Proceedings of the 5th WSEAS International Conference on Telecommunications and Informatics, Istanbul, Turkey, May 27-29, 2006 (pp243-248)

PERFORMANCE EVALUATION OF TCP/IP PROTOCOL FOR MOBILE AD HOC NETWORK

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Abstract:- Transmission control protocol (TCP) is a transport protocol designed specifically for wired Internet. In wireless ad hoc network, changes in topology can occur frequently and unpredictably which leads to packet loss and delay. TCP misinterprets that condition as congestion and it reacts by reducing the transmission rate and causes the performance to degrade and lower throughput. The TCP has to be modified if to recognize the difference between packet loss due to link failure or congestion. To adapt TCP to this demanding paradigm, some modifications have been proposed. This study evaluates the performance of the proposed enhanced TCP for mobile ad hoc network (MANET) environment. The enhanced TCP is integrated with Snoop protocol and installed in every node of the system model. The system model is designed and developed using OPNET software design tool. The simulation results show the enhanced TCP produces improved performance with higher throughput and support for node mobility.

Keywords:- TCP, ad hoc network, MANET, routing, congestion, throughput.

1.0 INTRODUCTION

Over the past few years, mobile ad hoc networks (MANET) are regarded as mobile nodes that are capable of communicating among themselves without the use any communication infrastructure. Mobile users can roam in the specified area and still can communicate directly with other mobile node. For this purpose, every mobile user also serves as a relay or router for other nodes. Previously most researchers are interested in routing protocol challenges for wireless ad hoc networks. However in this study the focus is on developing a mechanism, which can improve the performance of transmission control protocol (TCP) [1] along with Internet protocol (IP) [2] for MANET. The TCP/IP is widely accepted in Internet as the reliable end-to-end transport protocol. While the IP handles the actual data delivery, the TCP manages the individual packet for efficient routing in the Internet. By using flow control, sequence number, acknowledgement and timer, the TCP can ensure delivery from the sending process to the receiving process correctly, orderly and error-free. However in MANET environment, network topology changes and discontinuities occurs frequently causing packet loss, which TCP misinterprets as congestion [3]. The TCP will react by reducing the transmission rate and affect the performance to degrade with lower throughput.

The TCP assumes congestion has occurred whenever an acknowledgment fails to arrive before a time-out expires due to segment loss. The segment loss can be indicated in two ways namely:

i. Occurring of a time-out or;
ii. Receiving duplicate acknowledgements

The TCP must be modified in order to recognize the difference between link failure and congestion if to work effectively in MANET. The remainder of this paper is organized as follows. The next section reviews some existing schemes for improving TCP. Section 3 presents the proposed scheme and Section 4 describes the system model. Section 5 discusses the simulation results and finally Section 6 presents the conclusion.

2.0 CURRENT TCP MECHANISM

In this section, the more popular proposed schemes to improve TCP performance for MANET [4][5][6] architecture are presented.

2.1 Snoop Protocol

Snoop protocol [7] is designed to be TCP aware. The snoop protocol modifies the network layer software on the base station to cache the TCP packets and perform local retransmissions across the wireless links. It is implemented as a layer in TCP/IP architecture stack. It can be located both at the access point and the mobile node. The Snoop protocol runs on a snoop agent that is implemented in the base station or wireless devise. The agent monitors the packet that passes through and caches the packet into a table for TCP connection. Then the agent forwards the packets to their destinations and monitors the corresponding acknowledgements (ACKs) without forwarding the ACKs to the sender.

2.2 Mobile-TCP

Another solution is the mobile-TCP [8], which is a transport protocol for mobile computing designed specifically for lengthy disconnections or frequent disconnections. Mobile-TCP informs the sender that a disconnection has occurred. It ensures that handoff is efficient and the end-to-end TCP semantics are maintained. If TCP sender detects a packet loss (duplicate acknowledgement or timeout) it will perform retransmissions but without reducing its window size. Once disconnection ends, the sender is informed to resume normal operation.

2.3 ATCP Protocol

While the ATCP protocol [9] utilizes the network layer feedback. It does not impose changes to the standard TCP itself. It is a layer between IP and TCP that follows the network state information of "Destination Unreachable" message and the Explicit Congestion Notification (ECN) message provided by ICMP. In case of route failure, the ICMP "Destination Unreachable" message will allow the TCP sender to enter persist state. The ECN message can differentiates packet loss due to congestion or wireless transmission errors. In case of loss, the TCP sender enters persist state and in case of congestion, ATCP will not interfere with TCP congestion control algorithms but forwards the packet to TCP so that it can invoke its congestion control mechanism normally.

3.0 ENHANCING CURRENT TCP

The criteria or factors considered in this study in improving the current TCP to meet the demand of node mobility in MANET are identified. There are two major factors considered in order to improve the TCP throughput.

i. Route Failure:

The protocol must be able to distinguish between packet loss due to route failure and packet loss due to congestion.

ii. Congestion Window:

The protocol must not use the old route congestion window size for the new route, since it is unlikely for similar conditions also continue to exist in the new route. In reality, some of the ideas developed for the current solutions may also be enhanced [8][10], and new paradigms can be designed. In this work, we propose to integrate the current TCP with the Snoop protocol to match our requirement. The following factors are relevant to the proposed enhance wireless TCP protocol:

- The new protocol must preserve the TCP end-to-end acknowledgement and semantic in order to identify the presence of various network condition.
- The protocol must support wireless transmission errors, route failures and handoffs.
- The protocol can handle congestion well.
- The protocol uses a new congestion window size for a new route.
- The protocol will not affect the TCP structure.

3.1 Snooping in Ad Hoc Network

To improve the TCP performance the Snoop protocol is integrated in the ad hoc network, where each node acts as host as well as router for other nodes. In other words, every node in the network is equipped with a Snoop module. Snooping at each node will increase the packet availability even when nodes rearrange themselves by joining or leaving the network. The packet is sent from one mobile host to another with random speed and to random destinations. If two hosts are close enough to each other they can communicate directly. However, if they are far apart, then other host can relay the packets to and from these two distant users during the communication.

Working from the original Snoop protocol, all modifications take place at the base station and the hosts. The difference between wired network and ad hoc network is in the degree of the physical infrastructure present. The original Snoop protocol was designed with the vision of wireless network becomes an extension to the wired network. In ad hoc network scenario, each mobile node works with other nodes so as to dynamically maintain network topology by broadcasting packets to all the neighboring nodes. Each mobile user serves as a relay or a router for other nodes and allows communication among them.

3.2 Snoop Cache

The Snoop cache is used to cache packets that are received from the higher layer. It will retransmit these packets once Snoop detects a loss packet due to the received of duplicate ACK. As mention previously, the Snoop in each node will broadcast the packets to all neighboring nodes. Caching the packets at all nodes will increase the packets availability. Thus, each node requires bigger cache size. The number of packets in the cache will decrease as the Snoop protocol receives the ACK. The number of cached packets will become zero when the TCP connection is completed.

3.3 Snooping States

For data transfer in MANET, the Snoop protocol will control the data transmission. In doing so, the Snoop protocol implemented in every mobile nodes will function in several states. The possible states are:

- Normal State
- Congestion State
- Loss State
- Disconnection State

4.0 SYSTEM MODEL

The OPNET Modeler [11] is the simulation tool used to design and develop the system model. The standard 802.11 WLAN model [7][12] is selected for the node model. Similar parameters and attributes as the previous TCP model, the MANET routing protocol and the IEEE 802.11 WLAN model were adopted again excepts those that need some modification to validate the results. In particular the parameters are set up according to the standard IEEE 802.11b MAC Protocols. All nodes (workstations, LANs, server and routers) support TCP protocol and provide parameters that are configurable. The networks are modeled in a layered manner within the simulation environment. There are four layers of framework modeling for any network environment namely:

- Network Domain.
- Node Objects.
- Process Models/ State Transition Diagram (STD).
- Enter and Exit Executives Pads

4.1 Network Domain

The network domain for MANET environment consists of 10 nodes and each node has its own configuration. For wireless ad hoc network, each link in the network is unreliable. The approach taken to establish reliable link is by applying Snoop and caching at every node. The Snoop implementation does not take advantage of the fact that at the link layer any packet is broadcast to all the neighboring nodes. Caching the packets at all nodes will increase the packet availability tremendously. However in doing so, each node requires bigger cache size. The network components of the TCP system model comprise the following basic elements namely: servers, workstations, routers, switch, LAN and links.

4.2 Node Model

To comply with MANET model, the original snoop module is modified to satisfy the new TCP protocol for wireless environment. In addition, the Snoop and Packet Error Generator (PEG) layers are incorporated as new TCP features using the original WLAN node model. Thus emphasize the importance of snoop and PEG layers that are located above the Address Resolution Protocol (ARP) layer of the standard TCP. The WLAN node model is chosen as the standard for each layer in the node model design. There are other higher layers implemented in the WLAN node model such as the application, TCP and IP layers. The main interest is focused on the TCP and IP layers of the TCP node model.

Fig. 5 shows WLAN node model of the new TCP protocol integrated with modified snoop module. Snoop agent is added between ARP and IP layers. It means the snoop module is implemented in the wireless devise as the base station. The Snoop agent is used to cache packet that are received from the higher layer. To facilitate the Snoop protocol, an additional layer, called a PEG is added between ARP and IP layers, which is below the snoop agent layer. While packets are being sent, PEG will generate packet loss by dropping packets that was received from the upper layer or lower layer.

4.3 Process Model

The engine for snoop model is the process model, as shown in Fig. 6. It can be viewed as a series of logical operations performed on data. The process model represents the logical of the real elements in TCP snoop protocol. Any alteration to improve TCP performance such as congestion control and route running is made within this process. It will go deeply on the enter and exit executive pads where it is here that all the codes are noted down. The implemented process model can be different to the original Snoop since the only nodes existed in the network is the mobile nodes, and with no other fixed hosts or base station. The TCP model is developed by selecting the required node and link models from the OPNET Object Palette and activates the required applications and the supported profiles. Extensive simulation runs were performed on the models. Each parameter change creates a different scenario and the results were analyzed and compared in order to understand the network behavior. The simulation parameters considered for the network domain of the MANET model can be simplified as shown in Table 1 and Table 2 below.

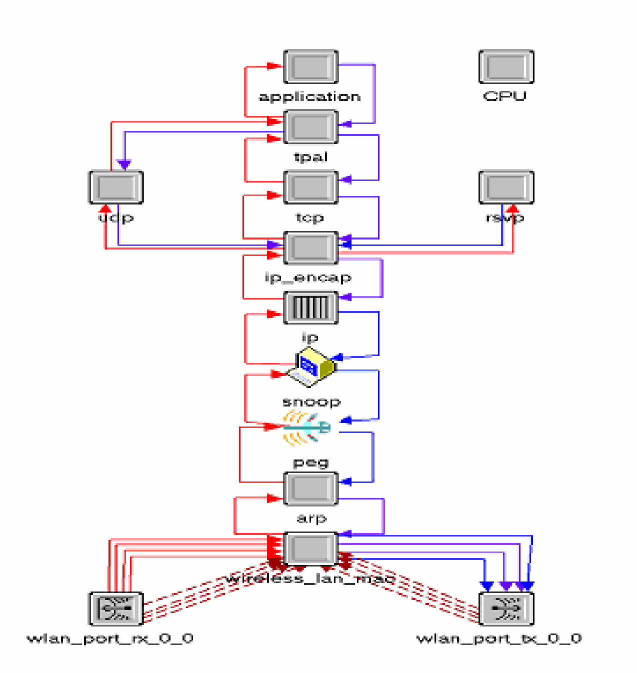

Fig. 5: WLAN Node Model with Snoop

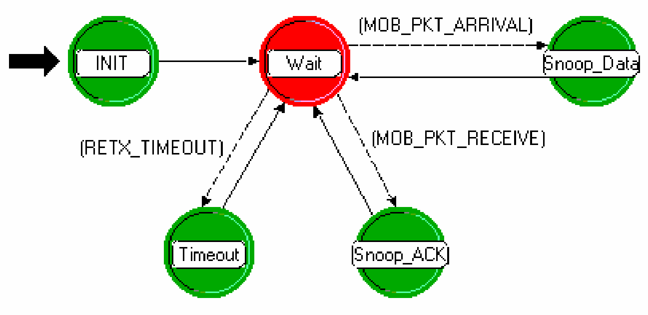

Fig. 6: Snoop Process Model

Number of mobile hosts	10
Field Size	300m x 300m
Simulation Time	1 hour
Maximum Segmented Size	2264 bytes
TCP Packet Size	536 bytes
Maximum Congestion Window	8
Maximum Receiver Window	8

Table 1: Network Topology Simulation Parameters

MAC Layer	IEEE 802.11b
Link Bandwidth	2 Mbps
Radio Transmission Radius	250m
Routing Protocol	DSR

Table 2: MANET Simulation Parameters

4.4 Simulation Set Up

There were 10 nodes on different locations of the receiver and sender in the range of 1 hop to 9 hops. Each node can be at maximum distance of 250m away from the nearest neighbor. From [13] the data throughput equation for IEEE 802.11 MAC for MANET is as follows:

$$\frac{\text{Data Packet}}{\text{Data Packet} + \text{Data Packet Overhead}} \times 2\text{Mbps} \qquad (1)$$

Data Packet Overhead = RTS + CTS + MAC Header + MAC ACK

- RTS (Request to Send) Size = 40 Bytes.
- CTS (Clear to Send) Size = 39 Bytes.
- MAC Header Size = 47 Bytes.
- MAC ACK Size = 39 Bytes.

When data packet of 536 bytes is applied, the IEEE 802.11 MAC data throughput is 1.53 Mbps. With various inter-frame timings are counted, this limit is reduced to 1.43Mbps (0.1Mbps for data packets). This is IEEE 802.11 MAC data throughput for a receiver of one hop away from the sender. On the other hand, by using (1) the new TCP data throughput can be calculated as (2) below:

$$\frac{\text{Data Packet}}{\text{Data Packet} + \text{Data Packet Overhead} + \text{TCP ACK Overhead}} \times 2\text{Mbps} \qquad (2)$$

Data Packet Overhead = TCP H. + IP H. + RTS + CTS + MAC H. + MAC ACK .
TCP ACK Overhead = TCP H. + IP H. + RTS + CTS + MAC H. + MAC ACK .

- RTS (Request to Send) Size = 40 Bytes
- CTS (Clear to Send) Size = 39 Bytes
- MAC Header Size = 47 Bytes
- MAC ACK Size = 39 Bytes
- TCP Header Size = 20 Bytes
- IP Header Size = 20 Bytes

With applied data packet of 536 bytes, the TCP data throughput is 1.13 Mbps. When inter-frame timings are considered, the limit reduces to 0.93Mbps (0.1Mbps for data packets and 0.1Mbps for TCP ACK). This is the result of the expected TCP throughput for a receiver that is one hop away.

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5.0 SIMULATION RESULTS

In this work, there are some configurations to be setup to establish the mobile ad hoc network model:

- Each node is implemented with Snoop module.
- The TCP and Snoop protocol are incorporated in MANET.
- Congestion can occur in the network.
- Mobility is part of the mobile hosts.

The MANET system model consists of 10 nodes, thus there can be 9 hops the most. The TCP throughput of the system model is measured and compared with the theoretical value. From channel utilization (1/n) as proposed by [13], where n is the number of hops, the theoretical result can be calculated For example, data packet sent from the first node to the second node, the measured throughput is 0.90Mbps, which is approximately equal to the theoretical value of 0.93Mbps. Thus the result is validated. Fig. 8 shows the TCP throughput decreases with increasing hop counts, since the first host is said to inject more data than other mobile hosts. Thus the throughput is highest at the sending node. The maximum throughput achieved at one hop is almost 0.93Mbps for both practical and theoretical conditions. As the number of hops is further increased, the TCP throughput decreases exponentially and approaches 0.10Mbps for both situations.

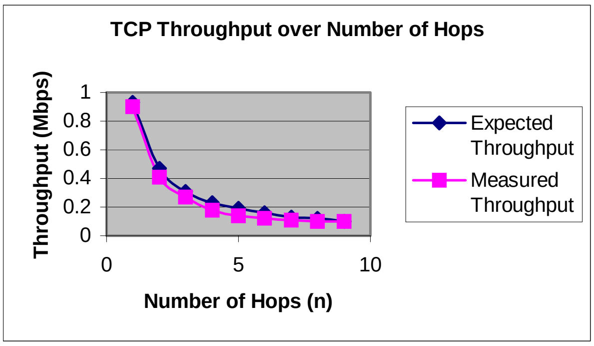

Fig. 8: TCP Throughput over Number of Hops

Clearly this is due to interference that every node experiences depending on its location in the ad hoc network chain. While Fig. 9 shows the improved TCP throughput performance for MANET network integrated with Snoop protocol. In an ad hoc network, data packets and acknowledgements must travel more dynamically, taking advantage of the available nodes. The throughput improvement is the result of high availability of packets achieved through caching at each node. The performance of cached packets is shown in Fig. 10. The benefits of cached packet at every node make it realistic for Snoop protocol to retransmit any data packets from its cache without informing the sender or waits for time RTO once packet lost is detected.

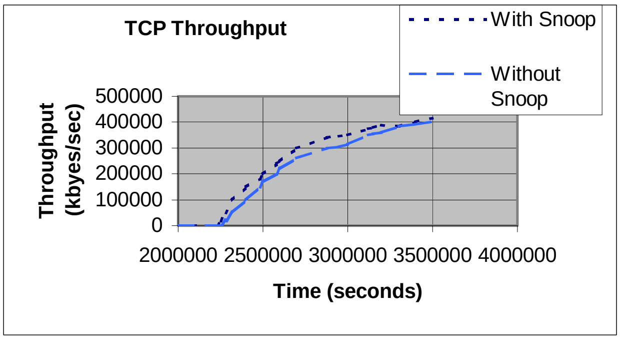

Fig. 9: TCP Throughput

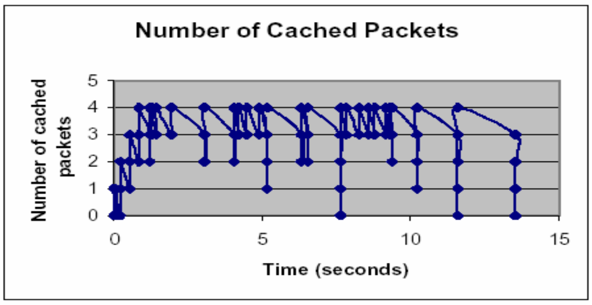

Fig. 10: Number of Cached Packets

In wireless network, packets losses are mostly due to the bit errors caused by the environmental impact such as noise and delay. Congestion has become the problematic factor in improving the performance of data transfer in wired or wireless network. Snoop protocol overcomes this issue by introducing the effect of caching packet. In this study, the Snoop protocol is implemented at each node, so as to prevent TCP congestion window from shrinking. TCP shrinks its congestion window when it detects packet lost. Shrinking the congestion window causes TCP to send less data in each packet. On the other hand, the network will still transmits more data packets. This creates greater chances for packets to get corrupted; and this in turn will shrink the congestion window and the condition repeats.

It is clear that without the Snoop Protocol, the TCP layer has to retransmit the same data packet (same sequence number) several times. This will cause timeout to expire and may invoke congestion control, thus degrades TCP performance. Hence, Snoop protocol solves this matter by detecting if the sequence is new, false or duplicate acknowledgement.

Snoop protocol acknowledges packets with reference to its sequence number and assumes all packets with higher sequence number are lost. The Snoop will retransmit packets only from the first lost packet.

6.0 CONCLUSIONS

The result obtained is validated since there is small difference between the two throughputs, theoretical and measured value. As the number of hops increases, the throughput degrades due to factors such as interference and high bit error rate. That is why the performance of traffic packet decreases as the data transmission distance from sender to receiver increases.

From the performance graphs shown, the Snoop protocol can improves the TCP throughput performance without changing other layer stacks. The TCP/IP layer is unmodified, so the semantics is preserved. The throughput performance is improved with Snoop protocol. Nodes with Snoop protocol can transfer more data packets compared to those without Snoop when transmitting almost the same data packets (sequence number) through the network. In addition, the result also shows that Snoop works well in preventing TCP congestion window from shrinking, hence increases the performance significantly. This proves the effect of caching at each node produce better results.

Therefore, the assumption that all losses are due to congestion becomes quite problematic over wireless links. Packets losses are mostly due to the bit errors caused by the effects of environmental impact such as noise and delay. Thus, numerous proposals for appropriate TCP modifications existed. To this end, we have implemented a new improved TCP protocol in the OPNET environment using the schemes of Snoop protocol, which serves as a benchmark in this study and analysis. Snoop at every nodes produce an improvement in the throughput. This mechanism seems appropriate and leads to the implementations of TCP over wireless link with better performance. The results obtained from extensive simulation run for mobile ad hoc network proves the new wireless TCP produces better throughput performance.

7.0 ACKNOWDEGEMENT

The authors would like to thanks the Ministry of Science, Technology, Malaysia and Innovation for sponsoring this work under the grant: IRPA 04-02-01-0023-EA0023.

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