

## An Interaction between Congestion-Control Based Transport Protocols and Manet Routing Protocols

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**Abstract: Problem statement:** Although many efforts have been done on studying the behaviour of TCP in MANET, but the behaviour of TFRC remain unclear in MANET. The purpose of this research is two folds. First, we studied the behaviour of TFRC and TCP over AODV and DSR as the underlying routing protocols in terms of throughput, delay and jitter. The second objective was to identify whether MANET routing protocols have an impact on transport protocols or not. **Approach:** Network Simulator 2 (NS-2) was used to conduct all of the experiments, i.e., TFRC over AODV, TFRC over DSR, TCP over AODV and TCP over DSR. We created 30 nodes on a 1000×1000 m location area and each node was assigned CBR traffic, transport protocol and routing protocol. In order to simulate the nodes mobility, we implemented a Random Waypoint mobility model with varying speeds of 5, 10, 15 and 20 m sec<sup>-1</sup> (m/sec) with a 10 sec pause time. **Results:** We observed that TFRC throughput increases almost 55% when using DSR as its routing protocol, but TCP throughput has no significant difference with different underlying protocols. However, in terms of jitter and delay, both routing protocols, i.e., AODV and DSR have the impact of more than 50% on TFRC and TCP. **Conclusion/Recommendations:** The results obtained also show us that TFRC or TCP should choose AODV as its routing protocol because it has less jitter which is one of the critical performance metrics for multimedia applications.

**Key words:** MANET, AODV, DSR, TFRC, TCP

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### INTRODUCTION

Since the introduction of cellular technology, which was called first generation or 1G, it has now gone through tremendous enhancements till the birth of 4G. The evolution of wireless or cellular technology could be divided into three phases (Mohapatra and Krishnamurthy, 2004). First, cellular technology was mainly used for basic communications such as voice calls and short messaging system. The prime objective was to have mobility where people can communicate anytime and anywhere. The rise in Internet services influenced the second phase of wireless technology. People started to have Internet connection while on the move where they can read and reply to email instantaneously and browsing their favorites websites. In the third wave of wireless evolution which is known as Ad Hoc networking, the primary aim was to set up communications for specialized, customized, extemporaneous applications in areas where there is no preexisting infrastructure, damaged infrastructure or for the emergency situations.

A wireless mobile network can be broadly categorized into infrastructure based with central administration and distributed coordination function without a central administration. The Mobile wireless Ad hoc Network (MANET) falls under the latter category which is a self-organized and dynamically reconfigurable wireless network of mobile nodes. MANET is a group of wireless mobile devices that connect to each other using wireless channel (Boukerche, 2009), forming a temporary network without the aid of a fixed infrastructure (Sarkar *et al.*, 2007). MANET represents a complex distributed system that can freely and dynamically self-organizes (Aggelou, 2005).

All nodes in MANET may utilize TCP or UDP as their transport protocols depending on the types of applications. However, TCP has undergone several enhancements to make it suitable for working in the wireless environment. A comprehensive survey of TCP enhancement in wireless networks can be found in the article by (Hanbali *et al.*, 2005). Unlike TCP, which adjusts the sending rate according to the traffic, UDP is considered as a greedy protocol. Thus, some still

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consider TCP to carry their multimedia traffics (Wang *et al.*, 2004) in order to maintain the stability of the Internet. However, multimedia applications carried over TCP suffer from low quality of service since TCP does not reply smoothly in the dynamic changing of networks especially in a wireless environment.

In response to the problems of TCP and UDP, a new transport protocol was proposed by the Internet Engineering Task Force (IETF), namely TCP-Friendly Rate Control protocol (Floyd *et al.*, 2008). The prime objectives of TFRC are to be friendly to TCP flows and at the same time maintain the smoothness of the changing rate to avoid severe performance degradation. TFRC is envisioned to be the choice of transport protocol for inelastic applications.

Most of the previous researchers studied and evaluated the performance of transport protocols in isolation from MANET's routing protocols. For example, just to name a few, (Thenmozhi and Rajaram, 2011; Qamar and Manoj, 2010; Kumar *et al.*, 2004; Al-Hanbali *et al.*, 2005; Al-Hunaity *et al.*, 2007; Luo *et al.*, 2009). Recently, researchers have started to take a look at the interaction between transport protocols and other networking layers, for example (Ahuja *et al.*, 2000; Kim *et al.*, 2005; Seddik-Ghaleb *et al.*, 2006; Dyer and Boppana, 2001; Noorani *et al.*, 2009). Although many efforts have been established to study the relationship of TCP and different MANET routing protocols, but, to the best of our knowledge, there is no existing work that investigates the interaction between equation-based congestion control transport protocols and the type of MANETs routing protocols. In order to make fair comparison between window-based and equation-based congestion control, we also carried out experiment for TCP although it has been evaluated by other researchers.

The main aim of this research is to gain deep understanding on the performance of transport protocols by using different MANET routing protocols. In addition, it also intends to identify the relationship between transport protocols and routing protocols. As such, three sub-objectives have been established. Firstly, to investigate the performance of TFRC and TCP using different routing protocols in terms of throughput, packet loss and jitter. Secondly, to identify whether or not routing protocols have an influence on transport protocols and finally to identify which routing protocols work well with which transport protocols.

**Related works:** There are tremendous works on improving TCP and TFRC in MANET. However, we will not discuss them because we are more interested in the behaviours of unmodified existing TCP and TFRC. Proposing new mechanisms for TCP and TFRC are beyond the scope of our research.

In (Wang *et al.*, 2003), TCP variants performance was analyzed in Mobile Ad Hoc Network. The throughput of TCP-Reno, TCP-Vegas and TCP-Sack were compared under static and dynamic topologies. In this research, the intention was purely to study the transport protocols without considering the impact of routing protocols and therefore only DSR was used as its routing protocol. 20 nodes were created within 1500×500 m and using random waypoint as their mobility model. The speed was set to 2, 5, 10, 15, 20, 25 and 300 m sec<sup>-1</sup>, with pause time 0. The findings have shown that without any modifications to the TCP variants, it results in poor performance. Furthermore, multi-hop link transmission and different mobility scenarios did not obviously affect the performance of TCP variants.

Research by (Kim *et al.*, 2006) reveals that MANET routing protocols have no impact on TCP performance. They simulated TCP-Reno and TCP-Vegas over AODV and OLSR. Despite the small differences of TCP-Reno and TCP-Vegas throughput over different MANET routing protocols, TCP-Vegas performs better in AODV while TCP-Reno is more suitable with OLSR. The researchers used NS-2 as the network simulation tool and implemented a random waypoint mobility model with 50 nodes positioned at random location over a 1000×1000 m area. The simulation was run for 500 sec long. Throughput and Window size were the basis for their performance metrics. On the other hand, (Yahia and Biro, 2006) shows that MANET routing protocols and propagation models have an effect on the performance of some TCP variants. For example, the throughput of TCP-Vegas over DSR is 61 Kbytes/s as oppose to OLSR which is only 0.01 Kbytes/s.

Limitations of TFRC have been discussed comprehensively in (Rhee and Xu, 2007). The research was conducted with the aim to identify why TFRC and TCP flows have different average sending rates. It was found that TFRC throughput is influenced by loss event rate estimation and delay estimation. However, this experiment was not conducted in the MANET environment. In order to overcome these problems, especially in MANET, (Zhai *et al.*, 2005) proposed a new scheme of rate-based control namely Rate-Based end-to-end Congestion Control (RBCC). As compared to traditional TCP, RBCC has better performance in terms of channel utilization, delay and fairness. RBCC was run with a pre-computed path and AODV as its routing protocols.

An attempt to study the performance of TFRC in MANET was done by (Chen and Nahrstedt, 2004). They studied in terms of throughput fairness and smoothness of TFRC with the existence of TCP

competing flows. Results show that while TFRC is able to maintain the smoothness, it obtains less throughput. Two types of MANET topology were simulated, i.e., static and dynamic. In the static topology, 2-7 nodes were created while in dynamic topology, 600×600 m with 50 nodes and 1500×300 m with 60 nodes. Their research objective was just to gain insights of TFRC in MANET without considering the impact of routing protocols. As such, only DSR was used as the underlying protocol.

Sun *et al.* (2008) compared the performance of Equation-Based and GAIMD Congestion Control in MANET. In static topology 3-6 nodes were created. In dynamic topology, 600×600 m with 50 nodes and 1600×600 m with 60 nodes were considered. In both scenarios, TCP, TFRC and GAIMD flows were created to compete with each other. In contrast with our research, all of the experiments considered only DSR as the routing protocols. Results obtained show that, the TFRC changing rate is smoother than TCP and GAIMD, although the throughput is less.

## MATERIALS AND METHODS

**Simulation settings:** The experiments were conducted by using NS-2 as 44% of the MANET research communities use it (Kurkowski *et al.*, 2005). The experiment environment is in MANET, where 30 wireless nodes were created. The size of the location area is 1000×1000 m with x and y coordinates. Each node will be assigned types of application, transport and routing protocols. Among these 30 nodes, a pair of nodes has been chosen to be measured. In order to simulate multimedia application, Constant Bit Rate (CBR) was used as type of application. The background traffic used were also CBR carried over UDP. There were 4 sets of experiments (a) TCP over AODV, (b) TCP over DSR, (c) TFRC over AODV and (d) TFRC over DSR.

The Table 1 below summarizes the simulation settings used in each of the experiment:

In NS-2, there are various mobility models available. Random waypoint mobility model was used in this research because it had been used in many prominent simulation studies of ad hoc network protocol (Camp *et al.*, 2002). In the random waypoint mobility model, all nodes will be randomly move at a given speed and pause time. The speed varies from 5, 10, 15 and 20 m sec<sup>-1</sup>, while the pause time was set to 10 sec. Each node picks a random destination and speed given in the rectangular area and then travels to the destination in a straight line. Once the node reaches its destination, then it pauses for 10 sec and then chooses another destination to continue onward. Three scenarios had been created to simulate each of the experiments.

Table 1: Simulation settings

Parameters	Settings
Application	CBR
MANET routing protocols	AODV, DSR
Transport protocols	TCP, TFRC
MAC Protocols	802.11
Simulation time	500 sec
Mobility model	Random waypoint
Packet size	100 bytes
Packet sent rate	0.01 Mbps
NS-2 version	2.34

**Performance metrics:** Since this research is a combination of transport and routing protocols performance analysis, suggestions on performance metrics by (Hassan and Jain, 2004) and (Corson and Macker, 1999) were taken into consideration. In addition, types of traffic such as elastic or inelastic, also play a critical role in choosing the correct performance metrics. In summary, three main metrics were use to be investigated, i.e. throughput, packet loss and jitter.

Throughput is considered as the actual rate at which information is sent over a channel and is measured in bits per second. Packet delay is a combination of delays caused by processing, transmission and queuing delays in routers, end-system processing delays and propagation delays in the links. Packet delay or end-to-end delay has focused on nodal delay, which is concentrated in a single router. The end-to-end delay is measured from source (sender) to destination (receiver).

Jitter is the delay variation when the time taken by an IP datagram to travel from source to destination varies from one datagram to the next datagram. A high jitter level can have a severe impact on the performance of multimedia applications.

## RESULTS AND DISCUSSION

In terms of throughput, although TCP over AODV is lower, it is smoother than TFRC over AODV. As shown in Figure 1a the highest value of differences at various speeds is only 0.6% for TCP over AODV. However, the differences in value at various speed for TFRC over AODV is 61%.

Figure 1b has clearly shown that TFRC over DSR have better throughput as compared to TFRC over AODV. It also indicates that in both routing protocols, TFRC throughput is better than TCP. Table 2 summarizes the percentage difference of throughput between TFRC over AODV and DSR.

However, the result of TCP throughput when using with different routing protocols does not have any significant impact. The highest percentage difference is only 5.84% as summarized in Table 3. Furthermore, no conclusion can be made whether AODV or DSR is better in working with TCP.

Table 2: Average throughput of TFRC over AODV and DSR

Speed	TFRC over AODV	TFRC over DSR	Difference (%)
5	73.7	192.9	61.8
10	28.3	110.9	74.5
15	49.3	78.3	37.0
20	29.4	53.8	45.4

Table 4: Average Jitter of TFRC over AODV and DSR

Speed	TFRC over AODV	TFRC over DSR	Difference (%)
5	23.3	51.2	54.4
10	16.2	109.4	85.2
15	12.6	161.3	92.2
20	27.0	206.6	87.0

Table 3: Average throughput of TCP over AODV and DSR

Speed	TFRC over AODV	TFRC over DSR	Difference (%)
5	10.76	10.67	0.84
10	10.70	11.07	3.35
15	10.76	10.13	5.84
20	10.78	11.34	4.93

Table 5: Average Jitter of TCP over AODV and DSR

Speed	TCP over AODV	TCP over DSR	Difference (%)
5	169.98	201.19	15.51
10	134.49	232.66	42.19
15	169.98	858.78	80.21
20	169.93	448.45	62.11

Table 6: Average Delay of TFRC over AODV and DSR

Speed	TFRC over AODV	TFRC over DSR	Difference (%)
5	557.5	573.3	2.7
10	132.2	669.9	80.3
15	180.8	1007.3	82.1
20	186.2	1118.8	83.4

Table 7: Average Delay of TCP over AODV and DSR

Speed	TCP over AODV	TCP over DSR	Difference (%)
5	128.15	294.30	56.46
10	209.16	236.42	11.53
15	203.87	700.34	70.89
20	207.69	557.79	62.76

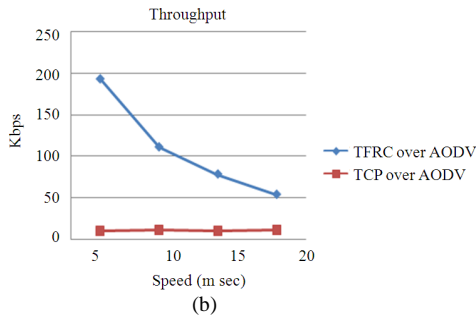
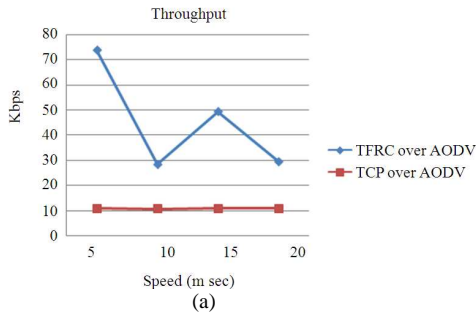


Fig. 1: (a) Throughput of TFRC and TCP over AODV, (b) Throughput of TFRC and TCP over DSR

TCP implement window-based congestion control where it uses additive increase/multiplicative decrease algorithm. In this algorithm, the window size will increase by 1 Maximum Segment Size (MSS) every Round Trip Time (RTT) until a loss is detected. When loss is detected, it will decrease the window size by half. This algorithm plus the delay that has to be incurred in searching new routes are the prime contribution to the low throughput of TCP, because in MANET environment there are many frequent changes or loss of routes.

The MANET routing protocols do have influence on the jitter for both window-based and rate-based congestion control protocols as illustrates in Fig. 2.

Table 4 and 5 show that TCP and TFRC have higher jitter when using DSR as the routing protocol.

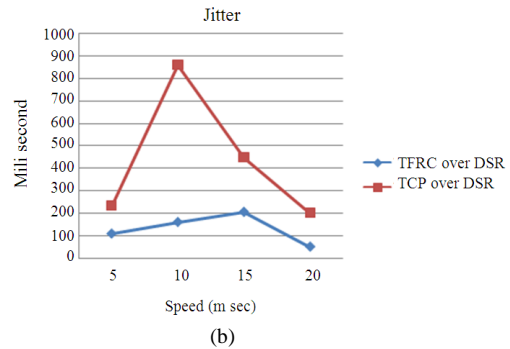
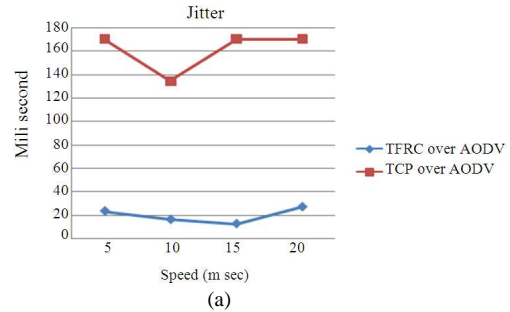


Fig. 2: (a) Jitter of TFRC and TCP over AODV, (b) Jitter of TFRC and TCP over DSR

On average, the jitter for TFRC when using with DSR is 79.7% higher as compared to TFRC over AODV, while TCP is only 50%.

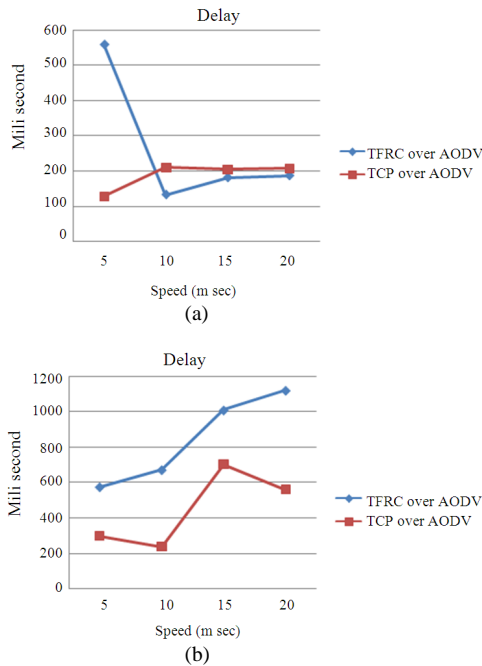


Fig. 3: (a) Delay of TFRC and TCP over AODV, (b) Delay of TFRC and TCP over DSR

Finally, in terms of delay, the performance of TCP and TFRC outperforms the one using DSR as shown in Fig. 3. Table 6 shows that the average delay for the differences is approximately 62.1% for TFRC and 50.41% for TCP as shown in Table 7.

### CONCLUSION

This research is focused on comparing the performance of TFRC and TCP in relation with AODV and DSR routing protocols. Results obtained have provided promising answers in fulfilling the research objectives set and are concluded below:

TFRC over DSR produced better throughput than TFRC over AODV and this pattern goes the same to TCP. Although the throughput values are low, the changes are smoother when using TFRC and TCP with AODV. Both transport protocols suffer from high delay and jitter if using DSR as the routing protocols. This is particularly true because the destination node in DSR has to reply to all RREQs, which increases the computing time to find the least congested route.

In order to conclude whether or not the routing protocols have an impact on transport protocols, it depends on the types of transport protocol itself. For instance, based on the simulation results, we found that TFRC throughput increases 55% on average when implementing DSR as the routing protocol. However,

TCP throughput difference is only 3.74% with different routing protocols. In summary, the throughput of TCP can be studied independently from the routing protocols, but for studying TFRC, the routing protocols have to be considered seriously. As for the jitter and delay, both routing protocols i.e., AODV and DSR have an influence on TFRC and TCP. The differences are more than 50% with different transport and routing protocols.

Depending on the performance metrics, different routing protocols provides different results with the transport protocols. If TFRC users consider throughput as the main criteria, than it is better to use DSR instead of AODV. As for TCP it does not make any difference in the throughput if different routing protocols are use. Should TFRC or TCP carry multimedia applications where the jitter is critical, then it is recommended to use AODV.

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