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Dynamic Deferred Acknowledgment Mechanism for Improving the Performance of TCP in Multi-Hop Wireless Networks

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Abstract*— Transmission Control Protocol (TCP) is a network communication protocol designed to send data packets over the Internet. This paper proposes to improve Transmission Control Protocol performance in multi-hop wireless networks by minimizing the number of acknowledgment using delayed acknowledgment mechanism. Generating an acknowledgment for each incoming data packet reduces the performance of Transmission Control Protocol. The main factors affecting Transmission Control Protocol performance in multi-hop wireless networks is the contention and collision between acknowledgment and data packets that share the same path. Transmission Control Protocol performance will be improved by lowering the number of acknowledgments using the delayed acknowledgment mechanism. A receiver with an adaptive delayed acknowledgment mechanism is proposed to improve Transmission Control Protocol performance in multi-hop wireless networks. A Delayed acknowledgment (DAK) Algorithm is proposed to improve the Transmission Control Protocol throughput compared to the regular Transmission Control Protocol. *The proposed approach is simulated in network simulator-2 (NS-2). Simulation results illustrate the efficiency of our technique in terms of packet loss.

***Keywords*— TCP, Delayed Acknowledgment, Throughput, Multi-Hop Wireless Network.**

I. INTRODUCTION

Multi-Hop Wireless Network consists of a collection of nodes or devices that can communicate with each other without any centralized infrastructure. These nodes can freely and dynamically self-organize into the arbitrary and temporary network. These nodes not only forward and receive the packet, but also act as a router and route maintenance and route recovery. Multi-Hop wireless Network has some befits, It can extend the coverage area and improve the connectivity, enables higher data rates and multiple paths are available that is used to improve the robustness of the network.

TCP is a connection-oriented transport protocol that sends data as an unstructured stream of bytes. By using sequence numbers and acknowledgment messages, TCP can provide a sending node with delivery information about packets transmitted to a destination node. Where data has been lost in transit from source to destination, TCP can retransmit the data until either a timeout condition is reached or until successful delivery has been achieved. TCP can also recognize duplicate messages and will discard them appropriately. If the sending computer is transmitting too fast for the receiving computer, TCP can employ flow control mechanisms to slow data transfer.

The reliable, flow-controlled TCP service is much more complex than UDP, which only provides a Best Effort service. To implement the service, TCP uses a number of protocol timers that ensure reliable and synchronized communication between the two end systems. The end-to-end argument helped determine how two characteristics of TCP operate; performance and error handling. TCP performance is often dependent on a subset of algorithms and techniques such as flow control and congestion control.

Flow control determines the rate at which data is transmitted between a sender and receiver. Congestion control defines the methods for implicitly interpreting transmission rate. TCP implements a window based flow control mechanism. Originally TCP's flow control was governed simply by the maximum allowed window size advertised by the receiver and the policy that allowed the sender to send new packets only after receiving the acknowledgment for the previous packet. Beside the receiver's advertised window, *awnd*, TCP's congestion control introduced two new variables for the connection: the congestion window, *cwnd*, and the *slowstart* threshold, ssthresh. The congestion window can be thought of as being a counterpart to advertised window. Whereas *awnd* is used to prevent the sender from overrunning the resources of the receiver, the purpose of *cwnd* is to prevent the sender from sending more data than the network can accommodate the current load conditions.

The performance of TCP degrades in wireless Network compared to wired because TCP is tuned for wired networks in the sense that packet loss is assumed to be due to congestion only. This assumption fails in wireless networks as error rates in wireless networks may be an order of magnitude larger than in wired networks. Hence, when packets are dropped or corrupted on the wireless link, the congestion control mechanism for the sender kicks in and as a result (of reduction in congestion window size) the throughput decreases significantly.

The factors that affect TCP performance in multi-hop wireless networks are:

- Mobility
- Energy Efficiency
- Medium contention and collision
- Channel Error

The main objective of this paper is to improve the TCP throughput in multi-hop wireless network by delaying the acknowledgment of receiving data packets in the network. Section 1 gives an introduction to multi-hop wireless networks and TCP and their characteristics. Section 2 presents the related work in this area of research. Section 3 gives a detailed discussion on Algorithm. Section 4 gives a detailed discussion on the results based on simulations. Finally, Section 5 gives the conclusion.

II. BACKGROUND AND RELATED WORKS

In this section we present various methods proposed in literature to improve the performance of TCP in Multi-hop wireless networks.

Yang and Wang in” Improving TCP performance for east experimental data in the wireless LANS” [1] proposed a dynamic delayed TCP ACK mechanism called AP-DDA at the access point (AP). This mechanism considers the four situations in TCP: congestion window size, sending situation of the current window, the TCP sending states and the special packets (such as retransmitted packet or out of order ACK).

Chen in “TCP with delayed ACK for wireless networks”, [3] proposed a scheme called TCP-DCA to select different delay windows based on the path length (number of hops). They found that TCP does not always get throughput gain by delaying unlimited ACKs. Furthermore, there exists an optimal delay window size at the receiver that produces best TCP throughput. TCP-DCA has shown good performance in multi-hop wireless networks.

Chen and Marsic in” Issues and Improvement in TCP Performance over multi-hop Wireless Network”, [4] suggested that TCP performance can be gained by making the receiver, wait until the ACK-delay time-out event occurs, no matter how many in-order packets are received during the time-out period. They use a large delay window to ensure the occurrence of time-out.

III. TCP PERFORMANCE IN DYNAMIC DELAYED ACK

A new dynamic delayed acknowledgment mechanism is proposed to improve TCP performance by lowering the number of ACKs to the minimum number, which guarantees TCP reliability and reduces channel contention. Delay window is introduced in delayed mechanism which has the numeric value and it will be set based on network condition.

The objective is to determine the number of ACKs by which the delay window should increase or decrease at each time instant by learning the network condition. In order to reduce the number of ACKs appropriately, protocol adjusts the delay window (*dwnd*) dynamically based on several conditions such as the *cwnd* size, which control the transmission rate of the sender, the inter arrival time of the packets, which indicates the network congestion level and the path distance, and the packets lost event. By adjusting the delay window, the ACK will be generated by receiving the *dwnd* of packets. In this manner, the receiver will be able to adapt itself to different values of delay imposed by the wireless channel.

TCP-DAK (Delayed Acknowledgment) algorithm proposes to improve TCP performance by lowering the number of ACK. TCP-DAK maintains an ack-count variable k which counts the data packet arrivals that have not been acknowledged. This variable increases from 0 to the current value of its delay window size (*dwnd*). If data packets arrive in order, the receiver generates one cumulative ACK by delaying *dwnd* data packets. After generating an ACK the ack-count variable is reset to 0. Receiving an out-of-order packet, or a packet that fills a gap in the receiver’s buffer is a sign of packet loss, thus TCP-DAK immediately generates an ACK to inform the sender of the packet loss/recovery in a timely manner. Moreover, learning the network condition is an important factor to set the delay window. To avoid the reliance on any explicit feedback from the intermediate nodes on the path, TCP-DAK estimates the network condition by observing the inter arrival times (IAT) of the TCP packets.

TCP performance does not always benefit from delaying the ACK for the whole size of *cwnd* due to the unrestricted value of *cwnd*. In other words, in normal conditions without losses, *cwnd* can be increased to a very large value and delaying the ack for this large amount of packets may affect the performance. Thus, TCP-DAK tries to keep the *dwnd* at a proper value to gain the best performance. In TCP-DAK design, If an in-order data packet arrives before the computed expected time, no time-out will be triggered and no unnecessary ACK will be generated.

IV. SIMULATION RESULT AND DISCUSSION

The parameter settings for the simulation experiments are illustrated in Table 1. The simulation was done using NS2 simulator.

Table 1: Simulation Parameter

Parameters	Value
Simulation Area	1500*1500m²
Simulation Time	300s
Transmission Range	250m
Routing Protocol	AODV/DSR
TCP Traffic Type	FTP Generic
Packet Size	512

The performance metrics that are analyzed for evaluation include throughput, number of data packets sent by the sender and the number of back received by the sender. After extensive simulations the inferences from the simulations depict the main reasons for TCP performance degrades due to generating ack for all incoming packets.

In this paper the interaction between data packets and acknowledgment has been studied through the simulation and the simulation result indicates the performance of TCP degrades for generating ack for each incoming packet instead of that the delay the ack for all data packets using TCP-DAK.

The wireless network topology was created with sender, receiver and with lots of intermediate nodes. FTP generic is used to transfer the packet, and TCP is used to provide reliable packet delivery. The Simulation was performed in various scenarios such as normal transmission and packet loss transmission. In this paper the interaction between data packets and acknowledgment was studied in various scenarios like normal transmission and packet loss transmission.

Simulation was done for the above topology in normal transmission and the observations are as shown in Table 2. The simulations were done to analyze the ratio of data packets sent and acknowledgments received.

Table 2: TCP's Parameter Value for Normal Transmission

Data Packet Sent by Sender	Data Packet Received by Receiver	ACK only Packet sent by Receiver	Duplicate ACK Packet Received by Sender
106	101	54	46
232	223	109	89
346	335	136	111
451	439	153	121
578	561	201	155
688	669	224	172
808	784	263	203

The Graph for above topology is shown in Figure 1. The simulations were done to analyze the ratio of data packets sent and acknowledgments received. It was found that approximately for every three packets an acknowledgment was sent.

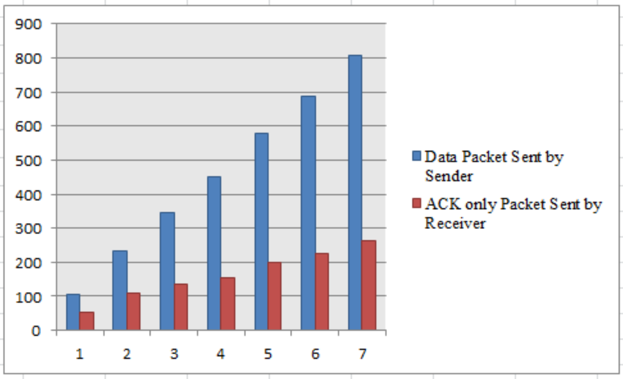

Fig: 1 TCP's Parameter Analysis for Normal Transmission

Simulation was done for the above topology in packet loss transmission and the observations are as shown in Table 3. The simulations were done to analyze the ratio of data packets sent and acknowledgments received. Manual Fault is created in the Node configuration with Static Type and analysis in performed to find the various TCP's parameters during the transmission.

Table 3: TCP's Parameter Value for Packet Loss Transmission

Data Packet Sent by Sender	Data Packet Received by Receiver	ACK only Packet sent by the Receiver	Duplicate ACK Packet Received by Sender
100	100	14	0
202	200	89	30
303	282	92	31

The Graph for above topology is shown in figure 2. The simulations were done to analyze the ratio of data packets sent and acknowledgments received. A packet loss was created by fault node configuration option in NS2. A fault was created at the interface between node and node. The time at which the fault occurs was set as 10s to 20s. Accordingly packet loss occurred at the 10s, then the number of packets sent and the acknowledgments vary depending on the duration of the fault. In this case, the number of duplicate acknowledgments also increased, and indicating that the number of retransmissions has increased.

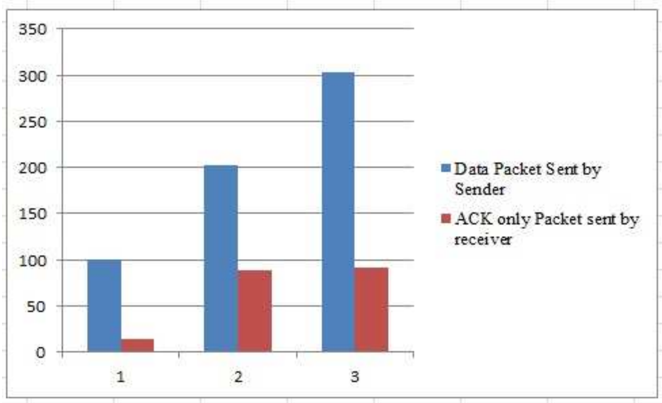

Fig 2: TCP's Parameter Analysis for Packet Loss Transmission

V. CONCLUSION

A new delayed-ACK mechanism (TCP-DAK) has been proposed to improve TCP performance over multi-hop wireless networks. Delayed ACK mechanism gains more TCP performance by dynamically reducing the number of ACKs to the minimum. The key idea of the dynamic behavior of TCP-DAK is to provide the capability to a TCP receiver to adjust itself in terms of data to ACK ratio. TCP-DAK focuses on long-path networks that are valuable for large sensor networks. TCP-DAK neither requires any change at the intermediate nodes nor expects any feedback from the network, thereby making its deployment easier.

In the future, TCP performance analysis can be done. For varying load, varying mobility, varying hop lengths and varying the packet error rate in different wireless technologies such as, 802.11, 802.15 and 802.16 using TCP- DAK.

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