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# Performance Evaluation of Transport Protocols for Mobile Ad Hoc Networks

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**Abstract:** Mobile Ad hoc Networks (MANETs) is a wireless technology that plays an important role in several modern applications which include military, civil, health and real-time applications. Providing Quality of Service (QoS) for this application with network characterized by node mobility, infrastructure-less, limitation resource is a critical issue and takes greater attention. However, transport protocols effected influential on the performance of MANET application. This study provides an analysis and evaluation of the performance for TFRC, UDP and TCP transport protocols in MANET environment. In order to achieve high accuracy results, the three transport protocols are implemented and simulated with four different network topology which are 5, 10, 30 and 50 nodes, respectively using well known Network Simulator (NS-2.35). Moreover, Constant Bit Rate (CBR) considered as a traffic source and On-demand Distance Vector (AODV) as the routing protocol. For evaluation performance, QoS metrics such as end-to-end delay, packet delivery ratio, throughput and jitter are measured. The results show that delay and jitter of TFRC are slightly less than UDP and TCP whereas UDP has the significantly better performance wise throughput.

**Key words:** MANET, TFRC, UDP, TCP, network topology, QoS metric

## INTRODUCTION

The Mobile Ad Hoc Network (MANETs) a paradigm rising wireless communication technology (Conti and Giordano, 2014). Its minimum configuration and flexibility have made it suitable for different application such as vehicular system (Dharmaraja *et al*., 2016)' disaster recovery (Liu and Kato, 2016) and military operations (Meena and Vasanthi, 2016). Basically, MANET is a set of mobile nodes are connected via wireless links with the infrastructure-less networks. These mobile nodes can move dynamically which lead to changing topology constantly (Khan *et al*., 2017). A hop is a link between two nodes established while both nodes are in the transmission range of each other. Whilst, a multi-hop path can be existed by connecting two nodes among other nodes which act as router nodes. Moreover, multi-hop communication is widely used in the MANET in order to increase network capacity (Patnaik *et al*., 2015).

The mobility of nodes, congestion and wireless link nature are the main reason for packet loss and end-to-end delay in mobile ad hoc networks. Mobility leads to change the network topology dynamically. So, it may cause packet drop in various ways. A packet dropped in intermediate nodes if the next hop link has broken or the queue that stores incoming packets is full. Also, it may be dropped if the route from source to destination is not available. Congestion occurs in a network when the data traffic exceeds the maximum bandwidth of a communication link (Zhang *et al*., 2015).

In fact, the performance of a MANET strongly depends on the efficiency of the transporting protocol that is used. The TCP-Friendly Rate Control (TFRC) (Handley *et al*., 2008) and User Datagram Protocol (UDP) (Postel, 1981) and Transmission Control Protocol (TCP) (Postel, 1981) are transport layer protocols provide communication between application. Here, TFRC is a connection-oriented protocol provides a congestion control mechanism and fairness, making it suitable for real-time application where smooth bitrate is important. Because connectionless and message-oriented are the features in UDP, it has attracted multimedia application. Whereas TCP is a highly reliable connection protocol provides a congestion control mechanism and guaranteed delivery of data. Table 1 explained a comparision of the features and service provided by three transport protocols.

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Table 1: Features and service provided by TFRC, UDP, AND TCP

| Features | TFRC | UDP | TCP |
|---|---|---|---|
| Connection oriented | Yes | No | Yes |
| Message oriented | No | Yes | No |
| Reliable | Yes | No | Yes |
| Congestion control | Yes | No | Yes |
| Sequence number | Yes | No | Yes |

However, the transport protocols TFRC, UDP and TCP are working fine in wired networks and can support different application. But these protocols face challenges when research on wireless networks or mobile ad hoc network environment. Studies must be conducted to know the best transport protocol for the application. Hence, this study presents a performance evaluation of TFRC, UDP and TCP transport protocols in mobile ad hoc networks. Furthermore, four different network topology used in the simulation in order to get accurate results. In addition, QoS metrics namely end-to-end delay, throughput, packet delivery ration and jitter measured for the performance evaluation. The simulation result obtained may give a good idea of selecting the best protocol for applications in MANET environment.

**Lierature review:** Many studies are mainly focused on the evaluation and comparison of the performance of transport protocols in mobile ad hoc network. By Nor and Dakkak (2016) researcher compared the performance of TFRC and SCTP transport protocols in MANET. Two scenarios implemented in the simulation with respect to background traffic. The result shows that SCTP has higher throughput whilst TFRC has low delay value. Gharge and Valanjoo (2014) presented a performance evaluation of TCP variants over protocol in mobile ad hoc networks. TCP variants evaluated over four different routing protocols in two scenarios which are link failure and signal noise scenario.

By Rajaboina *et al*. (2016) researcher evaluated and compared the performance of TCP, UDP and TFRC protocols in static wireless ad hoc networks. The simulation of the three transport protocols is divided into two modes which are independently mode and interoperation mode. Based on the simulation result, UDP outperforms in term of throughput as compared to other protocols. TCP is fairness than TFRC. Sharma and Patidar (2016) evaluated the performance of proposed TCP in a mobile ad hoc network. The proposed-TCP simulated and compared with different TCP variants to achieve better results.

By Wheeb (2015, 2017) researcher evaluated and compared the performance of UDP, SCTP, TFRC and DCCP protocols for different application traffic in a wired network environment. For the simulation, NS2 is used. Three different scenarios with different parameters are implemented in order to get high accuracy result. The result of this study shows that throughput of SCTP is higher than other protocol whereas DCCP performance is good in term of delay. Xiang and Yang (2018) evaluated reliability performance for mobile ad hoc networks based on transmission reliability.

## MATERIALS AND METHODS

**Simulation enviroment and parameter setting:** The performance of transport protocols is studied under different condition of network size on mobile multi-hop ad-hoc networks. Specifically, four network topology used in the simulation experiments for evaluation of TFRC, UDP, TCP protocols which are 5, 10, 30 and 50 nodes respectively. In addition, NS-2.35 (Issariyakul and Hossain, 2011) used as the simulation tool, since, it is preferred by researchers interested in the field of networking. Figure 1a-d depicts the topologies of 5, 10, 30 and 50 nodes in the sumlation.

In order to simulate a network environment, the setting of simulation network parameter is required. Table 2 displays simulation parameters used in the study.

Finally, regarding all the simulation experiments, Constant Bit Rate (CBR) used as a traffic source, since, it generates a data rate similar to that generated by real-time applications. Moreover, On-demand Distance Vector (AODV) implemented as the routing protocol in all mobile nodes of the network. The mobile nodes distributed randomly and move using a random waypoint algorithm with varied pause time. Queue length setup to 100 packet max.

## RESULTS AND DISCUSSION

In the simulation experiment, four performance metrics measured to evaluate the performance of the three different transport protocols. This metrics are end-to-end delay, packet loss rate, throughput and jitter (Floyd, 2008; Nor *et al*., 2017) (Fig. 1a-d and Table 2).

**End-to- end delay:** The time taken by a packet to transmit from sender to receiver is called end-to-end delay. For the real-time application, end-to-end delay represents an important factor. However, end-to-end delay contains the sum of processing delay, queuing delay and propagation delay, etc. it is measured in seconds. The following equation is used to measure end-to-end delay value.

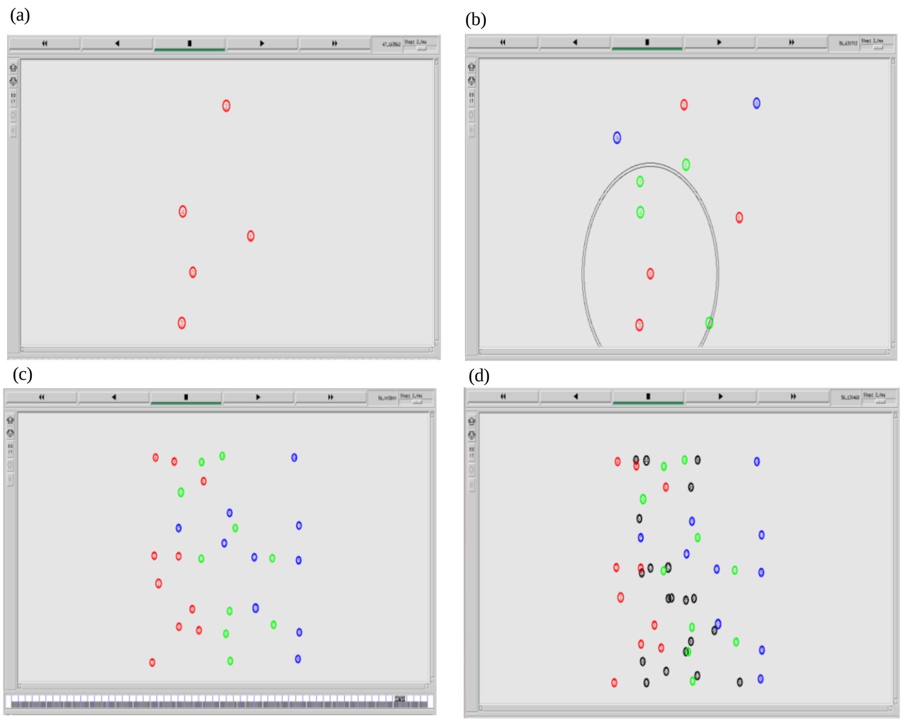


Fig. 1: a) Simulation topology of 5 nodes; b) Simulation topology of 10 nodes; c) Simulation topology of 30 nodes and d) Simulation topology of 50 nodes

Table 2: parameter setting of simulation

| Parameter | Values |
|---|---|
| Simulator | NS 2.35 |
| Channel | Wireless |
| Propagation | Two ray ground |
| Area (x) | 600 m |
| Area (y) | 600 m |
| MAC | 802-11 |
| Queue | Drop Tail-PriQueue |
| Routing protocol | AODV |
| Number of nodes | 5, 10, 30, 50 |
| Transport protocols | TFRC, UDP, TCP |
| Packet size | 512 bytes |
| Traffic type | CBR |
| Simulation time | 60 sec |
| Mobility model | Random way point |

$$\text{End-to-end delay} = T_r - T_s \quad (1)$$

Where:

$T_s$ = Sending time of the measured packet
$T_r$ = Receiving time for the same packet

As illustrated in Fig. 2, considerable variance in end-to-end delay is observed between the TFRC, UDP and TCP protocol. End-to-end delay of TFRC is low and less than that of UDP and TCP. UDP gives high end-to-end delay at a higher number of nodes, hence, the performance of UDP decrease as network density increases. At 5 and 10 nodes, end-to-end delay of TCP is higher than TFRC and UDP while at 30 and 50 nodes end-to-end delay of TCP higher than TFRC but less than UDP. To conclude TFRC provide better performance delay at MANET environment.

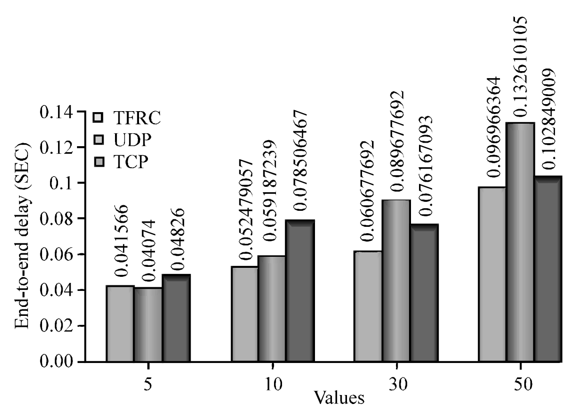


Fig. 2: End-to-End delay of TFRC, UDP and TCP for various node density

**Packet delivery ratio:** Due to the wireless link nature, packet loss occurs in MANET more than in wired networks. Packet Delivery Ratio (PDR) is the rate between the number of packets received and the number of packets sent across the network. However, QoS of application reduced when the packet loss is increased. Equation 2 explains the method used to measure the PDR.

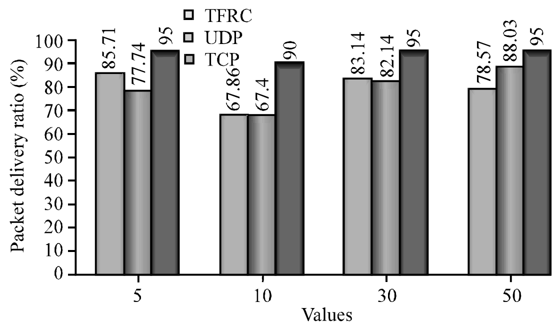


Fig. 3: Packet delivery ratio of TFRC, UDP and TCP for various node density

$$\text{PDR} = \frac{\sum \text{Total number of packet received}}{\sum \text{Total number of packet send}} \quad (2)$$

Figure 3 shows that the packet delivery ratio of TCP is relatively higher than UDP and TFRC. Both in TFRC and UDP loss many packets at 10 nodes. Notice clearly that UDP drop packet more than two protocols in all network nodes because it does not have a congestion control mechanism. Whilst, the packet delivery ratio of TCP is high and independent with consideration of increase network nodes. The result emphasizes the reliability of TCP performance in an environment of the MANET.

**Throughput:** Throughput is the amount of packet transmitted from source nodes to destination nodes, through the network at a specified time. Usually, it is rated in terms of packets per second or bits per seconds. To achieve good performance, the throughput must be relatively high. The value of throughput is measured by the Eq. 3.

$$\text{Throughput} = \frac{\text{Received packets}}{\text{Last packet } S_T\text{-first packet } S_T} \quad (3)$$

where, $S_T$ is sending time of a packet. According to Fig. 4 at 5 nodes throughput of TFRC is relatively less as compared to UDP and TCP. Also, Throughput of UDP is little better than the throughput of TCP. As the number of nodes increases to 10, 30 and 50 nodes the traffic load increase in the network. At the same time, UDP achieves the highest throughput superior on TFRC and TCP. The reason is UDP send packets at a constant transmission rate regardless the network sate. Furthermore, the overall throughput of TCP is higher than that of TFRC because TCP investing the bandwidth efficiently. Based on the results, UDP performs best among other two protocols at all network density.

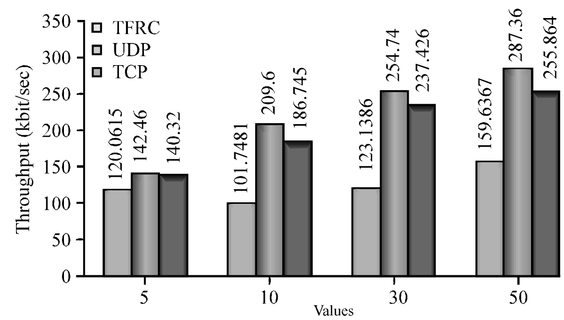


Fig. 4: Throughput of TFRC, UDP and TCP for various node density

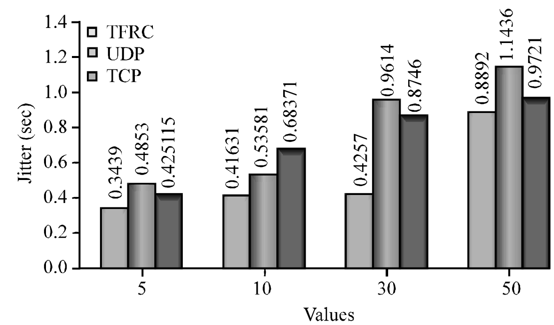


Fig. 5: Jitter of TFRC, UDP and TCP for various node density

**Jitter:** Jitter is the variation of packet arrival delay. It can be measured as the difference of delay of the current packet and previous packet. The streaming application such as a video stream or audio application is sensitive to delay and prefer a low value of jitter. Jitter is measured using Eq. 4:

$$\text{Jitter} = \text{Delay}_n\text{-Delay}_{n-1} \quad (4)$$

Where:

$\text{Delay}_n$ = Delay of the current packet
$\text{Delay}_{n-1}$ = Delay of the previous packet

Jitter performance analysis of TFRC, UDP and TCP protocols at 5, 10, 30 and 50 nodes is shown in Fig. 5. The result indicates that the TFRC is the best protocol concerning the jitter value. Also, it can be observed that UDP gives a high value of jitter and increases when the number of nodes increases. The reason behind this is jitter related to delay time. Jitter in TCP is better compared to UDP but less compared to TFRC. The reason is TCP monitor the network state. If congestion occurs in the network, then it reduces the data rate and stays monitor until next event which leads to the high value of jitter.

## CONCLUSION

The performance of TFRC, UDP and TCP in MANET was analyzed and evaluated. Four different network size used in the simulation. AODV consider as the routing protocol in mobile nodes and CBR employ as data traffic. Moreover, the performance of the three transport protocols evaluated according to QoS metrics. The experiment results show that TFRC performs better other protocol in term of end-to-end delay and jitter. Further, UDP gives a higher throughput subsequently it suitable for video applications. On the other hand, TFRC is appropriate for real-time applications like VoIP in MANET environment.

## SUGGESTIONS

In future research, non-standard transporting protocols and a high number of mobile nodes can be included.

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