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Cross Layer Design for TCP Optimization through Efficient Packet Handling Mechanism with Improved AMC in Wireless Networks

A.Manikandan, Dr.K.G.Shanthi, Venkatesh Perumal Pranay Chandragiri, B.Sai Vinoj
R.M.K College of Engineering and Technology

ABSTRACT

This paper presents a novel cross-layer technique to optimize the Transmission Control Protocol (TCP) performance in wireless networks by avoiding the bottleneck of packet losses between the network layers. The standard TCP used in wired network cannot be used in wireless networks due to the time varying nature of the channel. By considering this fact, a unique congestion control algorithm with the modified acknowledgement accumulating model is developed to circumvent packet losses and to address congestion control in the network. The proposed method utilizes the cross layer feedback from the top and underneath layers to enhance the TCP execution rather than calling on a congestion control protocol after packet loss. To optimize the TCP performance through error rate, an improved Adaptive Modulation and Coding AMC) has been used. The performance metrics used to evaluate the proposed system are end-to-end delay and end-to-end throughput with TCP Reno-2 model as simulation tool.

Keywords: TCP, ACK, cross-layer, segment error rate.

INTRODUCTION

Wireless communication occupies a preeminent place in the modern digital technological era. There is an unequaled growth of this field in recent times due to significant developments taking place in wireless networks. Wireless networks have progressively turned into a major infrastructure in building up reliable communication in the present reality applications. Transmission Control Protocol (TCP) is most preferred due to its connection-oriented, full-duplex and reliable transport features [1]. Abolhasan M et al. showed that the performance of the TCP was inefficient for wired networks. Significant research is being carried out to improve the performance of the wireless networks. Transmission control protocol is most preferred to establish a reliable transport layer protocol in wired networks. The implementation of TCP in mobile wireless communication degrades the performance [2]. This degradation in performance is due to packet losses, because of high bit error rates. The packet losses in wired communication are different from those in wireless communications. The packet losses in wired communication are due to congestion at various network nodes and routers. The Congestion control algorithms followed in wired communications are not suitable for wireless communication because of the time varying property of channels and intervention of other adjacent nodes. A revised cross-layer algorithm has been proposed for improving the TCP performance by using the data from the above and below layers. To minimize the packet losses, a cross layer algorithm with TCP and medium access control layer is developed. The TCP controls the data flow by windowing techniques and the medium access control layer adjusts the transmission power of the respective nodes in wireless networks, depending upon the channel condition and intervention. The user is given the privilege to set priorities for application thereby increasing the throughput of the application. The existing techniques allocate priority automatically. This small information by the user to the network protocol helps in increasing the throughput of the overall application.

In order to subdue the effectiveness of TCP in wireless networks, a lot of ground work was carried out. Hala Elaarag et al revealed that TCP suits best for wired network and not for wireless networks [3]. Ken, Tang et al did their ground work on studying the fairness in sharing of bottleneck for TCP performance over Carriersense Multiple Access (CSMA) and Frequency Allocation Memory Access (FAMA) [4]. This research also proved that the MAC Protocols without link loss protection breaks down the mobility factors. The researchers suggested more ground work for consistent performance of TCP and MAC layers in an Ad-hoc environment. V.Jacobson et al. elucidated that it was congestion leading to packet losses in the networks. Problems regarding the optimization based rate control for multipath sessions were also discussed [5]. High bit error rate also causes packet losses, resulting in the degradation in the transmission rate of TCP. An acknowledgement regulator comprising of radio networked controller for network models was developed by M.C. Chan et al [6]. The Radio Network Controller (RNC) is used to control the flow of acknowledgements moved between the nodes of wireless networks. The innovative idea in this proposal is to achieve maximum throughput in the downlink by controlling the number of acknowledgments sent to the client through RNC. The previous researches show that the TCP Friendly Rate Protocol (TFRC) found a better throughput result with Dynamic Source Routing (DSR) rather than Ad Hoc On-Demand Distance Vector (**AODV**)[7]. S.Pilos et al suggested a modified receiver's advertised window field in the ACKs, when the upstream and downstream in the TCP do not share a wireless medium [8]. Supporting high speed segment transmission is therefore a major challenge in network paradigm. To address congestion problem and to support high speed data transmission, it is a must to find optimum solution in the TCP environment through the parameters from lower layers. Significant research has been carried out in optimizing TCP performance by combining with Adaptive Modulation and Coding (AMC) in physical layer [9], [10] & [11]. Most of them focus on the integration to optimize the error rate in the transmission without considering the error correction or retransmission. All the previous work focus on the AMC selector or controller, the integration of TCP with AMC has not clearly justified. In this work, cross layer integration of TCP with AMC has been carried out through efficient packet handling mechanism. The rest of the paper is organized as follows: Section II deals with the proposed AMC. Section III deals with cross layer integration through efficient packet handling mechanism. Results and discussions have been presented in Section IV and followed by the conclusion.

SYSTEM MODEL WITH ADAPTIVE MODULATION AND CODING

Modulation is a process through which a carrier signal is able to deliver the message to the receiver. The essential components of modulation are amplitude, frequency and phase. Adaptive Modulation allows the system to pick the best modulation technique based on the channel conditions. The AMC selector deployed in the transmitter persistently listen to the feedback from the channel and selects the appropriate modulation to transmit the information further [13] & [14]. Based on the Channel State Information (CSI), the AMC selector applies the link adaptation to make use of the available channel capacity without wastage [15].

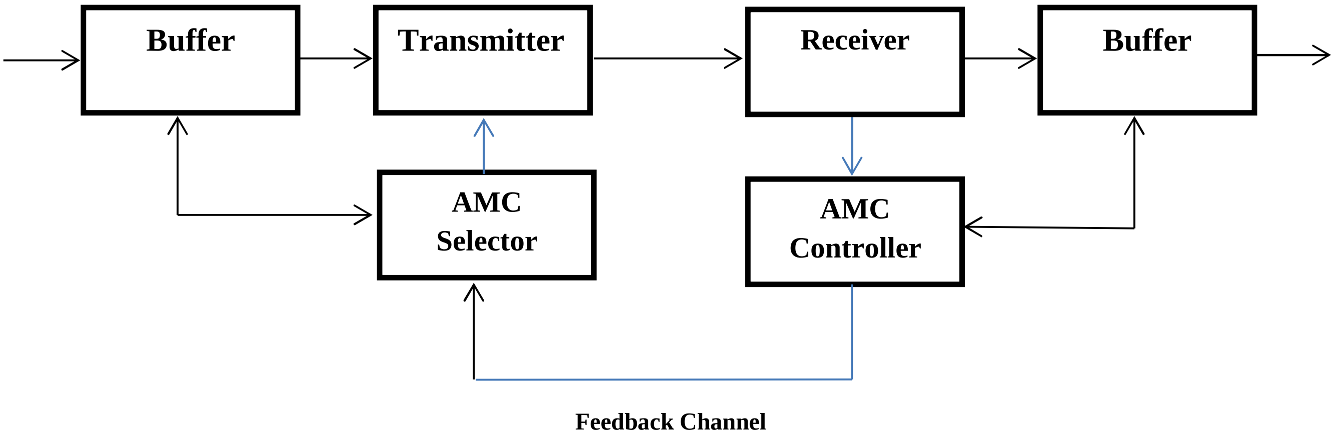

Fig.1. System Model with AMC

Figure 1 shows the simple model of AMC in cross layer design. The AMC selector adaptively learns, picks the best modulation and coding to maximize the spectral efficiency and throughput of the system. Initially, all the modulations are assigned equal probability. If 'n' number of modulations are available (as shown in Table-I) then each modulation will be allocated with a probability of '1/n'. At the end of each transmission, the AMC selector will receive the channel state information through the feedback channel thereby updating probability of each modulation [16]. Let the probability vector of AMC is $P = \{p_1, p_2 ....p_n\}$. These probability vectors of AMC will be updated at the end of each transmission as:

$$p_n(i+1) = p_n(i) + \mu\, p_n(i) \sim(i) \qquad (1)$$

Where μ is the scaling parameter and

$$\sim(i) = \frac{\eta_{req} - \eta_{av}}{\eta_{req}}$$

η_{req}- Requested throughput; η_{av} -Average achieved throughput

The algorithm needs the channel state information at each Transit time. The proposed adaptive method haphazardly selects the modulation prior to the transmission. Henceforth the probability vector is updated as an iterative process such that the probability of choosing the best modulation is maximized. Based on the received throughput and the requested throughput, the probability vector will be updated at each transit time.

TABLE-I(Traditional AMC as given in [17])

Transmission Modes in TM With convolutionally coded modulation

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
Modulation	BPSK	QPSK	QPSK	16-QAM	64-QAM
Coding Rate R_c	½	½	¾	¾	¾
R_n(bits/symbol)	0.50	1.00	1.50	3.00	4.50

PACKET HANDLING MECHANISM

The TCP model of J. Padhye et al.[18] is used in the proposed work. The Segment Transmission rate of the TCP[10] is given by,

$$B \approx \frac{1}{RTT}\sqrt{\frac{3}{2bp}} \qquad (2)$$

Where RTT is Round Trip Time; b is the number of segments acknowledged by received ACK and p is segment loss rate.

The proposed acknowledgement aggregating technique is used to improve the performance of wireless networks by reducing packet loss and shuns congestions. The state diagram for TCP packet handling mechanism is shown in Figure 2. The initial state i.e., the idle state is set for the time period when no acknowledgement is handled by the TCP [19]. On receiving a TCP acknowledgement, the current idle state is switched to acknowledgement pending state. ACK count is now incremented by one and the packet is aggregated into the ACK buffer with a header. The final packet is then calculated and the ACK timer is set up. When an additional acknowledgement is got, the ACK count is incremented by one and the acknowledgement is added to the buffer. This is similar to the preceding state. The final packet size is then computed and compared to the admissible MTU [20]. When the size of the added packet is greater than the admissible MTU, then current state is switched to the send ACK state, if not it changes to idle state. When the send ACK state is reached, the state machine settles on finalizing the added packet [21]. The size of the MTU is verified so that it does not exceed the maximum allowable MTU size. Now if the condition fails, one of the acknowledgements is discarded from the packet

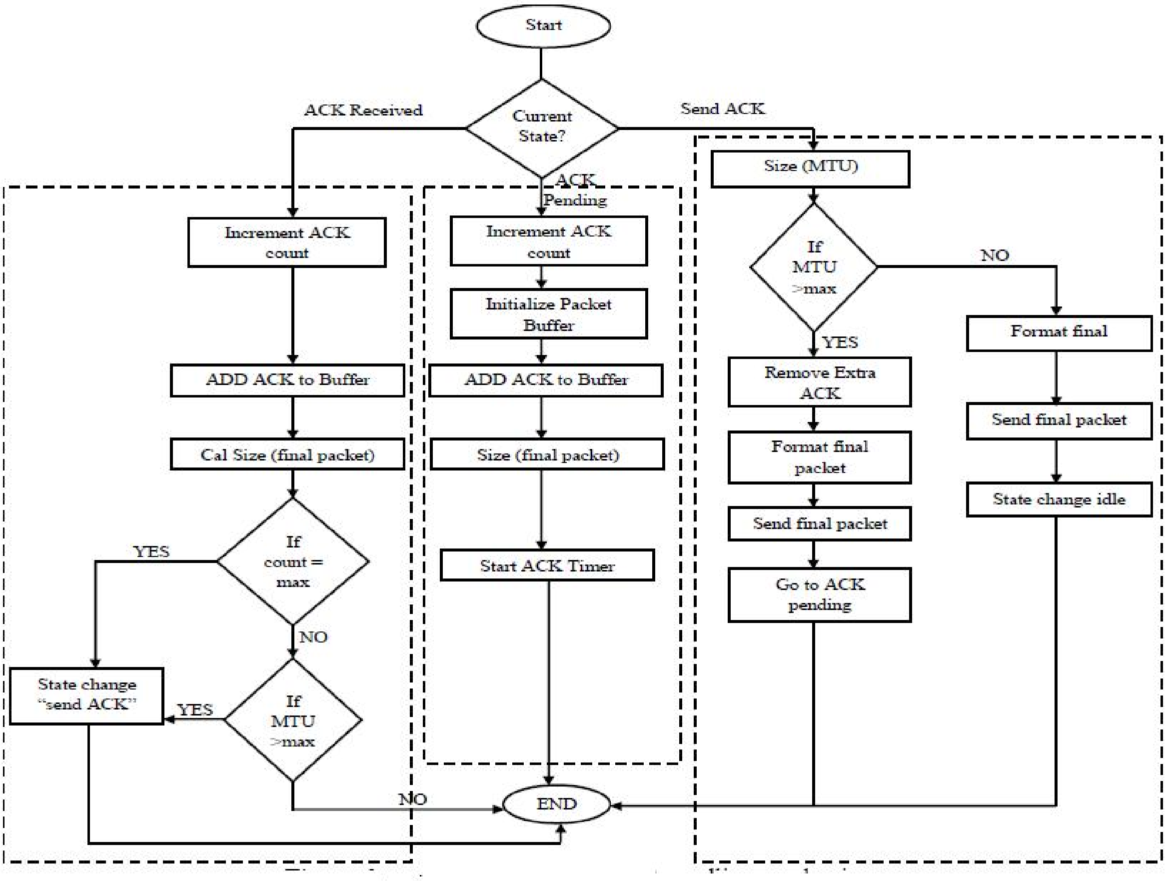

Fig.3. Flowchart for TCP packet handling mechanism

and the final packet is formatted and finalized. Now the final packet is transmitted and on receiving a new ACK, the current state is set to acknowledgement pending state and a new ACK buffer is created. If the size of MTU is verified successfully, the state machine moves directly to clinch the aggregated packet and itself sends the packet. After this, the current state is set to idle state. The flow is elucidated in Figure-3.

RESULTS AND DISCUSSIONS

All the simulations were carried out in a 3G simulation environment. The simulation results show that the proposed algorithm can provide the guaranteed QoS for the users admitted at different rates. The simulation environment is designed as two pairs of transmitters and receivers (model of TCP Reno-2) in the presence and absence of attackers.

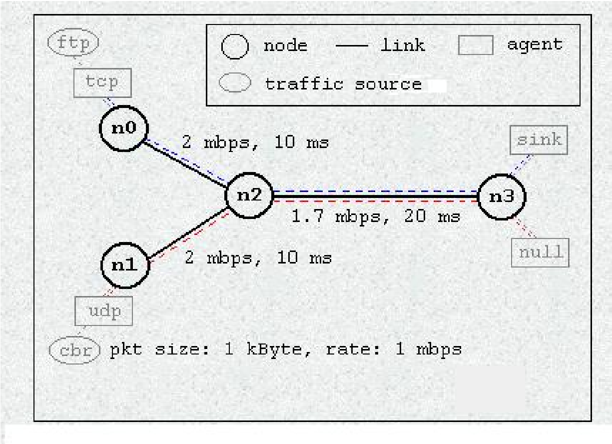

Fig.4 Topology TCP with CBR

Figure 4 is the network topology of simple TCP Reno-2 with 4 nodes. The duplex of these nodes were assigned with 2Mbps of bandwidth and 10ms of delay. A simple TCP agent is associated with node n_0 and the sink will be connected through it. This TCP generates the maximum size packet of 1kB. File Transfer Protocol (FTP) and Constant Bit Rate(CBR) traffic is assigned to the agents at regular intervals. With these specifications, the proposed TCP Reno-2 has been implemented under CBR and guaranteed conditions.

Table II Throughput of the proposed Algorithm through Reno-2

	Without SNR		With SNR	
delay	RTT(ms)	Throughput (Mbps)	RTT(ms)	Throughput (Mbps)
0	1.010	1.064	0.848	1.990
6	1.034	1.285	0.869	2.403
20	1.359	2.085	1.142	3.899
26	1.241	1.982	1.042	3.706
28	1.281	1.456	1.076	2.723
30	1.272	3.876	1.068	7.248
32	1.304	1.675	1.095	3.132
34	1.287	6.176	1.081	11.549
38	1.266	4.234	1.063	7.918
45	1.354	5.246	1.137	9.810

Table I shows the throughput comparison of proposed cross layer design with the existing system. From the table, it is clearly observed that the RTT has been extended beyond the tolerance level of 1.3ms, which minimizes the throughput. The proposed packet handling mechanism minimizes the RTT with the optimized SNR through AMC. At the end of each transmission, the AMC selector will select the best modulation and coding with maximum SNR which reduces the RTT.

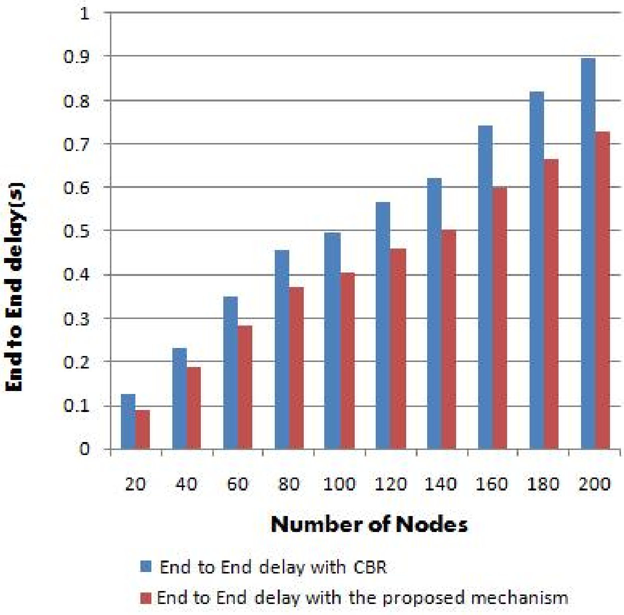

Fig.5 Number of nodes Vs End to End delay

From figure 5, it is apparent that the proposed algorithm has minimum delay even with maximum number of nodes. The proposed packet handling mechanism turns down the End to End delay to 71% from the CBR (without SNR).

CONCLUSION

This paper elucidates a well organized and competent cross layer design to maximize the throughput of the system. Simulations were carried out to examine the congestion control with the improved packet handling mechanism. The simulation environment was developed with the presence and absence of attackers. From the results obtained, it is clearly apparent that the proposed cross layer design optimizes the end to end delay and throughput of the system. Thereby all the users can provide the fair Quality of Service as requested.

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