Performance Evaluation of Routing Protocols in Wireless Mesh Networks

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Abstract: Wireless Mesh Networks (WMNs) are the set of wireless nodes that can communicate with each other and forwarding each other's packets. WMNs are multi-hop networks consisting of routers, gateways and mobile nodes. WMNs act as a key technology for next generation WMNs. Because of their low cost and relative ease of deployment, they are an attractive paradigm and are advantageous to other wireless networks. The aim of WMNs is to guarantee connectivity. WMNs build a multihop wireless backbone to interconnect isolated Local Area Networks and to extend backhaul access to users not within range of typical access points. This research has carried out current/existing literature in WMNs. It has analysed routing protocols such as AODV, DSR, GRP, OLSR and TORA used in WMNs where AODV and DSR are reactive routing protocols, OLSR and GRP are proactive routing protocols and TORA is a hybrid routing protocol. The routing protocols have been analysed with the performance metrics of throughput and delay under the simulation of ftp traffic. The simulator used is OPNET. With the help of OPNET, results show that in terms of ftp traffic load, TORA has very long delay. For throughput, OLSR outperforms the other routing protocols.
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1. Introduction

Wireless mesh networks (WMNs) are dynamically self-organized and self-configured, with the nodes in the network automatically establishing an ad hoc network and maintaining the mesh connectivity (Akyildiz and Wang, 2005). WMNs, consisting of wireless access networks interconnected by a wireless backbone, present an attractive alternative. Compared to optical networks, WMNs have low investment overhead and can be rapidly deployed. They can extend Internet Protocol (IP) connectivity to regions otherwise unreachable by any single access technology (Waharte et al. 2006).

WMNs combine concepts from a diverse set of existing and emerging wireless technologies, including cellular technologies, ad hoc networks, and sensor networks (Waharte et al. 2006). The multi-hop wireless nature of a WMN demands a different approach to routing from conventional wireless access networks. It has much more in common with the ad hoc and sensor network fields.

WMNs use three categories of protocols which are proactive, reactive and hybrid. Proactive routing protocols maintain routes to all destinations, regardless of whether these routes are needed or not. To preserve correct route information, a node must periodically send control messages. Therefore, proactive routing protocols may waste bandwidth since control messages are sent out unnecessarily when there is no data traffic. Reactive routing protocols only set up a route between a source and its destination when required. Hybrid routing protocols combine both reactive and proactive routing to increase the overall scalability in the networks (Waharte et al. 2006; Rahman et al. 2009).

2. Routing protocols overview

Routing protocols are very important in WMNs for forwarding packets from source to destination. A WMN shares some features with ad hoc networks so that routing protocols used in a Mobile Ad hoc Network (MANET) can be applied to a WMN. Routing protocols in WMNs can be categorised into 3 classes or groups namely: proactive routing, reactive routing and hybrid routing protocols. AODV and DSR are reactive routing protocols, GRP and OLSR are proactive routing protocols and TORA is a hybrid rouing protocol which will be briefly discussed in this section.

2.1 Ad hoc on Demand Distance Vector

AODV is a reactive distance vector routing protocol that has been optimised for mobile ad-hoc wireless networks. AODV makes extensive use of sequence numbers in control packets to avoid the problem of routing loops. It has Route Request Packet (RRP) which helps for communication to the unknown destination node and RRP contains an ID which will identify route request (Zakrzewska et al. 2008). AODV is divided to reverse route establishment and forward route establishment. In route establishment, the source node broadcasts the

RREQ packets and when the destination node receives the RREQ packet, it will send the Route Reply (RREP) packet to the source node. The forward node is established from source node to the destination node and is used to transmit packets (Yu et al. 2010).

2.2 Dynamic Source Routing

DSR is a reactive routing protocol which maintains information about the whole path from the source to the destination node. It discovers a route only when it is needed. DSR consists of two types of mechanisms namely: routing discovery and routing maintenance. Routing discovery is responsible for route calculation from source node to destination node. Routing maintenance monitors the availability of the current node (Yu et al. 2010).

2.3 Geographic Routing Protocol

GRP is classified as a proactive routing protocol. It is hop-by-hop routing and its routing principle relies on geographic position information. Global Positioning System (GPS) marks each node's location. It uses flooding location distance update when a node moves and crosses a neighbourhood. Route locking is advantageous for node to return its packet to the last node (Islam et al. 2012).

2.4 Optimized Link State Routing

OLSR is a proactive routing protocol. The routes is usually stored and updated when the route is needed. The route is immediately presented without any initial delay. There are some candidate nodes called multipoint relays (MPRs) which are selected and they are responsible for forwarding broadcast packets during the flooding process. OLSR is a hop by hop routing where each node uses its most recent routing information to route packets.

2.5 Temporally-Ordered Routing Algorithm

TORA is a hybrid protocol and it is for multihop networks and is considered to minimise the communication overhead associated with adapting to network topology (Qasim et al. 2008). As an algorithm protocol based on the link reversal concept, it also improves the partial link reversal method where it detects partition and stopping no-working link reversals. The effect in TORA is localised in a set of a nodes that are affected (Lin and Kaiser, 2005).

TORA has three operations namely:

- Route creation
- Route maintenance
- Route erasure

3. Related work

A study by Zakrzewska et al. (2008) proposed a performance evaluation of routing protocols for WMNs using DSDV, OLSR, AODV and DSR. Their performance comparison was done with regard to the network size, network load and nodes mobility. The simulator used for the evaluation was NS-2. They compared the routing protocols with regard to network size, network load and the mobility of nodes, simulation model, and network size from different number of nodes. The packets size used were 512 bytes and simulation run time was 90- seconds. The results showed that for network size, AODV performs better in scenarios of high mobility and network load, OLSR performs much better than DSDV and DSR.

Yu et al. (2010) carried out a study on performance evaluation and comparison from the simulation and analysis for DSR and AODV of the reactive routing protocols in WMNs. The simulator used for evaluation was OPNET. They used the same scenarios, settings and configuration parameters for both DSR and AODV. In their simulation the network was set to 40 or 20 nodes, the traffic was FTP mode, the data transmission rate was 1 mbps, the transmission power was 0.0005 Watts, the file size of sending was 1024 bytes and the simulation time was 3600 seconds. They compared AODV and DSR using performance metrics namely as: network throughput and routing discovery time and average number of hops per route. Their results showed that DSR network delay is very longer than AODV, the routing discovery time of DSR is less than that of AODV, and from their analysis, it shown that DSR is not suitable for wireless transmission while AODV is suitable with rapid change of network topology.

Kumar and Snegupta (2010) also analysed and simulated the AODV and OLSR routing protocol for both wireless ad-hoc networks and WMNs. They used the OPNET modeler version for their simulation. Their results show that AODV performs better with static traffic while OLSR is best in networks with high density and highly sporadic traffic.

Ashraf et al. (2007) provided a paper on evaluation of routing protocols for the WMN. They analysed the performance of four ad hoc routing protocols which are two reactive (DSR, AODV) and two proactive (OLSR, DSDV) protocols for WMNs using simulation. They used NS2 to simulate the four routing protocols. They used three metrics to evaluate performance and these metrics are: routing overhead, packet delivery fraction and end-to-end delay. The results showed that DSR performance is best. They performed their analysis using different scenarios with different network settings. DSR performed best in all scenarios. AODV followed DSR but not for large networks. OLSR ranked in third. It gave stable performance due to its periodic routing exchange and DSDV performed worst in their simulation. They concluded that reactive protocol performs better than proactive protocols.

4. Methodology

Simulation is a methodology used in science and engineering to carry out the aims and objectives of research. Simulation based research is more commonly used in computer networks. It is a very important technology where it gives advantages of modelling real-life objects with hypothesis on computers so that the real-life objects can be studied.

This section presents the conceptual model used for modelling and simulation. Performance metrics for the methodology of this paper and the simulation setup of the WMN designed are also presented in this section.

4.1 Conceptual Model

The conceptual model of the WMN to be modeled consists of 15 nodes, a wireless local area network (WLAN) server and one LAN Ethernet router. They support wireless communication at rate of up to 11Mbps.

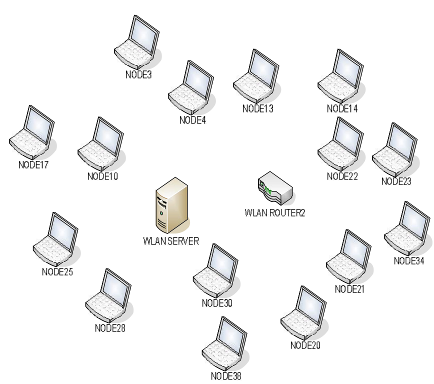

Figure 1: Conceptual Model for the WMN

4.2 Performance Metrics

Two performance metrics used in this paper are:

- Delay: is the packet generated time by the source up to the destination reception and this time is the one that the packet takes to go across the network. Short delay is considered.
- Throughput: the ratio of the total data reaches a receiver from the sender (Bilandi and Verma, 2010). It is expressed as bits per sec. Limited bandwidth, limited energy, and unreliable communication are the factors that affect throughput.

4.3 Simulation Setup

OPNET (Optimized Network Engineering Tools) version 14.0 is a discrete event simulator used for performance evaluation of the routing protocols mentioned earlier in section 2. In this paper 15 nodes randomly distributed in an area of 5km × 5km were run for simulation models. The nodes moved in a random waypoint model with a speed of 10 meters per second and the pause time of 100 seconds. AODV, DSR, GRP, OLSR and TORA are routing protocols that were studied in the simulation.

Three profiles were modeled in this paper:

- Ftp low: profile that is under low ftp load conditions.
- ftp medium: profile that is under medium ftp load conditions
- Ftp high: profile that is under high ftp load conditions.

The data rate transmission supported for nodes in WMN was 11 Mbps with a power of 0.005 watts. The packets size used for modeling was 1024 bytes. Every profile created during simulation was applied to each of the protocols. Figure 2 shows simulation preparation of the WMN used in this paper.

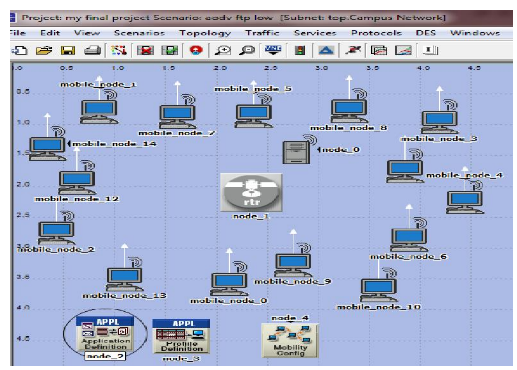

Figure 2: simulation setup of WMN

5 Results and discussion

The experimental results carried out after simulation are presented and discussed in this section. The performance analysis of the selected routing protocols namely: AODV, OLSR, GRP, DSR and TORA are carried out based on throughput and delay performance metrics.

5.1 Delay Comparison under low ftp, medium ftp and high ftp

Figure 3, figure 4 and figure 5 demonstrate delay comparisons obtained for AODV, DSR, GRP, OLSR and TORA over ftp low load, ftp medium load and ftp high load. The x-axis in figure 3, figure 4 and figure 5 represent time in minutes and y-axis represent delay in seconds.

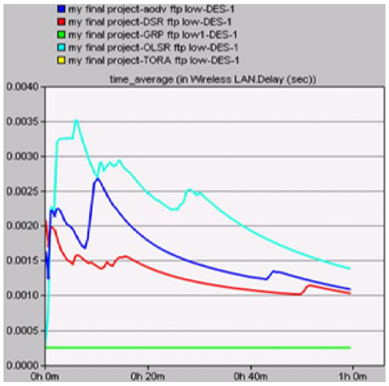

Figure 3: Delay of all the selected routing protocols under low ftp

Figure 3 demonstrates the delay of the routing protocols under ftp low traffic load. It is observed that OLSR had worse delay, AODV ranked number two with worse delay and DSR also has long delay. GRP and TORA have lower delay and they remain constant.

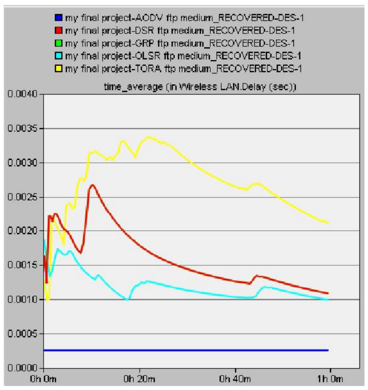

Figure 4: Delay of all the selected routing protocols under medium ftp

Under medium ftp, Figure 4 depicts that TORA has worse delay; GRP and DSR rank number two after TORA with long delay and followed by OLSR ranking in number three with long delay. AODV is the only protocol with low delay.

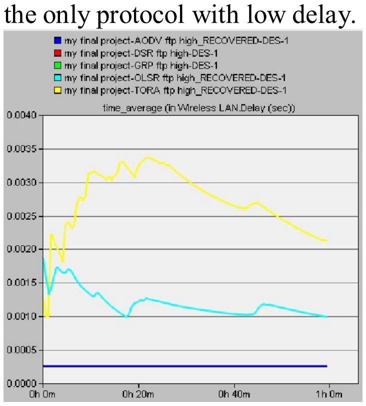

Figure 5: Delay of all the selected routing protocols under high ftp

Figure 5 indicates that under high ftp, TORA experienced very worse delay and OLSR had long delay. AODV, DSR and DSR are observed to have very low delay and they are constant.

5.2 Throughput Comparison Under Low ftp, medium ftp and high ftp

Figure 6, figure 7 and figure 8 demonstrate throughput comparisons obtained for the performance of AODV, DSR, GRP, OLSR and TORA under ftp low load, ftp medium load and ftp high load. The x-axis in figure 6, figure 7 and figure 8 represent time in minutes and y-axis represent the throughput in bits per seconds.

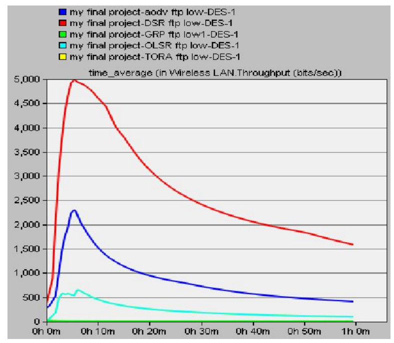

Figure 6: Throughput of all the selected routing protocols under low ftp

Figure 6 demonstrates the throughput of selected routing protocols under ftp low traffic load where DSR outperforms the other routing protocols. AODV performs better than TORA, OLSR and GRP. TORA and OLSR ranked number three with low throughput. GRP throughput generated is constant and is very low.

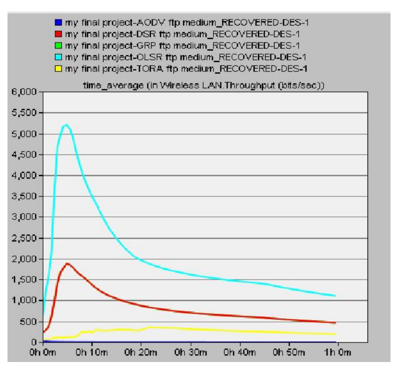

Figure 7: Throughput of all the selected routing protocols under medium ftp

Figure 7 depicts throughput under ftp medium traffic load. OLSR outperforms all other routing protocols with high throughput. GRP and DSR perform better than TORA and AODV. TORA has low throughput but is better than of AODV. AODV has very low throughput and is constant.

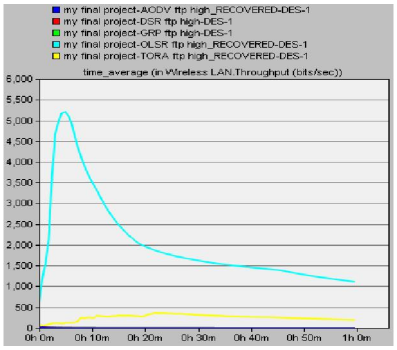

Figure 8: Throughput of all the selected routing protocols under high ftp

Figure 8 shows the throughput of selected routing protocol under ftp high traffic load. OLSR has high throughput and outperforms the other routing protocols. TORA outperforms DSR, AODV and GRP. AODV, DSR and GRP throughput generated is very low and remains constant.

6 Conclusion

We have analysed and evaluated the five routing protocols performance in ftp traffic loads. The performance metrics used to evaluate performance of AODV, DSR, GRP, OLSR and TORA routing protocols include delay and throughput. We discovered that in terms of delay under ftp medium load and ftp high load, TORA is leading with high delay. GRP has very short delay that is continuous in ftp high load and ftp low load. For throughput OLSR outperforms other routing protocols under ftp medium load and ftp high load. AODV had low throughput.

7 Future Works

The WMN modeled and designed in this research used 1 mesh router and 15 nodes. In future the study could be done by adding more mesh routers and increasing the number of nodes in the network and by including routing overhead performance metrics. Further study could also evaluate video conferencing traffic in WMNs under the same conditions used in this project.

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