International Journal of Science and Modern Engineering (IJISME)
ISSN: 2319-6386, Volume-2 Issue-1, December 2013

TFRC for Congestion Control in Wireless Environment

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Abstract: Real Time Applications (RTAs) have stringent requirements. Congestion in the network results in packet loss, delay and reduction in throughput which are not tolerable by RTAs. Proper congestion control mechanisms are necessary for RTAs. TCP provides congestion control mechanisms. But it is a protocol which is designed for wired networks. TCP treats packet loss as an indication of congestion which is not true in wireless networks. In wireless networks packets may be lost due to various other reasons. UDP has no congestion control mechanisms and is not good for the stability of the Internet. TCP Friendly Rate Control (TFRC) protocol is designed by Internet Engineering Task Force (IETF) especially for RTAs. This paper studies the performance of TFRC, TCP and UDP in wireless environment.

Index Terms- Real Time Applications, TFRC, TCP, UDP.

I. INTRODUCTION

TCP [1] is important protocol in the TCP/IP protocol stack. It is a very robust protocol, tuned to wired networks. TCP permits reliable transfer of byte stream between two processes running on two different computers. Internet meltdown in 1986 has motivated the introduction of congestion control mechanisms into TCP. TCP treats packet loss as an indication of congestion and to recover from congestion it decreases the data rate. Wired networks are reliable and probability of packet loss due to other reasons is negligible. This is not the case with wireless networks where the packets are dropped due to various other reasons.

There are two modes of operation of wireless networks: infrastructure mode and adhoc mode. In infrastructure mode of operation, wireless nodes communicate with the access point.All the communication between the devices is via the access point and no direct communication between the nodes takes place. In adhoc mode of operation there is no access point and nodes have to communicate directly. If the nodes are in the direct communication range of one another then source node directly communicates with the destination node. If the nodes are not in the communication range then communication takes with the help of other nodes resulting in multihop routing. A node in adhoc network acts both as a router and a host.

Some of the characteristics of wireless networks are:

- High error rate
- Low bandwidth
- Variable bandwidth
- Dynamic nature of the nodes
- Unfavourable environmental conditions
- Battery operated nodes

Manuscript received December, 2013.

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Due to all these characteristics use of TCP directly will deteriorate its performance. TCP guarantees reliable delivery of data and also guarantees that packets will be delivered in the same order in which they were sent. This results in lot of overhead which is not tolerable for many applications. Applications that do not require the reliability of a TCP connection may instead use the connectionless UDP, which emphasizes low-overhead operation and reduced latency. UDP has no congestion control mechanism and it may result in instability in the network.

TFRC [2] [3] is a congestion control mechanism designed for unicast flows operating in an Internet environment and competing with TCP traffic. TFRC is designed to be reasonably fair when competing for bandwidth with TCP flows, where a flow is "reasonably fair" if its sending rate is generally within a factor of two of the sending rate of a TCP flow under the same conditions. However, TFRC encompasses a much lower variation of throughput over time compared with TCP.

TFRC mechanism works as follows:

- The receiver calculates the loss event rate and the received rate, then inform it to the sender in a feedback message.
- This feedback to the sender besides the loss event rate and the received throughput includes the echoed timestamp of the last data packet and a delayed time between the arrival of the last data packet and the generation of the feedback. These last two parameters are necessary to calculate the round trip time (RTT) at the sender.
- The feedback packets are sent at least each round trip time or immediately after a new loss event rate is detected (without waiting one RTT).

II. RELATED WORK

Bin Zhou and Cheng Peng Fu [4] develop the Reno equation with the Veno equation, which is derived from the throughput model of TCP Veno, to enhance TFRC performance over wireless networks. In wireless networks TFRC is same as TCP Reno, and suffers significant performance degradation. So, they modify TFRC by replacing the Reno equation with the Veno equation, which only modifies TFRC on the sender side, that is, the sender now adjusts its sending rate based on the following equation:

$$X\_calc = \frac{s}{RTT \cdot \left[\sqrt{\frac{2b(1-\gamma)\cdot p}{1+\gamma}} + \left(12 \cdot p \sqrt{\frac{b(1-\gamma^2)\cdot p}{2}} \cdot p \cdot (1+32 \cdot p^2) \right) \right]}$$

Here γ is in the range [0.95, 0.5].

This new equation is directly derived from the modelling of the wireless TCP rather than the wired TCP.

Their simulation results indicted the TFRC Veno has a good fairness than TFRC and TFRC Veno. They concluded that the TFRC Veno can improve TFRC performance significantly over wireless networks for multimedia transmission.

Christos Bouras, Vassilis Papapanagiotou, Kostas Stamos, Giannis Zaoudis [5] present the TFRC protocol in the area of efficient wireless video transmission and its possible usage in cross-layer power management mechanisms. The basic aspects of TFRC operation are presented, along with the suitability of TFRC usage for video transmission. They significantly improve both the objective quality of the transmitted video, and make a more optimal usage of available power. They use cross-layer optimization techniques to improve quality and reduce power consumption.

III. PERFORMANCE METRICS

Packet delivery ratio: The ratio of total number of packets successfully received by the destination nodes to the number of packets sent by the source nodes.

End-to-End delay: The average delay of all the packets while travelling from source node to destination node.

Packet loss ratio: The ratio of number of lost packets to the sum of number of packets received and number of lost packets.

IV. SIMULATION ENVIRONMENT

The network simulator NS-2, version 2.34 is used for simulation. NS2 [6] is an event driven simulation tool that has proved useful in studying the dynamic nature of communication networks. NS-2 supports TCP, UDP traffic with FTP, CBR and Telnet applications. In wireless environment, the mobility of the nodes is created using random way point model in a rectangular field of 1000 x 1000 sqm. A node chooses its initial position randomly, chooses the next position also randomly and moves towards it with chosen speed and pause time. In this simulation different pause times and speeds are used. Pause time is the amount of time a node remains stationary at a fixed position before moving from that position. A pause time of zero means continuous movement and a pause time equivalent to simulation time means node is static. Traffic models supported by NS2 are used to generate the traffic. Simulation time is restricted to 100sec. Post processing of the trace files generated by NS2 is done using awk scripts.

V. RESULTS AND ANALYSIS

In this, we compare the performance of TCP, UDP and TFRC using Packet delivery ratio, End-to-End delay and Packet loss ratio.

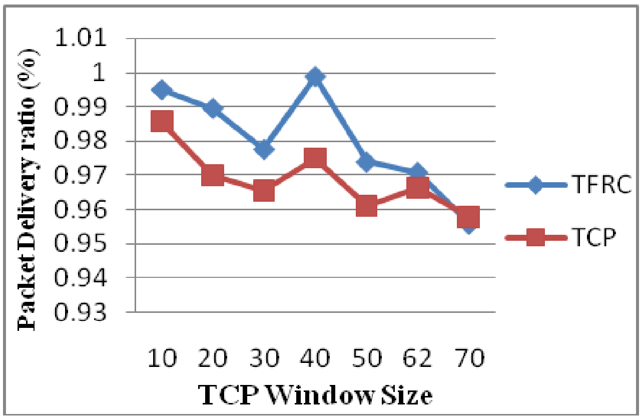

Figure 1: Packet Delivery Ratio of TFRC and TCP with 14 nodes

Figure 1 shows, the packet delivery ratio of TFRC is more than the TCP. Number of nodes is set to 14 and TCP window size varied from 10 to 70.

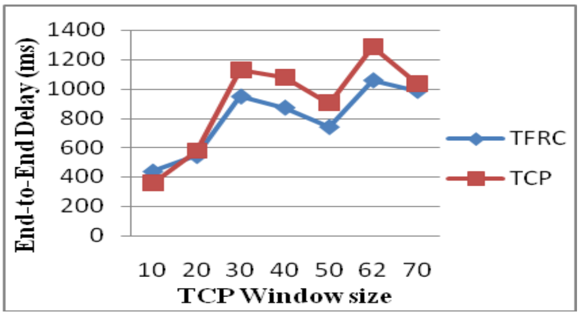

Figure 2: End-to-end delay of TFRC and TCP with 14 nodes

The result shows, the end-to-end delay of TFRC is less than the TCP. The TCP window size and TFRC rate are increased simultaneously for allowing same sending rates.

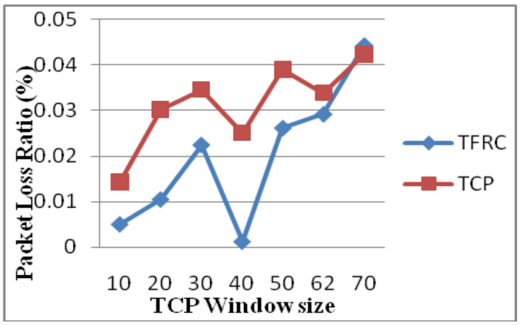

Figure 3: Packet Loss Ratio of TFRC and TCP with 14 nodes

Figure 3 shows the packet loss ratio of TFRC is less than the TCP.

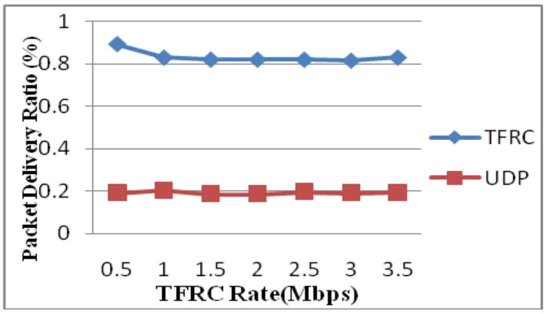

Figure 4: Packet Delivery Ratio of TFRC and UDP with 14 nodes

Figure 4 shows, the packet delivery ratio of TFRC is more than the UDP. The TCP window size and UDP rate are increased simultaneously for allowing same sending rates.

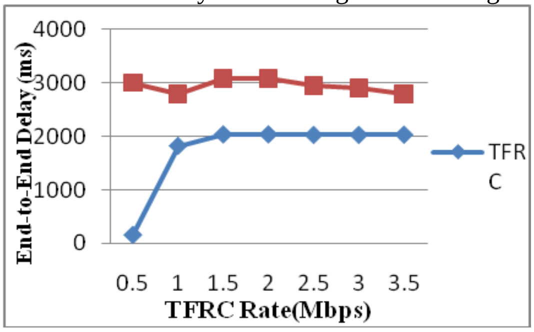

Figure 5: End-to-end delay of TFRC and UDP with 14 nodes

The result shows, the end-to-end delay of TFRC is less than the UDP. The UDP rate and TFRC rate are increased simultaneously for allowing same sending rates.

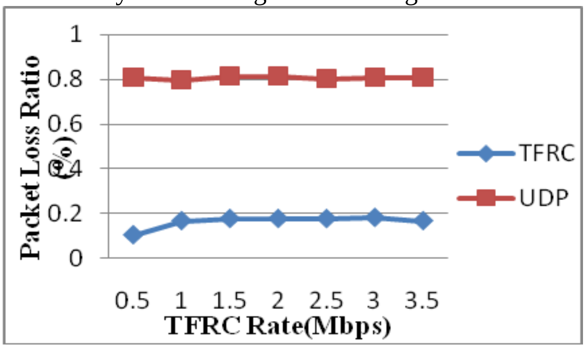

Figure 6: Packet Loss Ratio of TFRC and UDP with 14 nodes

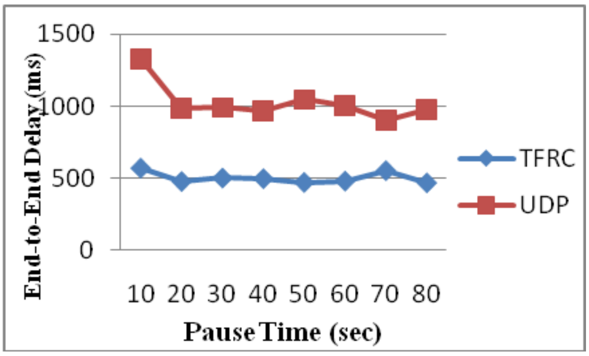

Figure 7: End-to-End Delay of TFRC and UDP with 6 nodes at varying Pause Times in Wireless Environment.

Figure 7 shows, the end-to-end delay of TFRC is less than the UDP at varying pause times. Number of nodes is set to 6, TFRC rate is set to 1Mbps and UDP rate set to 1Mbps and speed is set to 10 m/sec.

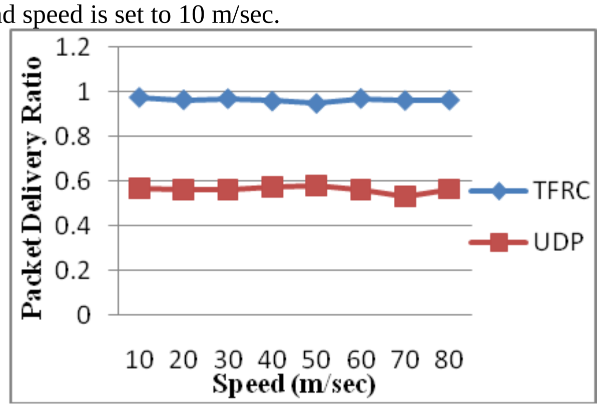

Figure 8: Packet Delivery Ratio of TFRC and UDP with 6 nodes at varying Speeds in Wireless Environment.

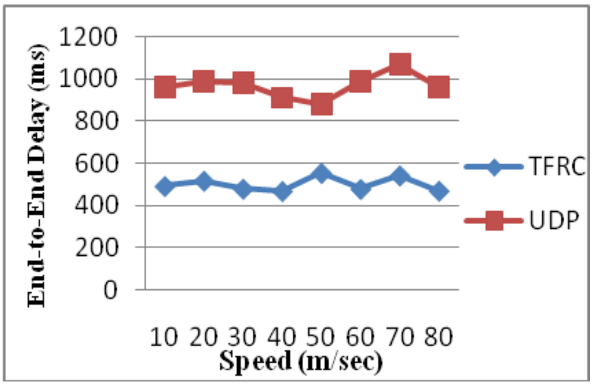

Figure 9: End-to-End Delay of TFRC and UDP with 6 nodes at varying Speeds in Wireless Environment.

Figure 8, Figure 9 shows the performance comparison of TFRC and UDP. Number of nodes set to be 6, pause time set to be 10 and speed varied from 10 to 80.

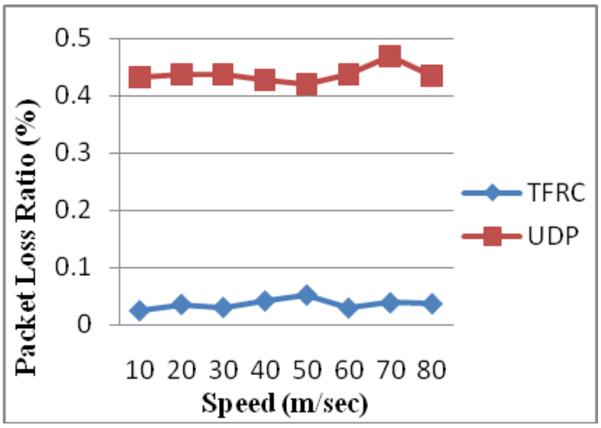

Figure 10: Packet Loss Ratio of TFRC and UDP with 6 nodes at varying Speeds in Wireless Environment.

Wireless Environment – Static nodes

Table 1 shows the performance of TFRC and TCP.

TFRC rate (Kbps)	TCP Window size	TFRC		TCP	
		Sent	Received	Sent	Received
161	10	4026	4025	4022	4021
162	20	4061	4055	4046	4045
163	30	4039	4036	4071	4068
164	40	4066	4060	4096	4093
165	50	4078	4058	4122	4121
166	60	4110	4104	4146	4146
167	70	4089	4059	4172	4170

Table 1: Performance of TFRC and TCP

In this work, pause time is set to 2 sec, speed is set to 10 m/sec, TCP window size and TFRC rate is increased substantially for same data rates.

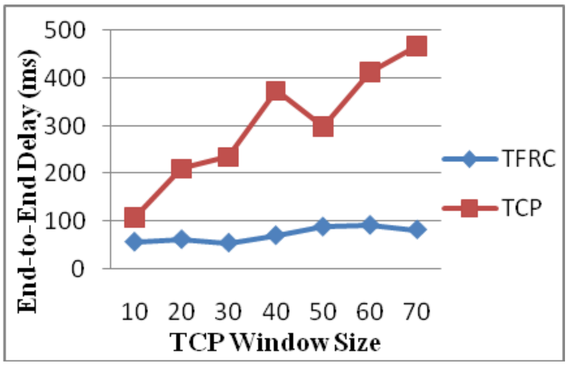

Figure 11: End-to-end delay of TFRC and TCP with 6 nodes

The result shows, the end-to-end delay of TFRC is less than the TCP. The TCP window size is varied from 10 to 70 and number of nodes is set to 6.

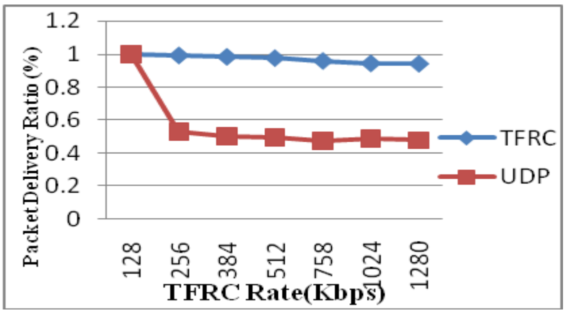

Figure 12: Packet Delivery Ratio of TFRC and UDP with 6 nodes

Figure 12 shows the packet delivery ratio of TFRC is more than the UDP.

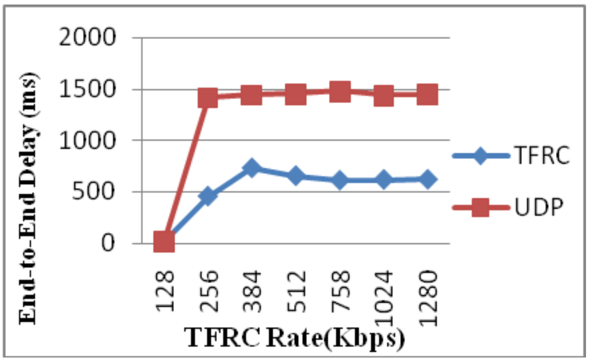

Figure 13: End-to-end delay of TFRC and UDP with 6 nodes

The result shows, the end-to-end delay of TFRC is less than the UDP. The UDP rate and TFRC rate are increased simultaneously for allowing same sending rates.

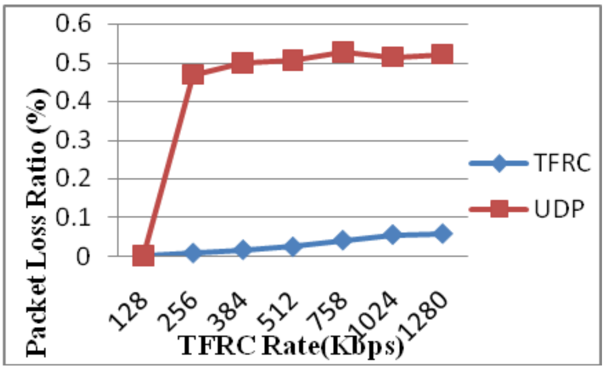

Figure 14: Packet Loss Ratio of TFRC and UDP with 6 nodes.

Figure 14 shows, the packet loss ratio of TFRC is less than the UDP.

VI. CONCLUSION

In this paper performance of TFRC is compared with both TCP and UDP in wireless environment. TFRC performance is found to be better than both TCP and UDP. TFRC is fair with TCP and TFRC outperforms UDP. This indicates that TFRC has the congestion control mechanisms and it competes with other data flows. If other flows also use congestion control mechanism then it is fair with other flows, otherwise if the other flows are aggressive then it prevents the other flows from capturing its share of the bandwidth.

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