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Multipath optimized link state routing for mobile ad hoc networks

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ABSTRACT

Multipath routing protocols for Mobile Ad hoc NETwork (MANET) address the problem of scalability, security (confidentiality and integrity), lifetime of networks, instability of wireless transmissions, and their adaptation to applications.

Our protocol, called MultiPath OLSR (MP-OLSR), is a multipath routing protocol based on OLSR [1]. The *Multipath Dijkstra Algorithm* is proposed to obtain multiple paths. The algorithm gains great flexibility and extensibility by employing different link metrics and cost functions. In addition, *route recovery* and *loop detection* are implemented in MP-OLSR in order to improve quality of service regarding OLSR. The backward compatibility with OLSR based on IP source routing is also studied. Simulation based on Qualnet simulator is performed in different scenarios. A testbed is also set up to validate the protocol in real world. The results reveal that MP-OLSR is suitable for mobile, large and dense networks with large traffic, and could satisfy critical multimedia applications with high on time constraints.

1. Introduction

Staying connected anywhere to a network is really the main objective of mobile technologies. Mobile Ad hoc NETwork (MANET) may provide a solution. With MANET, all nodes are routers and forward packets without any infrastructure. This kind of network is spontaneous, self-organized and self-maintained. In this context, routing the data is the big challenging task since many issues are covered: scalability, security, lifetime of network, wireless transmissions, increasing needs of applications.

Many routing protocols have been developed for ad hoc networks [2]. They can be classified according to different criteria. The most important is by the type of route discovery. It enables to separate the routing protocols into two categories: proactive and reactive. In reactive protocols, e.g. Dynamic Source Routing (DSR [3]) and Ad hoc On-demand Distance Vector routing (AODV [4]), the routing request is sent on-demand: if a node wants to communicate with another, then it broadcasts a route request and expects a response from the destination. Conversely, proactive protocols update their routing information continuously in order to have a permanent overview of the network topology (e.g. OLSR [1]).

Another criterion for ad hoc routing protocol classification is the number of routes computed between source and destination: multipath and single path routing protocols. Unlike its wired counterpart, the ad hoc network is more prone to both link and node failures due to expired node power or node mobility. As a result, the route used for routing might break down for different reasons. To increase the routing resilience against link or/and node failures, one solution is to route a message via multiple disjoint paths simultaneously. Thus, the destination node is still able to receive the message even if there is only one surviving routing path. This approach attempts to mainly address the problems of the scalability, mobility and link instability of the network. The multipath approach takes advantage from the large and dense networks.

Several multipath routing protocols were proposed for ad hoc networks [5]. The main objectives of multipath routing protocols are to provide reliable communication and to ensure load balancing as well as to improve quality

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of service (QoS) of ad hoc and mobile networks. Other goals of multipath routing protocols are to improve delay, to reduce overhead and to maximize network life time.

Multiple paths can be used as backup route or be employed simultaneously for parallel data transmission (like round robin). The multiple paths obtained can be grouped into three categories:

1. *Disjoint*: This group can be classified into node-disjoint and link-disjoint. In the node-disjoint multipath type, there are no shared nodes between the calculated paths that links source and destination. The link-disjoint multipath type may share some nodes, but all the links are different.
2. *Inter-twisted*: The inter-twisted multipath type may share one or more route links.
3. *Hybrid paths: The* combination of previous two kinds.

Of all the multipath types, the node-disjoint type is the most disjointed, as all the nodes/links of two routes are different i.e. the network resource is exclusive for the respective routes. Nevertheless, the pure disjoint approach is not always the optimal solution, especially for sparse networks and multi-criteria computing. As we will see, our Multipath Dijkstra Algorithm is more flexible when keeping all the solutions in the shortest paths algorithm.

In this paper, we started from the MultiPath Optimized Link State Routing protocol (MP-OLSR) presented in [6] which was thoroughly revisited and upgraded. Contributions are multiple. First, a major modification of Dijkstra algorithm allows for multiple paths both for sparse and dense topology. Two cost functions are used to generate node-disjoint or link-disjoint paths. Second, the OLSR proactive behavior is changed for an on-demand computation. MP-OLSR becomes a source routing protocol. Third, to support the frequent topology changes of the network, auxiliary functions, i.e. *route recovery* and *loop check*, are implemented. The contribution of these two functions is quantified in terms of quality of service parameters and compared with OLSR. Fourth, the backward and forward compatibility study with its single-path version (OLSR) is proposed. The cooperation between the two protocols is expected here to facilitate the application and deployment of the new protocol. Simulations and real testbed demonstrate all the contributions.

The remainder of the paper is organized as follows. In Section 2, related works on multipath routing protocols are summarized. In Section 3, we introduce our protocol MP-OLSR and its auxiliary functionalities. Simulation and performance evaluation are presented in Section 4. Section 5 presents the testbed and provides related test results. Compatibility between OLSR and MP-OLSR is studied in Section 6. Finally, we conclude this paper.

2. Related works

In this section, we will first present the current situation of OLSR standardization, which includes both OLSR version 1 and OLSR version 2. Then some typical multiple path routing protocols for MANET are presented. And a related study based on testbed for MANET is introduced at the end.

2.1. OLSR version 1 and OLSR version 2

OLSR, the most popular proactive routing protocol for ad hoc networks and OLSR version 1 (OLSRv1), has been standardized as an experimental RFC [1]. It is a link state protocol in which each node will send out *HELLO* and Topology Control (*TC*) messages periodically. It reduces the overhead of flooding link state information by requiring just Multi Point Relay (MPR) to forward the *TC* messages. A routing table is maintained to keep the next hop information to all the possible destination nodes.

OLSR version 2 (OLSRv2) has the same algorithm and ideas as OLSRv1. Being modular by design, OLSRv2 is made up from a number of generalized building blocks, standardized independently and applicable also for other MANET protocols. Currently, RFC 5148 – Jitter Considerations in mobile ad hoc networks [6], RFC 5444 – Generalized MANET Packet/Message Format [7] and RFC 5497 – Representing Multi-Value Time in mobile ad hoc networks (MANETs) [8] are published as RFCs, with the remaining constituent parts (MANET Neighborhood Discovery Protocol [9] and OLSRv2 [10]) being in the final phases of standardization. It has a more modular and extensible architecture, and is simpler and more efficient than OLSRv1. The multipath and its compatibility that we propose can also exist as additional modules in the OLSRv2 framework.

2.2. Multipath routing protocol for ad hoc networks

Most of the proposed multipath protocols are based on the single-path version of an existing routing protocol: AODV and AOMDV [11], DSR and SMR [12].

Most of these protocols are based on a reactive routing protocol (AODV [4] or DSR [3]). In fact, reactive multipath routing protocols improve network performances (load balancing, delay and energy efficiency), but they also have some disadvantages:

- *Route requeststorm: Multipath* reactive routing protocols can generate a large number of route request messages. When the intermediate nodes have to process duplicate request messages, redundant overhead packets can be introduced in the networks [13].
- *Inefficient route discovery:* To find node-disjoint or link-disjoint paths, some multipath routing protocols prevent an intermediate node from sending a reply from its route cache [14]. Thus, a source node has to wait until a destination replies. Hence, the route discovery process of a multipath routing protocol takes longer compared to that of DSR or AODV protocols.

Compared to reactive routing, the proactive routing protocols need to send periodic control messages. Hence, several researchers consider proactive routing protocols as not suitable for ad hoc networks [5]. For a network with low mobility and network load, the reactive routing protocols generate fewer control messages. However, given a network with high mobility and large traffic, the cost of