Study of performance of regular TCP in MANETs (using simulator)

Course: Mobile Computing (CS 653)

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Introduction

In mobile ad hoc networks (MANET), TCP performance is not as stable as in wired networks. Various wireless ad hoc network characteristics not found in wired networks - node mobility, Unpredictable radio medium, external interference/jamming and multiple access contention - create a host of problems not all of which can been satisfactorily solved. Among them, frequent link breakages due to mobility are one of the major factors degrading TCP performance. Three different types of challenges are posed to TCP design by wireless ad-hoc networks.

1. First, as the topology changes, the path is interrupted and TCP goes into repeated, exponentially increasing time-out with severe performance impact.

2. The second problem has to do with the fact that TCP performance in ad hoc multihop environment depends critically on the window in use. If the window grows too large, there are too many packets (and ACKs) on the path, all competing for the same medium. Congestion builds up and causes “wastage” of the broadcast medium and severe throughput degradation.

3. The third problem is due to the interaction of the 802.11 MAC layer protocol, more precisely, the hidden terminal problem and binary backoff scheme etc., with the TCP window mechanism and time out. This TCP/802.11 interaction causes unfairness among competing TCP flows and (in extreme cases) “capture” of the channel by a few flows.

Problem Definition

Study of performance of regular TCP in MANETs (using simulator)

The performance of TCP in terms of following parameters was studied:

- Variation of Throughput in wireless (Static MANET) and wired Network
- Variation of Throughput with respect to mobility and its reaction to different Routing protocol.
- Variation of Throughput with respect to multiple hop count.
- Variation of Throughput and fairness with different flow channel.
- Variation of Good put with respect to different TCP variant.
- Variation of Throughput with respect to TCP window Size.

Experimental Setup

For above mentioned experiments a standard Qualnet 4.5 wireless simulator was used . For the evaluation of the different experimental performance of the TCP over MANET , different topologies, different node count, different network parameter were used with respect to objective evaluation.

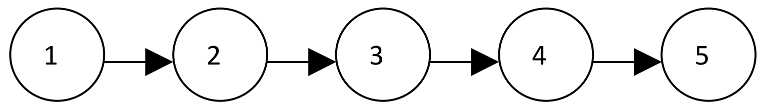
General experimental setup:

- The scenario size = 3000 m X 1500 m
- The TCP variant = TCP Tahoe (Default)
- Routing protocol = DSR
- Noise factor = 0
- Path loss = Free Space
- # of hop count and # of Nodes varying according to experiment requirement.
- Distance between two nodes 300 to 350 m.

Experimental setup used for different objective evaluation as elucidated below:

1. **Variation of Throughput in wireless (Static MANET) and wired Network**

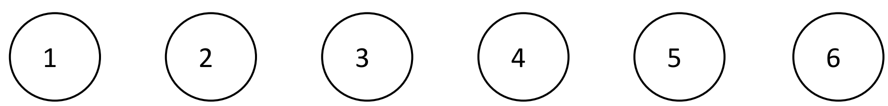
For evaluation of standard TCP for the MANET, a wired TCP connection for 5 nodes was setup using FTP application. The data rate was setup at 2 Mbps with 1 ms delay, with RIP routing protocol. The simulation was run for 100 second and very high number of source packets used. The application from node one was given explicit link to node 2, node 3, node 4 and node 5.



For the wireless MANET , 5 GSM nodes were take with data rate 2 Mbps, with DSR as the routing protocol .An FTP server was setup at node one and each other node ranging from 2 to 5 were given explicit connection. For both setup we used the TCP Tahoe. The RTS threshold was taken as zero and hence for every packet sent there was RTS associated with it.

2. Variation of Throughput with respect to mobility and its reaction to different Routing protocol.

In this experiment, The throughput of traffic for FTP transfer was analyzed as function of mobility of the nodes with different routing protocols were conducted. The routing protocol selected were DSR and AODV and the throughput of the traffic was analyzed for the following mobility with mean speed of 2,5,10,15 m/s. In order to analyze the results in a better way the mobility was enabled using random waypoint model with 10 s pause for node 2, node 5 and node 6 . The rest were made static for the entire simulation time of 100 seconds.



The implicit parameters used for different routing protocol are

DSR: The max buffer packets was setup to 50

AODV: The max hop count was set as 35. The node traversal time was set to 40ms and route time out as 3 s . The hello packets were send at 1 s interval . Max buffer packets were set as same as of DSR i.e. 50

3. Variation of Good put with respect to different TCP variant.

Goodput is defined as the numbers of packets send without errors (retransmission) to respective destination. The goodput with respect to different TCP variants were analyzed during with the help of this setup. For the same node configuration as in 2.2 with AODV routing protocol and the same setup, different simulation was conducted over TCP RENO, TCP LITE and TCP SACK with respect to mobility.

4. Variation of Throughput with respect to TCP window Size.

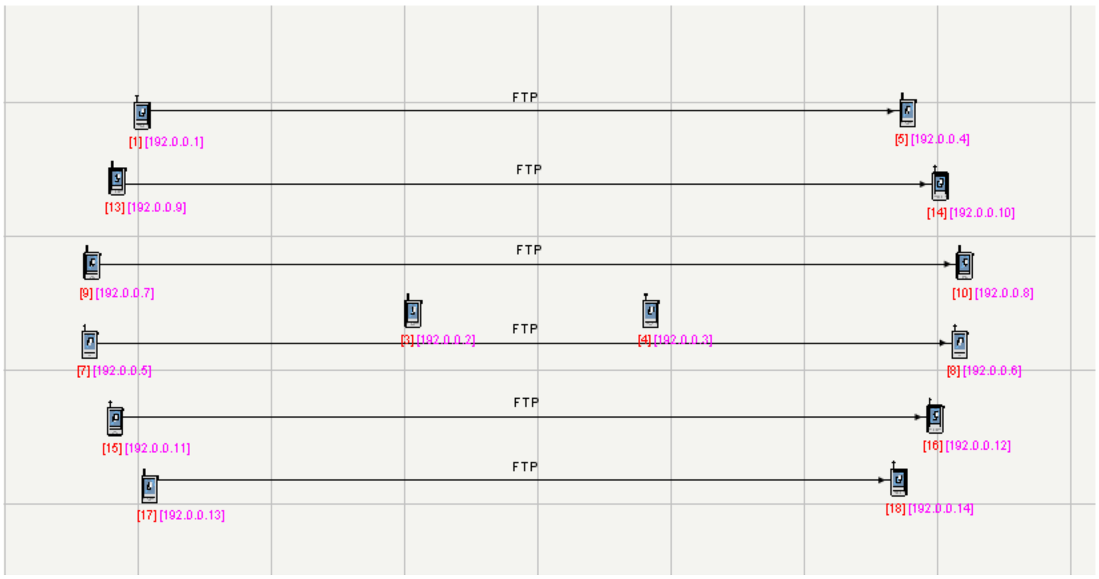
To show this, 6 nodes were taken and data rate was 2Mbps run over FTP application. The routing protocol used was AODV with the same configuration as 2.3 . The send and receive buffer size was modified to change the TCP window size. The window size was varied from 2 – 40 packets and simulation was run for each of the scenario. The packet size was setup at constant of 512 bytes. The rest of the parameters of simulation were same as that of the experiment setup 3.

5. Variation of Throughput with respect to multi-hop network of varying length.

TCP throughput is usually less than optimal/expected due to sender's inability to accurately determine the cause of a packet loss. Here we simulate a static network of 8 nodes which form a linear chain of 7 wireless hops. The data rate is fixed at 2 Mbps and the DSR routing protocol is employed. The rest of the parameters were kept the same. A FTP application is run between the two nodes at the two ends of the linear chain and TCP throughput is measured between these nodes. Finally we represent the measured throughput as a function of number of hops.

6. Fairness issue in the wireless medium and degradation of the throughput.

TCP takes care of the fairness with the different protocols implemented at MAC layer but as we don’t have the wired MAC layer in the wireless domain, the wireless transmission of the packets the flows are not having fair chance to send the data packets. So we have simulated this scenario by having two intermediate nodes which are responsible for sending the all the traffic from one side to the other side. And all the sending nodes as well as the receiving nodes are only one hope away from the two intermediate nodes.

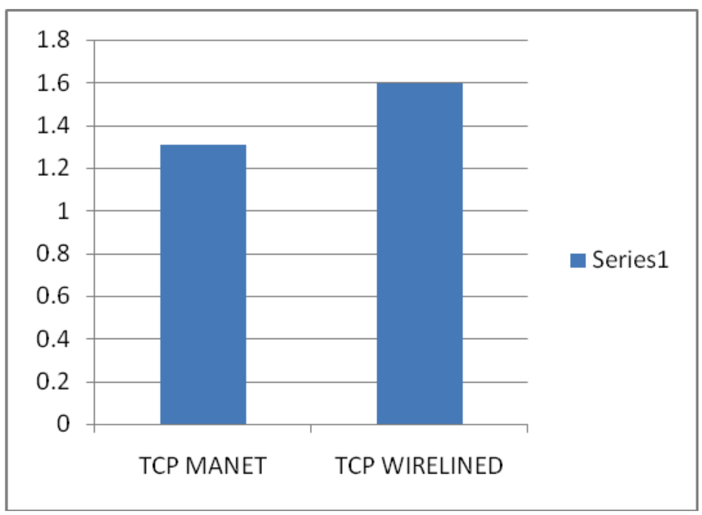


Results

The result for various experimental setups mentioned in section 2 is outlined below:

1. Variation of Throughput in wireless (Static MANET) and wired Network

The throughput (in Mbps) of the wireless MANET is reduced, this is because in the MAC layer when the sender(other than node 1) in the intermediately stage sense the medium before sending , it would find that medium is busy and it would go on incremental back off. Unlike in the wire lined structure the medium is very scarce resource and there will contention for accessing the medium always. Now as the back off value increases the TCP of the original sender would undergo a RTO, TCP window size will be reduced. Thus reducing the throughput.



Wireless and wired TCP comparison

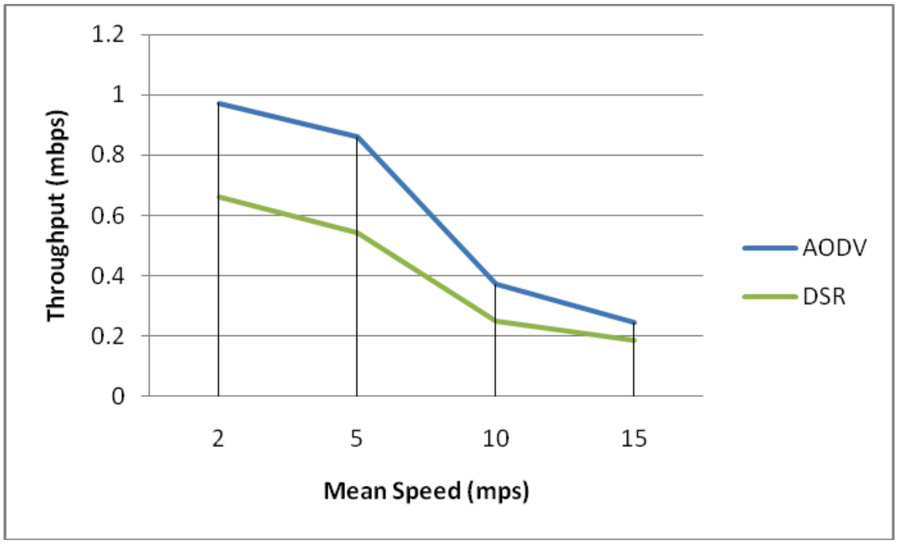
In wire lined structure where there is no congestion, as in this case, the Node 1 is able to send all its data to node 5. There is no intermediately media access contention as in the wireless case. And hence the throughput is high with respect to the same topology in the wireless scenario. This experiment was done to show that in MANET with static nodes, there is reduction in throughput. Now we proceed to experiments where mobility plays a great role in throughput.

2. Variation of Throughput with respect to mobility and its reaction to different Routing protocol.

We investigate the performance of TCP of various routing protocols for mobile ad hoc networks. The routing protocol can be proactive or reactive based on the route discovery. If its proactive then there is route setup to the destination all the time but in reactive case , the route is set up only when the need arises . There are numerous evidence which suggests that reactive protocols work better than proactive protocols this is because of the mobility factor and route is discovered on demand basis which would be more accurate but this causes an overhead.

Destination Source Route (DSR) is composed of two entirely on-demand mechanisms: Route Discovery and Route Maintenance. When a source node wants to send packets to a destination, and a route is not available in its cache, it initiates a Route Discovery by broadcasting a route request. Upon receiving a route request, a node sends a route reply to the sender if a route to the destination is available in its cache; otherwise, it adds its address to the source route in the packet header and re-broadcasts the route request. When the route request eventually reaches the destination, it sends a route reply to the source containing the route from the source to the destination. A connection is thus established and all subsequent packets contain the complete route in the packet header. No routing information is maintained at the intermediate nodes. In Route Maintenance, when the data link layer at a particular node encounters a transmission failure, it issues a route error notification to the source and a new route search is initiated.

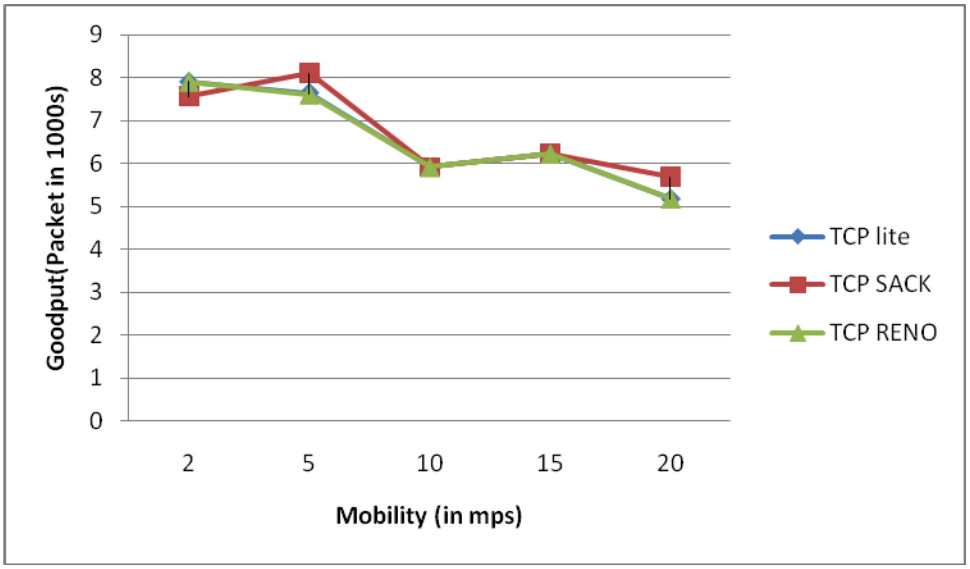
Ad-Hoc On-demand Distance Vector routing (AODV) algorithm borrows its salient features from DSR and DSDV. When a source needs a path to the destination, it broadcasts a route request until it reaches a node that has a route to the destination. A route reply generated by the destination propagates along the reverse route and establishes the forward route information at the intermediate nodes. Each node records only the next hop for a destination and not the entire route as in DSR. Failure of a link can be detected via hello messages or link layer detection. When a link fails, the upstream nodes are notified of the failure and the destination is marked as unreachable in the routing tables of these nodes.



As per the evidence given in [**2**], the DSR should work in a better way for TCP as its on demand protocol and proactive protocol like AODV should suffer when the node mobility increases , otherwise it would be the same . But we came to know that to , contrary there AODV performed better than DSR in all cases. In the initial phase when the mobility is low , throughput is reduced because the route has to setup for every transmission in DSR but in AODV each node keeps the next hop destination and linkage is checked throughout using hello packets . But in DSR during medium and high mobility case, there are stale routes because of route caching and this is not detected until the packet arrives whereas in AODV the next hop is still maintained using hello messages and the probability of not going traversing a wrong route compared to DSR is less , which would save RTO of TCP and thus an increased throughput .

3. Variation of Good put with respect to different TCP variant.

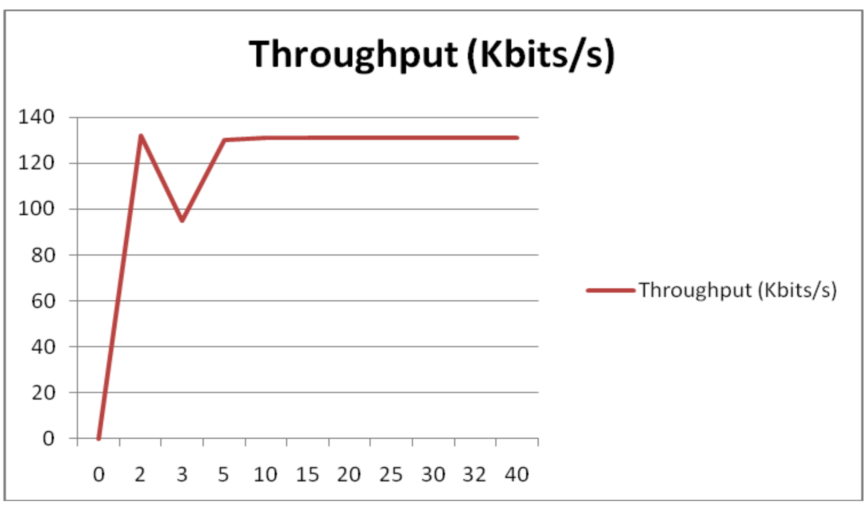
3 Different variants of TCP were taken, namely TCP RENO, TCP Lite, TCP SACK. TCP SACK was designed to work in multiple segment loss and the sender retransmit only those segments which have been lost . In highly mobile environment, multiple packets will be lost due to intermediary node mobility and from the result it is seen that if such a mechanism exist like in SACK for selective acknowledgment of the packets that’s been received, it would be better.



SACK works on par with Lite and Reno on low mobility but slightly performs better in highly mobile case.

4. Variation of Throughput with respect to TCP window Size.

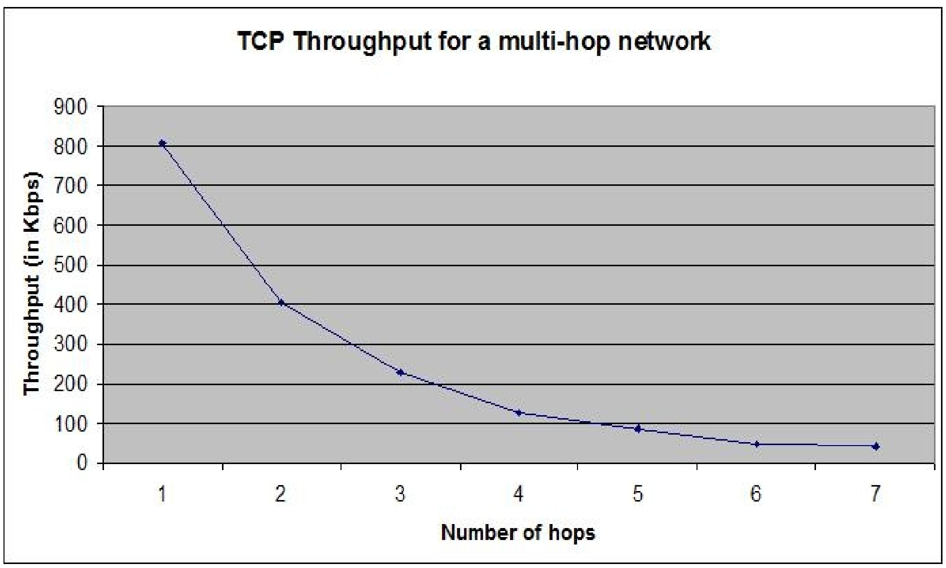
According to [3] there is maximal throughput at hop count/4 window size after that it would reduce and then increase to become a saturated value. The same is shown below, For a 4 hop network the throughput increases and become constant.



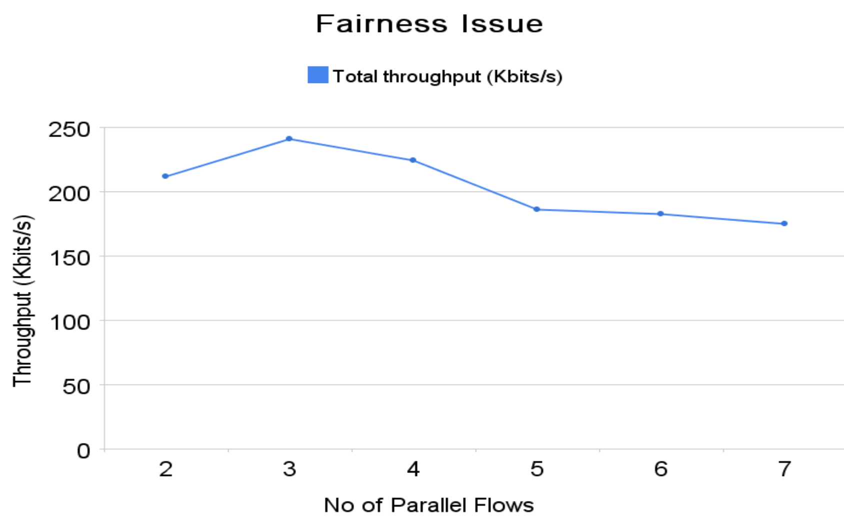
The throughput becomes constant after a particular window size because there are many in flight packets in the network and because of contention in between network the TCP suffers because of time outs and hence the throughput cannot be increased beyond that point.

5. Variation of Throughput with respect to multi-hop network of varying length.

Using the experiment setup described earlier, the simulation was performed and the throughput was calculated between the end nodes of the chain. Then the measured throughput was shown as a function of number of hops. As we can observe from the graph below, the throughput rapidly decreases when the no. of hops is increased from 1 and then saturates once the no. of hops is quite large. We can clearly see that multi-hop connections are at clear disadvantage with respect to single hop network. In case of channel contention the multi-hop connection mostly gets zero throughput. Our findings confirm the fact that end-to-end TCP throughput drops very rapidly as path length increases.



6. Fairness issue in the wireless medium and degradation of the throughput.



When we start the simulation it shows that some of the nodes capture the medium for some time and starts sending the data. While others go in random back-off. So the throughput of each flow is different from the other.

And we have also visualized that up to some limit the increase in flows the throughput is increasing and after some limit as the numbers of flows are increasing so because of the collision in the wireless medium the throughput is constantly decreasing.

Conclusion

TCP is a connection oriented and reliable system in wired architecture but is not a viable option in MANET where mobility and multi-hop communication plays an important role. Due to high mobility, the predictability of TCP is not ensured. For a packet loss scenario, which is common in wireless network, TCP would react in the same manner as though it is a congestion related problem. This would reduce the throughput as shown from our experimental results. Similarly in multi-hop communication, due to intermediary MAC contention for medium, the throughput of the TCP suffers due to frequent timeouts. Different existing variants of TCP were also unable to solve the problem of mobility and thus increase the throughput as shown by our experiments. Also, TCP fairness is highly affected in case of multi-hop networks as seen from our results. On single hop, TCP fairness remains unchanged. But as number of hops or number of flows increase, one of the flows captures the maximum share of the network bandwidth while other flows are starved. This unfairness results from the nature of the shared wireless medium and location dependency. When the TCP fairness is reviewed when the number of flows are increased to certain flows the through put is increased and then after the throughput decreases. In case of multi-hop mobility, the throughput reduces further and approaches almost zero.

References

[1].Z. Fu, P. Zerfos, H. Luo, S. Lu, L. Zhang, and M. Gerla, “The *impact of multihop wireless channel on TCP throughput and loss*”, in Proc. of IEEE INFOCOM, San Francisco, USA, Apr. 2003.

[2].A. Ahuja, S. Agarwal, J. P Singh, R. Shorey. “*Performance of TCP over different routing protocols in mobile ad-hoc networks”.* In in Mobile AdHoc Networks”, in IEEE VTC 2000.

[3].S Papanastasiou, M Ould-Khaoua, L Mackenzie. “*On the evaluation of TCP in manets*”. Proceedings of the International Workshop on Wireless Ad Hoc , 2005.

[4]. Kaixin Xu, Sang Bae, Sungwook Lee, Mario Gerla - “*TCP behavior across multihop wireless networks and the wired internet”* International Workshop on Wireless Mobile Multimedia. Proceedings of the 5th ACM international workshop on Wireless mobile multimedia, Pg 41-48 , 2002

[5]. G Holland, N Vaidya. “*Analysis of TCP Performance over Mobile Ad Hoc Networks”*. Wireless Networks, Springer.pp 275-288, Volume 8, Numbers 2-3 / March, 2002.