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Simulation study of MANET routing protocols under FTP traffic

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Abstract

Mobile Ad Hoc Networks (MANETs) use many different routing protocols to route data packets between nodes. The performance of these routing protocols has been widely studied and evaluated. However, previous studies evaluate the performance of routing protocols using traffic generators that do not correspond to specific applications. Additionally, the scenarios used in previous research are rather simple and do not correspond to real and complex situations, where various types of traffic coexist in the network. We study the performance of proactive and reactive routing protocols when specific application traffic exists in the network. A number of nodes need to receive large data files from the same source node, using File Transfer Protocol (FTP), while other non-specific application traffic also exists in the network, thus comprising a complex and more real-like scenario. We examine the generic case where the data to be transferred is different for each destination node, so multicasting algorithms cannot be used. By executing several simulations, we conclude that the type of the traffic load in the network plays an important role on the performance and operation of the most popular routing protocols used in MANETs, regardless of the mobility model employed by the relay nodes.

Keywords: routing protocols; DSR; AODV; OLSR; FTP; simulation

1. Introduction

Mobile Ad Hoc Networks (MANETs) [1] are self-organizing networks without predefined infrastructure. Routing in this type of networks can be implemented by many routing protocols that can be categorized under different criteria [2]. The most general distinction of MANET routing protocols is proactive and reactive, with hybrid protocols spanning between these two categories. Some of the most popular protocols examined in previous studies are Dynamic Source Routing (DSR), Ad-hoc On-demand Distance Vector (AODV) and Temporally-Ordered

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Routing Algorithm (TORA), which belong to the reactive or on-demand category and Optimized Link State Routing (OLSR), Destination-Sequenced Distance-Vector (DSDV) and Wireless Routing Protocol (WRP), which belong to the proactive or table-driven category. There have been made several performance evaluation studies that examine the performance and operation of these protocols, comparing them in terms of various metrics [3-8].

In this study we investigate the performance of the routing protocols under a different perspective. We examine the operation and performance of the most popular routing protocols in a case study, where a varying number of nodes need to receive large data files from one common source node (server). In order to achieve this, File Transfer Protocol (FTP) is used. Although there is a trend towards HTTP for downloads, FTP is still a candidate for use in modern applications for Internet of Things or Smart Cities. Therefore, studying its impact can provide valuable information. Previous work conducted in this area uses traffic generators that do not correspond to specific applications, and they are the only type of traffic spanning the network at any given time. To the best of our knowledge, there have not been studies on the performance of routing protocols when various types of traffic coexist and use the same network resources, which is the case in real applications. When FTP traffic exists in the network, along with other less demanding traffic, the performance of the routing protocols could be prominently different than in the simple scenarios studied in the past, which do not apply in real situations.

The number of the destination nodes is varied and so the volume of traffic and the congestion in the network is varied too. Since high volumes of traffic need to be transferred from one source to a number of destinations, the nodes that are close to the source are expected to be highly congested from ftp traffic, thus degrading the overall performance of the network. The routing protocol should be capable of selecting alternate routes to overcome this obstacle, and it is rather interesting to examine whether the routing protocols under investigation have that capability. We also use different mobility models for the relay nodes to examine whether the mobility model has an impact on the performance of the routing protocols.

We explicitly examine proactive and reactive routing protocols and compare their performance in terms of various metrics. The routing protocols under investigation are DSR [9], AODV [10] and OLSR [11]. DSR and AODV are reactive routing protocols while OLSR is a proactive routing protocol. All of them are used in flat network topologies. Although there are improved protocols based on them, these are the most widely used and they are the base for all protocols proposed since their development.

The rest of the paper is organized as follows. Section II provides an overview o f related work. In Section III we describe the case study scenario. In section IV, the simulation results are presented. Conclusions are presented in section V.

2. Related work

As stated earlier, there have been several performance evaluation and comparison studies, which examine the performance of various routing protocols in MANETs. Each of these studies examines different number and/or categories of routing protocols, with different mobility patterns and traffic conditions. However, in all of the articles mentioned in this section and similar studies published in the past, the traffic sources were considered to send Constant Bit Rate (CBR) traffic and traffic resulting from specific applications has not been taken into account. Although CBR is the common traffic source used for evaluation of protocols' performance, it is not common for a real network to transfer only that kind of traffic, since in most real networks many different applications and types of traffic coexist. Although in some studies the traffic load is varied, it still is generated by non-specific traffic generators as CBR. In this section we present some of the most prominent work done in this field in contrast to our study.

In [3], AODV and DSR are compared by varying network load, mobility, and network size and measuring the performance differences of the two protocols in terms of packet delivery ratio, end-to-end delay and normalized routing and Medium Access Control (MAC) load. The mobility model used is random waypoint. This paper focuses on the interactions between routing and MAC layers and the way it affects the performance of the protocols.

In [4], AODV, DSR, TORA and DSDV are compared in terms of end-to-end delay, jitter, packet loss ratio, throughput, normalized routing load, scalability and connectivity by varying the network size, thus providing a table with a ranking based on the protocols' performance.

In [5], AODV, DSDV and OLSR are compared using three real-life scenarios in terms of packet delivery ratio, delay, average delay, throughput and total energy consumption. The packet size, the number of packets, the transmission interval, the nodes' speed, the mobility models, the number of receivers and transmitters, and the Direct Sequence Spread Spectrum rate (DSSS) are varied among the scenarios, and the most appropriate routing protocol in each scenario is suggested.

In [6], DSDV, AODV and DSR are compared in terms of packet delivery ratio, throughput, end-to-end delay and routing overhead by varying packet size, time interval between packet sending, and mobility of nodes.

In [7], DSR, AODV and OLSR are compared in terms of throughput, goodput, routing load and end-to-end delay, by varying network load, number of flows, network size and mobility. The paper concludes that proactive routing protocols have better performance than reactive routing protocols.

In [8], DSR, AODV and WRP are compared in terms of packet delivery ratio, average end-to-end delay, throughput and routing message overhead, by varying pause time, offered load and average node speed. Other types of traffic, besides CBR, are examined, namely FTP and TELNET traffic. Nevertheless, they are studied independently, i.e. one type of traffic exists in the network in each simulation, while in our study FTP and non-specific application traffic coexist in the network.

We examine DSR, AODV and OLSR when FTP traffic coexists in the network with other non-specific application traffic, like CBR or traffic bursts. Using this concept we approximate traffic conditions that are closer to real networks, where various applications can be used simultaneously by different or even by the same nodes. By varying the number of the relay nodes and the number of nodes requesting files from the source we study the performance of the above-mentioned protocols in terms of packet delivery ratio, average end-to-end delay and routing overhead.

3. Case study scenario

In this section we describe the case study scenario used for the set up and execution of the simulations. The simulation field dimensions are 1000m x1000m. There are static destination nodes randomly placed on the right edge of the field and a static source node on the left edge of the field.

Two sets of simulations are executed. In the first one, there is non-specific application traffic in the network using CBR and burst traffic generators, while in the second one, FTP traffic coexists with non-specific application traffic. In both cases the whole traffic generators' configuration is adapted to maintain the total load of the network equal between the two sets of simulations. In the second one, large files are transferred from the source node to each of the destination nodes using FTP during the whole simulation. The files transferred are considered to be different for each destination node, so multicasting algorithms could not be considered in the study. In the field there is a number of randomly moving nodes that are going to be used as relay nodes between the source and the destination nodes. The transmission range of each node is set to 250m. All of the general simulation parameters are noted on Table 1.

We use two different mobility models to investigate whether there is an impact on the performance due to different mobility patterns: Random Way Point and Gauss Markov.

We use the following metrics to measure and compare the performance of the protocols:

- Packet Delivery Ratio (PDR): It is the percentage of successfully received data packets and is computed by dividing the total number of received data packets by the total number of sent data packets.
- Average End-to-End Delay (AEED): It is the average time a data packet needs to be delivered to its destination. It is computed by averaging the delay for all the data packets successfully delivered to their destinations.
- Normalized Routing Overhead (NRO): It is the ratio between control traffic and the total throughput of the network.

Although other metrics could also be utilized, these are the most frequently used and they are selected for easier comparison to previous work on this field. For all the above-mentioned metrics the total amount of traffic is considered for the calculations.

Table 1. Simulation parameters.

Parameter	Value
Simulation Area	1000m x 1000m
Simulation Time	1000s
Radio Propagation Model	Two Ray Ground
Transmission Range	250m
Routing Protocols	DSR, AODV, OLSR
Packet Size	512bytes
Application	FTP
MAC	802.11
Number of FTP source nodes	1
Number of FTP destination nodes	1, 2, 5, 10
Number of relay nodes	20, 50, 75, 100
Mobility Models	Random Way Point, Gauss Markov
Relay Nodes' Speed	2-10m/s

4. Simulation results

Simulations were performed using OMNeT++ [12] and inetmanet framework [13]. OMNeT++ is a component-based C++ simulation library and framework, used primarily for building network simulators. Inetmanet framework is a protocol model library which contains models of the Internet stack, wired and wireless link layer protocols, support for mobility, MANET and other protocols and components. Changes have been made to the provided routing protocols' models in order to extract the desired metrics. Simulations have been repeated several times with different seeds and the results are averaged.

In Fig. 1, the PDR versus the number of relay nodes is depicted for DSR, AODV and OLSR for different number of FTP destination nodes. In Fig. 2, the average End-to-End Delay can be observed. Finally, in Fig. 3, the Normalized Routing Overhead is presented in the same way. Compact lines represent the value of the respective metric when FTP traffic coexists with non-specific application traffic, while dashed lines represent the same metric when only non-specific application traffic exists in the network. In both cases, the total network load has been computed and set up in the simulation to be equal. All metrics are depicted versus the number of relay nodes for easier comparison with previous studies that have adopted this way of presenting results.

As we expected the performance of the network degrades when more traffic is present in the network destined towards more FTP destination nodes. Additionally, when the network becomes of high density there is significant impact on all of the three protocols' performance metrics that we considered in this study. As the traffic load and density of network increases, the PDR decreases, while the average End-to-End Delay increases, for all the protocols under consideration. This happens because of the increased probability of collisions and packet drops due to network congestion, when traffic load and network density increases. Normalized routing overhead also increases as the number of relay nodes and the amount of traffic increases, but not significantly. In the case of OLSR protocol, NRO has a high value for all network densities and traffic loads, due to its need to always maintain an up-to-date routing table towards all the nodes of the network.

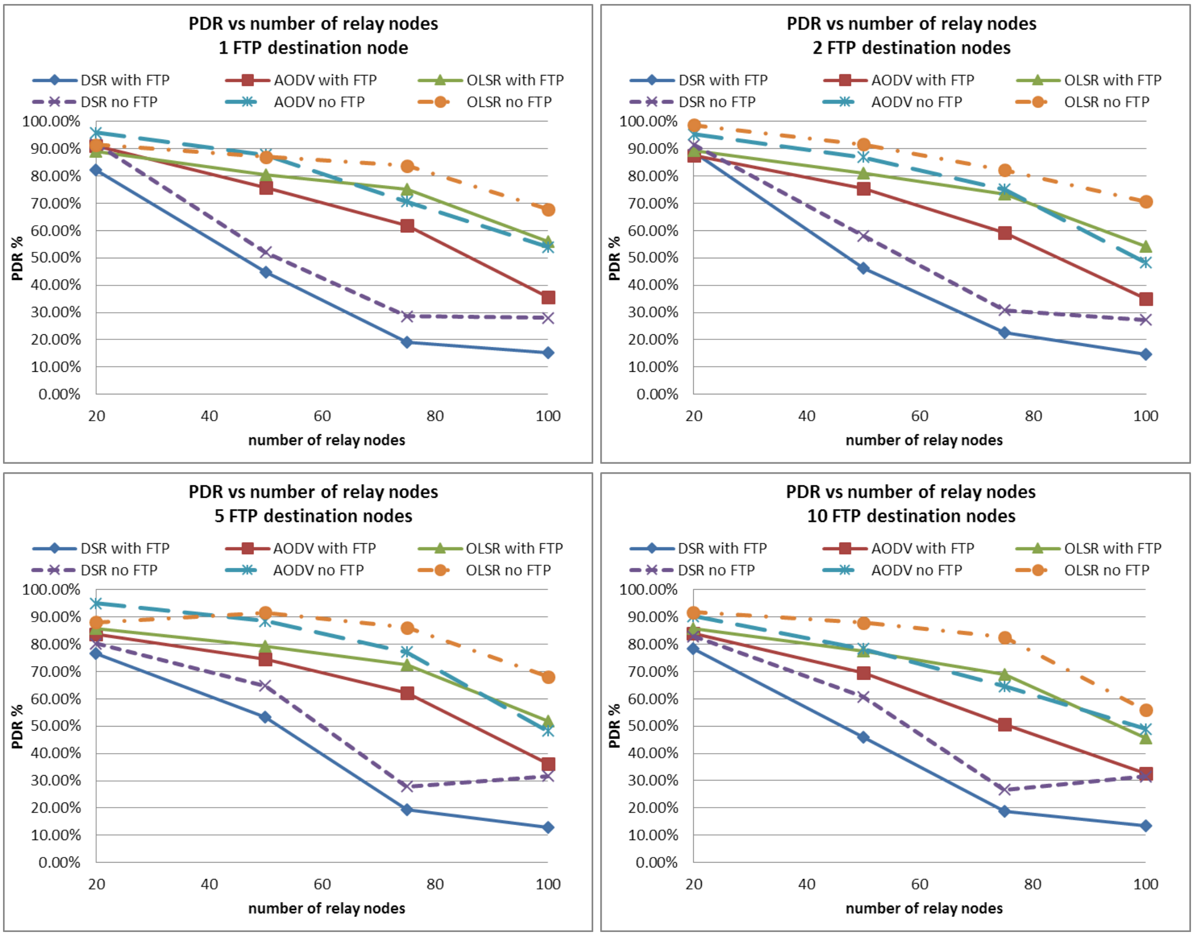

Fig. 1. PDR vs number of relay nodes when 1, 2, 5 or 10 FTP destination nodes or equivalent traffic exists in the network

The impact of the presence of FTP source and destination nodes on the performance of the protocols is obvious in all of the simulation cases. A set of simulations was performed without the presence of FTP traffic but with additional non-specific application traffic in order to maintain the total load of the network equivalent to the load with FTP source and destination nodes. The performance of all the protocols is significantly better, as can be seen in all the figures. In all the simulation cases OLSR outperforms DSR and AODV in all of the performance metrics, except for low traffic and low density cases. Then, the three protocols have similar performance in terms of PDR and AEED, but defer at NRO with OLSR producing significantly more overhead than AODV and DSR. The latter has the less overhead, since it does not need to periodically sent HELLO messages as AODV or to always maintain an up-to-date routing table as OLSR. OLSR performance is not affected by the density of the relay nodes in the network and is slightly affected by the number of FTP flows present in the network.

Although in all the simulations the protocols follow the above patterns, OLSR seems to have better performance than the other two in high density and high traffic cases. Nevertheless, it uses a significant amount of overhead traffic to achieve this. DSR performance is adequate for low-density and low-traffic cases without burdening the network with excessive overhead traffic. In dense and high-traffic cases though, its performance is rather poor, although there is not significant impact on the overhead. AODV performance is adequate in all network densities and traffic loads, while overhead is maintained at reasonable levels.

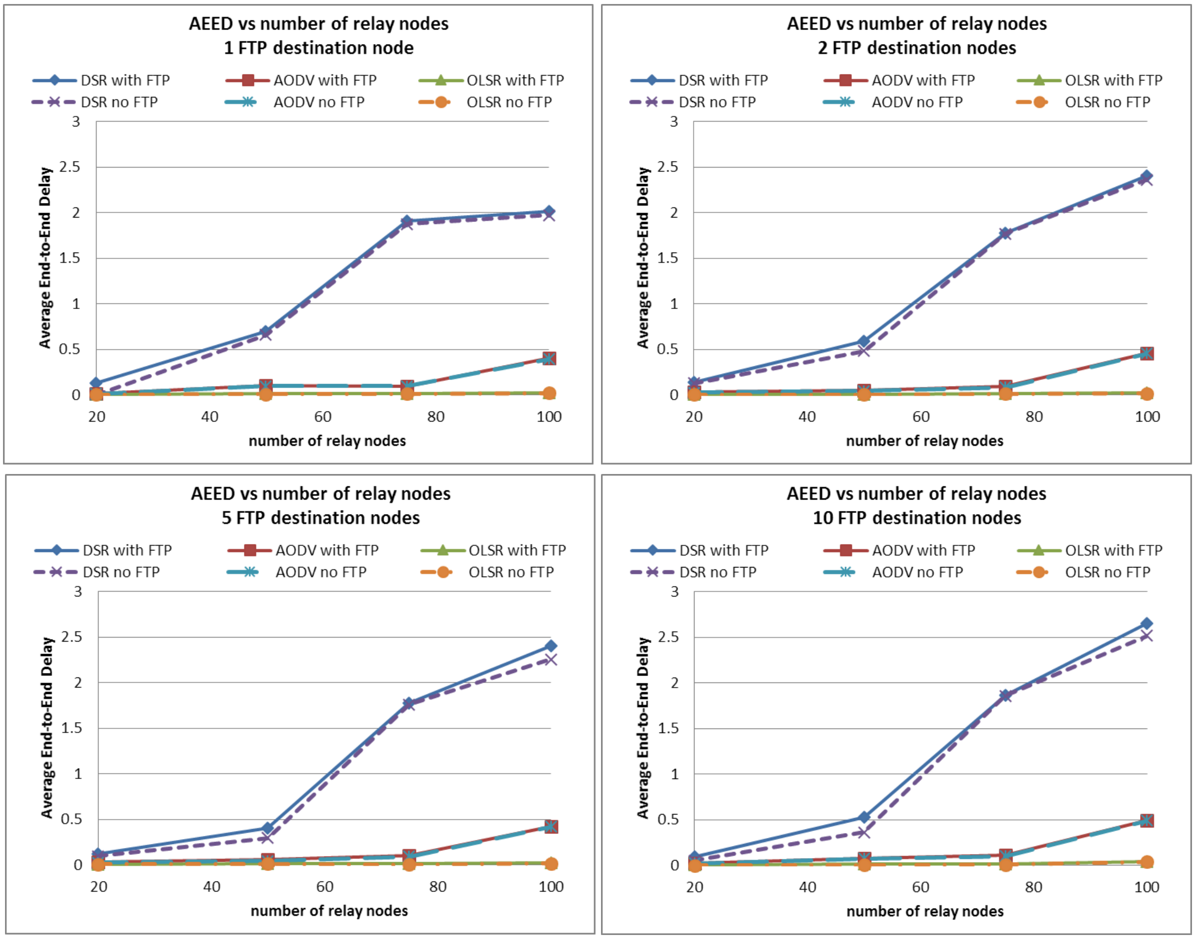

Fig. 2. Average End-to-End Delay vs number of relay nodes when 1, 2, 5 or 10 FTP destination nodes or equivalent traffic exists in the network

Finally, we investigate the impact of different mobility models on the performance of the routing protocols. The simulation results using Random Waypoint and Gauss-Markov mobility models are similar for all cases examined, without important differences. Therefore, we presume that the mobility pattern does not have any impact on the performance of the routing protocols.

5. Conclusions and future research

In this paper we investigated the performance of three popular MANET routing protocols. In our scenario we used non-specific application traffic (like CBR and burst traffic generators) and FTP traffic at the same time. We compared the simulation results to the results of a simulation where FTP was absent but the total traffic load was the same. Then, the three protocols have better performance in terms of PDR and NRO for all the cases studied, while AEED remains in the same level as when FTP traffic coexists in the network. The NRO of OLSR is not affected by the density of the relay nodes in the network and is slightly affected by the number of FTP flows that are present in the network. Therefore, we conclude that the type of traffic affects the performance of the routing protocols. By repeating the simulations for a different mobility model, we concluded that the mobility pattern does not have any impact on the performance of the routing protocols.

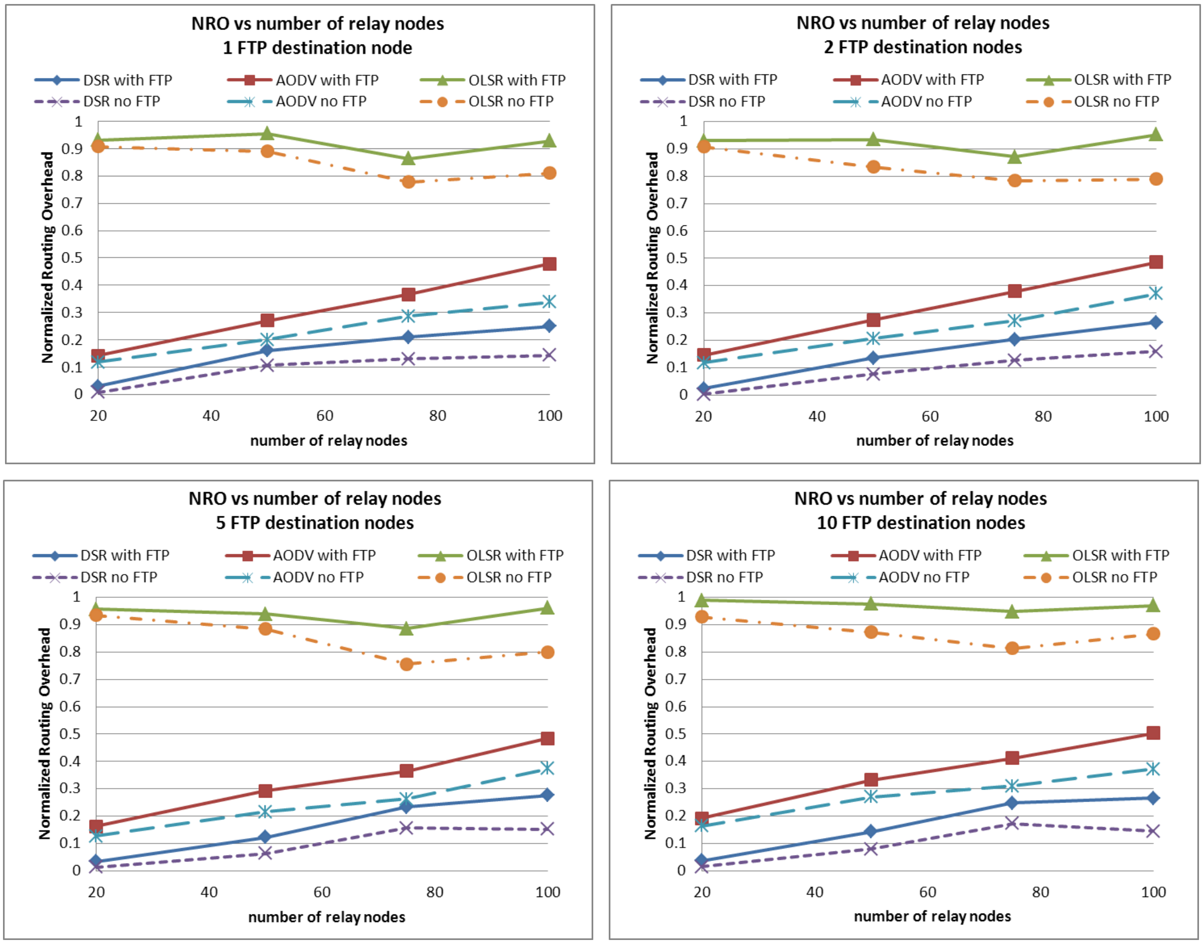

Fig. 3. Normalized Routing Overhead vs number of relay nodes when 1, 2, 5 or 10 FTP destination nodes exist in the network

Although OLSR has the best performance of all three protocols in terms of PDR and AEED, it produces significantly more overhead traffic to maintain updated routing tables. DSR has poor performance in contrast to AODV and OLSR in all metrics considered in this study. Finally, AODV has adequate performance and in the same time keeps the overhead traffic rather low in contrast to OLSR. Overall, OLSR performs better than AODV and DSR, but it is not the best choice in case we need to keep overhead traffic low.

It is finally obvious that the type of traffic in the network has a significant impact on the performance of the three protocols under investigation. In the future we plan to further investigate the impact of other applications' traffic (e.g. HTTP) on routing protocols' performance and expand our study towards hybrid routing protocols, considering more metrics and more complex scenarios.

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