ROUTING PROTOCOLS FOR MOBILE AD-HOC NETWORKS PERFORMANCE ENHANCEMENT

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Abstract

Current research on routing protocols for Mobile Ad-hoc NETwork (MANET) has converged to several dominating routing protocols, including Optimized Link State Routing (OLSR), Ad-hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR). At the same time, classic routing protocols such as Open Shortest Path First (OSPF) and Destination Sequenced Distance Vector (DSDV) are improved for the MANET context. Research efforts also focus on issues such as Quality of Service (QoS), energy efficiency, and security, which already exist in the wired networks and are worsened in MANET. This paper examines the routing protocols and their improvements. We discuss the metrics used to evaluate these protocols and highlight the essential problems in the evaluation process itself.

I. Introduction

In the recent years, research efforts have been focusing on improving the performance of routing protocols in MANET. The Internet Engineering Task Force (IETF) created a MANET working group (WG) to deal with issues related to the complexity of constructing MANET routing protocols. The MANET WG coordinates the development of several candidates among the protocols including OLSR and AODV. These protocols are classified into two classes based on the time when routing information is updated, the Proactive Routing Protocols (PRP) and Reactive Routing Protocols (RRP). The WG may also consider a converged approach such as hybrid routing protocols.

There are other classifications of routing protocols such as the distance vector (DV) class and link state (LS) class based on the content of the routing table. The DV protocols broadcast a list of distances to the destinations and each node maintains the routing table of the shortest paths to each known destination. On the other hand, the LS protocols maintain the topology of the network. Each entry in LS routing table represents a known link. In LS routing, each node needs to calculate the routing table based on the local (link state) information in order to obtain a route to destination. The OLSR is the most widely used link state protocol, while AODV is the most popular distance vector protocol.

Another classification of routing protocols is source routing and hop-by-hop routing. In source routing, the source computes the complete path towards the destination, which consequently leads to loop-free routing. In hop-by-hop routing, each intermediate node computes the next hop itself.

II. Proactive Routing Protocols (PRP)

In proactive (table-driven) protocols, nodes periodically search for routing information within a network. The control overhead of these protocols is foreseeable, because it is independent to the traffic profiles and has a fixed upper bound. This is a general advantage of proactive routing protocols.

DSDV: The Destination-Sequenced Distance-Vector (DSDV) Routing protocol is based on the idea of the classical Bellman-Ford Routing Algorithm with certain improvements such as making it loop-free. The distance vector routing is less robust than link state routing due to problems such as count to infinity and bouncing effect. **OSPF:** OSPF is the dominating link state routing protocol in wired IP networks. Consequently, it is possible to adapt OSPF to the wireless networks in order to establish a seamless ubiquitous IP network. The main goal of OSPF is to quickly update the routing tables after the topology changes in a consistent way. OSPF uses Dijkstra's shortest path algorithm to construct the forwarding tables based on the network link state database. In, an improvement of OSPF to adapt to the MANET context is presented, by: introducing the OLSR multicast mechanism to OSPF to reduce the broadcasting overhead, replacing the unicasted acknowledgement with implicit acknowledgement.

OLSR: III. REACTIVE ROUTING PROTOCOL (RRP)

The reactive (on-demand) routing protocols represent the true nature of ad hoc network, which is much more dynamic than infra structured networks. Instead of periodically updating the routing information, the reactive routing protocols update routing information when a routing require is presented, consequently reducing the control overhead, especially in high mobility networks where the periodical update will lead to significant useless overhead.

AODV: Ad hoc On-demand Distance Vector Routing (AODV) is an improvement of the DSDV algorithm. AODV minimizes the number of broadcasts by creating routes on-demand as opposed to DSDV that maintains the list of all the routes. The on-demand routing protocols suffer more from frequent broken source-to-destination links than table driven routing due to the delay caused by on-demand route recalculation. AODV avoids such additional delay by using distance vector routing.

IV. Hybrid Routing Protocols

The Ad Hoc network can use the hybrid routing protocols that have the advantage of both proactive and reactive routing protocols to balance the delay and control overhead (in terms of control packages). Hybrid routing protocols try to maximize the benefit of proactive routing and reactive routing by utilizing proactive routing in small networks (in order to reduce delay), and reactive routing in large-scale networks (in order to reduce control overhead).

The results show the hybrid routing protocols can achieve the same performance as the OLSR and are simpler to maintain due to its scalable feature. The common disadvantage of hybrid routing protocols is that the nodes that have high level topological information maintains more routing information, which leads to more memory and power consumption.

ZRP: The Zone Routing Protocol (ZRP) localizes the nodes into sub-networks (zones). Within each zone, proactive routing is adapted to speed up communication among neighbors. The inter-zone communication uses on-demand routing to reduce unnecessary communication. An improved mathematical model of topology management to organize the network as a forest, in which each tree is a zone. This algorithm guarantees overlap-free zones. Furthermore, the concept introduced in this algorithm also works with QoS control because the topology model is also an approach to estimate the link quality.

V. Analysis

There are two approaches to evaluate routing protocols: using simulation or performing experiments on real hardware. In both cases, the performance metrics as well as the network context are equally important. In the rest of this paper we focus on the simulation approach in which the network parameters must be specified first.

A. Network Environment Parameters

The network context has a strong impact on the performance of routing protocols. The essential network parameters include: network size: presented as number of nodes; connectivity: the average degree of a node, normally presented as number of neighbors; mobility: the topology of the network, relative position and speed of the nodes; link capacity: bandwidth, bit error rate (BER), etc. The above metrics form the basic subset of network parameters. In order to design realistic mathematical network models, additional metrics are required. A good description of novel mobility models and their parameters is proposed. In this model, however, there is a very complex relation between the properties of the routing protocols and those of the mobile nodes. For example, node speed changes have impact on several parameters of the routing protocol functions.

B. General Performance Metrics of Routing Protocols

The major four metrics used for evaluation of the relative performance of ad hoc routing algorithms are as follows: message delivery ratio: the total number of messages received at their intended destination divided by the total number of generated messages. Please note that there is a heavy dependence of the measured results and the test duration for certain protocols; control overhead: this can be measured in terms of number of control packets or as the ration of the number of control bytes and the total number of bytes transmitted by the network; hop count: also referred as path optimization, the average number of hops that successful messages did travel to reach their final destination. end-to-end delay: the average delay time of all successfully delivered packets.

C. Additional evaluation criteria

In addition to the above performance parameters, several important non-quantitative aspects are used to compare the routing protocols, more precisely QoS support, energy efficiency and security.

QoS Support: Traditional ad hoc routing protocols just consider links as available for transmissions or not existing. In MANET, however, the link stability is dynamic and has a direct impact on QoS. A general model of MANET link stability is established for QoS analysis. Another approach is to apply an algorithm that enables link quality-awareness in cognitive packets. Those packets observe the quality of the links and other network metrics (e.g. delay), and exploit this information in the establishment of robust multi-hop routes. Because OLSR supports multiple routing searches, it is possible to support QoS routing with little modification within the frame. The QoS routing mechanism for is introduced.

Security: Without some form of network-level or link layer security, MANET routing protocols are vulnerable to many forms of attack. While the concern exists within wired infrastructures and routing protocols as well, maintaining the .physical. security of the transmission media is harder in MANET.

Energy Efficiency: As most of the ad hoc mobile nodes are standalone and depends on battery energy, the ad hoc routing protocols must be energy efficient when forwarding data packages among the nodes. One example of the energy consumption model of routing protocols in MANET , considering topology related broadcasting, state of the nodes, and traffic characteristics. As the topology has a strong impact on energy consumption, dedicated algorithm that constructs a multicast tree in MANET considering energy efficiency is defined. For cluster-based networks, an improvement of topology construction process is presented .

D. The current evaluation methodology evaluated

Various open source and commercial simulators are used for MANET routing protocols evaluation, e.g. NS-2, OPNET and APE, just to name a few. Furthermore, different simulators implement MANETs in unique ways and some of them can be characterized as platform dependent. For example, the produced results may be influenced by certain properties of the simulation platform such as processor architecture, clock frequency and memory sizes and speed. To clarify this we selected three different studies of DSR and AODV protocols performed using similar test scenarios. The three studies did use the following test setting: Mobility model: random waypoint; Node speed: 0-20m/sec; Number of nodes: 40-50; Traffic type: Constant Bit Rate (CBR), 20 sources; Test duration: 900 sec. In table I, the results of the different studies in the form Value AODV / Value DSR are depicted.

TABLE I

AODV AND DSR SIMULATION RESULTS

data references	[33] (40 nodes)	[34] (50 nodes)	[22] (40 nodes)
end-to-end delay[a]	$\sim 45/\sim 68sec$	$\sim 1.8/\sim 8ms$	NA
control overhead	$\sim 20k/\sim 5k$	$\sim 2/\sim 0^b$	$\sim 50k/\sim 10k$
throughput	NA	99%/99%	85%/97%

[a]those are average values of the reported results

[b]packet overhead normalized per data packet is reported [34]

It can be observed from table I, the results can give only a relative indication that AODV performs better than DSR in terms of average delay under the considered test scenario. The exact ratio, however, can not be clearly defined.

VI. Conclusions

The recent research efforts have made big progress on ad hoc network routing, both in theory and in practical implementation. The tendency in proactive routing protocol research is to apply OLSR-like multicast mechanism to other proactive routing protocols in order to optimize flooding. On the other hand, the competitive reactive routing protocols, AODV and DSR, both show better performance than the other in terms of certain metrics. It is still difficult to determine which of them has overall better performance in MANET. From the study of the performance evaluation of routing protocols in MANET, we know the results are highly disturbed by the network model and network parameters.

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