Network Performance Evaluation of Different MANET Routing Protocols Configured on Heterogeneous Nodes

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Abstract. The recent communication technology tends to be wirelessly for the mobility reason. Mobile Ad-hoc Network (MANET) can be established without any infrastructure or centralized controller. It can be constructed quickly in rural areas, military zones, and in emergency cases like earthquake. Three different types of routing protocols were categorized according to their work’s nature, which are Proactive, Reactive and Hybrid routing protocols. Due to the mobility characteristic of MANET nodes, routing protocols play important role in determining the network efficiency where the network topology is changed frequently. Many studies are conducted to analyze network performance and specify the best routing protocol using different simulation tools. In this paper, the performance of network is analyzed and evaluated when heterogeneous nodes are configured with these three types of protocols under heavy traffic load (VOIP). The result of our simulation shows that OLSR protocol has the highest throughput among others while DSR protocol shows the best performance in terms of Network load. Generally, the performance of routing protocol differs depending on the network type and use.

Keywords. AODV, DSR, OLSR, GRP, TORA, OPNET.

1. Introduction

Wireless technology has become an essential communication medium for all smart devices. One of the most applicable branches to this technology is Mobile Ad-hoc Network (MANET). It is widely used when infrastructure absent especially in military fields (war zones) as well as disaster cases where establishing infrastructure is very expensive or impossible. Nodes within Ad-hoc network are communicating with each other and routing the packets from source to destination via Bluetooth or 802.11 standards without central controller. Therefore, nodes play two roles in the network either as a host or as a router. Because of the mobility characteristic of the nodes, the network topology is changed randomly and at uncertain periods. At this point, implementing effective routing protocol is an essential
element to maintain the network reliability and robustness. On the other hand, many challenges and limitations are facing this technology such as dynamic network topology due to node movement within broadcasting range. Moreover, limited bandwidth in wireless networks compared with wired networks due to interference, fading effects, and noises, which affect QoS of the network and degrade the performance of network. Because of portable devices has limited power supply and depends on batteries, energy constrains is another challenge to the MANET. Lastly, wireless networks are more susceptible to attacks compared to wired networks, which can be exposing the network to various threats such as eavesdropping and denial of Service [1]. To illustrate the MANET routing protocols, the background stated in the following part followed by the related work. Section 4 contains simulation environment and results while section 5 includes the conclusion.

2. Types of MANET Routing Protocols
The quality of routing protocol depends on how fast the node can discover the path to deliver packets without exhausting their resources and network resources. Typically, there are three main types of routing protocols as follow:

2.1. Proactive Routing Protocols (Table-driven Protocols)
Proactive protocols maintain the full path to deliver the packets (i.e. the address from source to destination is known previously). Routes information to every other node in the network are contained in one or more tables and keep updating this information periodically. All nodes are sharing these tables frequently to optimize the whole network topology. The major drawback of this type is utilizing bandwidth where unused path still occupied and available even if the network topology is changed. Proactive routing protocols such as DSDV, OLSR, WRP, STAR, etc [2].

2.2. Reactive Routing Protocols (On-Demand protocols)
In this type of protocols, route discovery procedure is invoked when it is required to deliver the packet from the source to the destination. In other words, the route is created only when needed where the node uses flooding technique to broadcast a request to all neighbor nodes to discover the new route. After that, the new route keeps valid until packets finish transmitting or the route is no longer required. The major drawback of this protocol is the latency in discovering the route. An examples of Reactive routing protocols are DSR, AODV, TORA, etc. [3].

2.3. Hybrid Routing Protocols
Hybrid protocols combine the advantages of the previous two types of routing protocols. The idea is to divide the total network nodes into multiple groups of nodes where each node acts as reactively within its neighbor-hood and work proactively when communicates with other regions. CEDARS, ZRP, GRP are instances of this type of protocols [4].

3. Related Work
Anjali et al, used OPNET simulator to evaluate the performance of AODV, OLSR and GRP protocols by considering IEEE 802.11 standard. The environment of simulation contains a medium scale of (80 nodes) and large scale (100 nodes) with examining FTP traffic type. Four network metrics where applied which are Media Access Delay, throughput, Retransmission Attempts, and Data Dropped (Retry Threshold Exceeded). This analytical study came to the point that the performance of routing protocols varies with network and influence the efficiency of that network [5].

S. Mahajan et al, simulated the performance of three routing protocols (AODV, OLSR and TORA) using OPNET modeler. The simulation environment employs two groups of nodes (15, 30) nodes with heavy traffic flow (VOIP) application. They analyzed five network parameters Delay, Network Load, Throughput, Jitter, and MOS (Mean Opinion Score). The result showed that TORA protocol has the best performance among two others with small and large sized networks. Also, the simulation demonstrated
that OLSR performs well in terms of throughput jitters with taking in consideration the type of network as well [6].

Ghulam Y. et al, compared in their work named “MANET Routing Protocols for Real-Time Multimedia Applications “the performance of different routing protocols using multimedia application (video traffic). They explained the performance of AODV, DSR, TORA and OLSR using different parameters over MANET using multimedia application (video transmission) and analyze the performance of the network. The study of these routing protocols showed that the OLSR has the best performance compared to all other protocols in terms of Load, throughput, end-to-end, packet delivery ration and media access delay parameters. Oppositely, DSR protocol shows the worst performance[7].

R. Sachdeva et al, deployed a comparison of two routing protocol’s performance (AODV and OLSR) using FTP and HTTP traffics. The simulation was carried out using OPNET simulator which examines 75 and 150 nodes along with five network parameters (Throughput, Delay, Network Load, Traffic Sent, Traffic Received). The result showed that AODV demonstrate good performance in terms of network load and throughput under normal state or under the case of node failure. On the other hand, OLSR showed better result regarding data dropped and retransmission process due to the nature of proactive routing protocols [8].

D. Chitra et al, analyzed the performance of AODV, DSR, TORA and OLSR routing protocols using OPNET simulator. FTP application traffic was used to evaluate four network metrics which are routing overhead, packet delivery ratio, packet end-to-end delay and network throughput. The simulation is run over three groups of nodes (10,20 and 50) nodes for an (1 hour). The results showed that within heavy load condition, AODV had low delay whereas DSR performs well in routing overhead. In addition, the throughput of AODV and DSR was better than OLSR routing protocol [9].

M. Keshtgary, et al, performed an evaluation study to the three main types of MANET routing protocols (Proactive, Reactive and Hybrid). Two traffic loads UDP and TCP were applied on the network of 20 nodes while the metrics considered were delay, network load, throughput, media access delay and load. The result showed that AODV and OLSR protocols has better performance than DSR and GRP protocols as well as DSR is the worst [10].

Jazyah Y. H. et al, presented in their work named “Performance Evaluation of Wireless Routing Protocols for MANET” the comparisons between four wireless routing protocols for MANT (AODV, OLSR, TORA, and DSR) were performed using OPNET simulator in addition to comparison between some common simulators in use. The comparison were performed on protocols in terms of delay, throughput and network overhead, simulation results shows that DSR is the best protocols among the four tested ones in terms of delay while TORA has the highest delay, the same results are recorded for network overhead, AODV has the best throughput and DSR has the least throughput[11].

Rao Y. C. et al, analyzed in their work named “Riverbed Modeler Simulation-Based Performance Analysis of Routing Protocols in Mobile Ad Hoc Networks ”different routing protocols that are AODV, OLSR, GRP and DSR, they considered eight performance metrics from a MANET which are RTS(routing traffic sent), RTR(routing traffic received), network load, data dropped, throughput, E2E delay, MA delay, and retransmission attempts. From the simulation results, the OLSR protocol has performed better than the other three protocols AODV, GRP and DSR in terms of E2E delay, data dropped and throughput. OLSR protocol has the highest throughput which is 469661 bits/sec, minimum data drop almost which is negligible and very low E2E delay (0.0011 sec), OLSR protocol has performed better in the mobile ad-hoc network in different quality of service parameters[12].

Fendji J. L. et al, presented in their work named “energy and performance evaluation of reactive, proactive, and hybrid routing protocols in wireless mesh network”, the comparison between AODV, OLSR and HWMP in its proactive and reactive modes. They used NS3 simulator and the following metrics: energy consumed, throughput, PDR, delay, e-throughput and e-PDR. And evaluated the routing protocols using two topologies: a grid topology and a mobile nodes topology. From the results, OLSR is globally the most performant routing protocol especially in terms of PDR and delay. However, its throughput can be highly affected by mobility and scalability. AODV can offer the same performance
as OLSR in several scenarios and seems to be more stable in different network environment than OLSR[13].

Thambusamy V. et al, in their work named “A Comprehensive Analysis of Simulated Results for the Performance of AODV and TORA Routing Protocols in Mobile Ad-hoc Networks” the performance evaluation has been carried out on AODV and TORA protocols. These routing protocols are evaluated with respect to data packet transmission between source node and destination node using simulation tool NS-2. The simulated results led to the mobility model is suitable for small and medium sized networks. The TORA protocol is achieved around 58% packet delivery ratio when the mobile sink movement speed is 5 ms. But, the AODV got more than that of TORA. Hence, from the results of AODV and TORA, both are compared under normal situations, the AODV is observed as better than the TORA. The AODV protocol is recognized and recommended for the MANETs environment chosen in this simulation. In both scenarios, the AODV is observed as the perfect candidate in terms of its performance via its simulation time. Hence, this work concludes that the On-demand protocol, AODV performed better than the TORA protocol under the taken hypothesis[14].

4. Simulation Environment

For analyzing the performance of the three types of MANET protocols under specific environmental changes, an simulation model is developed using OPNET (Optimized Network Engineering Tools) simulator. It is an active software that allows users to design and emulate different network types, various devices, various protocols in such flexible and scalable way [15]. The software version 17.5 is used to create different scenarios. The simulation parameters are summarized in the table 1.

| Parameter                  | Value                          |
|----------------------------|--------------------------------|
| Network scale              | Campus                         |
| Scenario Size              | 1000 X 1000 (m x m)            |
| Model Family               | MANET                          |
| Protocols                  | AODV, DSR, TORA, OLSR, GRP     |
| Performance Parameter      | Network Load, Throughput        |
| Ground speed               | 3 m/s                          |
| Application traffic        | VOIP                           |
| Simulation period          | 15 minutes                     |
| No. of Nodes               | 20,80                          |
| Number of Rows             | 4                              |
| Start time (seconds)       | 100.0                          |
| Packet Inter-Arrival time  | Exponential(1)                  |
| (seconds)                  |                                |
| Packet size (bits)         | Exponential(1024)               |
| Stop Time (seconds)        | End of Simulation              |
| Physical Characteristics   | Direct Sequence                |
| Data Rate (bps)            | 11Mbps                         |
| Transmit Power (W)         | 0.005                          |

Two scenarios were run, one for 20 mobile nodes and the second for 80 mobile and fixed nodes. Each scenario carried out five simulations for five routing protocols that represents, Proactive protocol (OLSR), Reactive protocols (AODV, DSR, and TORA) and Hybrid protocol (GRP). The main objective of this work is to evaluate the performance of the scalable network under heavy traffic load using VOIP application. Global discrete Event Statistics (DES) was collected for each protocol and Wireless LAN.
Figure 1. Simulation Scenario have 20 mobile nodes.

Figure 1. shows the simulation environment of one scenario having 20 mobile nodes and running AODV routing protocol.

4.1. Performance Metrics
The following criteria will be used to measure performance:

1- Network load: The metric represents the total data traffic (bits/sec) received by the entire WLAN BSS from the higher layers of the MACs that is accepted and queued for transmission.
2- Throughput: Represents the total number of bits (bits/sec) forwarded from wireless LAN layers to higher layers in all WLAN nodes of the network.

4.2. Simulation Results
OPNET modeler 17.5 was used to carry out the simulation environment. Two scenarios were performed to evaluate the performance of considered routing protocols with 20 and 80 nodes.

Figures 2, 3, 4 and 5 illustrates the network load and throughput with respect to the simulation time which is considered as 10 minutes for with the simulation was run. According to the parameters mentioned above, the simulation was run, and the following results are obtained:

1- Network Load:
Figure 2 shows the network load when running VOIP traffic for 20 mobile nodes. As mentioned above, network load is the total packets (bit/sec) that transmitted via the network and consumes its bandwidth. When the simulation run for 10 minutes, the network load using GRP protocol decreased dramatically within first minute then continue steadily as second protocol after DSR protocol that has less network load. In addition, the figure shows that OLSR protocol has the highest protocol that exhausts network bandwidth.

Figure 3 shows the network load when running VOIP traffic for 80 mobile and fixed nodes. the result shows that GRP protocol has the same behavior when it run for 20 mobile nodes. On the other hand, the figure shows that AODV protocol has the highest load comparing with others although it starts with no load until minute two when starts increasing. It is noticeable that the network load for three reactive protocols stops around minute three due to the nature of the reactive protocols’ work.
2- Throughput:

Figure 4 shows the throughput when running VOIP traffic for 20 mobile nodes. The throughput of network is the total successful packets (bit/sec) that deliver to its destination via the network. When the simulation run for 10 minutes, the throughput using GRP protocol decreased dramatically within first minute then continue steadily as third protocol that has less network throughput. Also, the figure shows that OLSR protocol has the highest throughput among the other protocols.

Figure 5 shows the throughput when running VOIP traffic for 80 mobile and fixed nodes. The result shows that GRP protocol has the same behavior when it run for 20 mobile nodes. Similarly, the figure shows that OLSR protocol has the highest steady throughput comparing with others as it reaches to 6000000 (bit/sec). The throughput of the network for AODV protocol stops around minute three. The DSR and TORA protocols have least throughput when they are deployed in both scenarios.

Conclusion
In this paper, an analytical process was conducted using OPNET simulator to evaluate five routing protocols that represent Proactive, Reactive and Hybrid protocols types. The simulation demonstrates the behavior of different network sizes under heavy traffic load (VOIP) and two network parameters were examined. The results discussed above showed that OLSR protocol has the highest Throughput when deployed in small and large network sizes as well as the highest Network load when deployed only in small network size. In contrast to the weak throughput of DSR protocol over different sizes of network, it performs the best in terms of the network load comparing with other protocols. Hence, DSR protocol shows the advantage of Reactive protocols where it launches the route discovery process when required therefore it does not consume network bandwidth. Thus, the divergence in performance of routing protocols relies on network type. At the end, it is important to choose an appropriate routing protocol carefully according to the type and the use of network where it effects the reliability of that network in magnificent way.

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