is restricted to only a certain number of nodes, it achieves a second communication within the ring. Though, token ring networks were designed to establish a collision free communication by introducing the token scheme, the communication here is done with a token and a ticket. This is possible because it's a wireless medium.

The advantages here are relatively less idle time, message delay and improved usage of bandwidth. When a batch of messages has to be passed from one node to another, using a secondary communication helps the entire communication to end within a smaller time interval. The basic assumption here is that the rings are large.

The overhead here is that managing the ticket and the token at the same time is an overhead with some extra buffer memory required at the nodes. With memory costs on the decline, this is no longer an issue. Time management is an overhead considering the fact that the nodes have to check and compute when the secondary communication has to be stopped. There is a relative increase in the throughput as there is an extra communication taking place at the same time.

Chapter 6

Conclusions

The drawbacks with WTRP include high message delay and high idle time of stations.

In this thesis we have proposed mechanisms to significantly bring down the afore said network parameters and to deal with limitations of WTRP. Our simulation results show that the idle time, the token rotation time and the message delay of stations significantly come down because by implementing our proposed extensions.

6.1 Future work

The future work in this area can be extended to

1. Bandwidth utilization when nodes are mobile.
2. Bandwidth utilization when a network has multiple rings, with common nodes.
3. Bandwidth utilization with varying ring size because of nodes joining and leaving the ring.

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