# Combining Temporal and Spatial Partial Topology for MANET routing - Merging OLSR and FSR

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***Abstract*—**
**In this paper, we propose an extension to the Optimized Link State Routing (OLSR) protocol, a proactive link-state routing protocol optimized for mobile ad-hoc networks, introducing temporal partial topology as a mechanism for reducing control traffic overhead. The extension is inspired from Fisheye State Routing (FSR), and complements the spatial partial topology of OLSR in extending scalability of manet routing protocols to large, dense networks.**

**Through simulations, the paper justifies that through introducing temporal partial topology information in OLSR, the control traffic overhead in some manet configurations can be reduced.**

## I. Introduction

The objective for routing protocols is to provide multi-hop paths between any (source,destination) pairs. Wireless interfaces and node mobility introduce an additional objective for ad-hoc routing protocol: fast convergence with minimal control traffic. AODV [7]), DSR ([3]), OLSR ([1]) and TBRPF ([5]) utilize partial spatial topology towards reducing control traffic: AODV and DSR maintain only information describing active routes; OLSR and TBRPF maintain routes to all destinations, carefully diffusing only the partial link-state information required to provide shortest-path routes.

An alternative approach is Fisheye State Routing, FSR [6]: a node sends frequent link-state advertisements (LSAs) about nodes which are close, while sending LSAs about far away nodes less frequently. Effectively, information about a node, $a$ is thereby accurate in nodes close to node $a$ while possibly blurry or slightly incorrect when farther away.

Based on OLSR, this paper applies the idea from FSR: information about a destination is maintained progressively less accurate as the distance from the destination increases. The objective is to use FSR to increase the scalability in very large OLSR networks. This paper, therefore, specifies an extension to OLSR, utilizing the ideas from FSR while maintaining complete compatibility with OLSR.

We compare OLSR with the FSR extension to basic OLSR through simulation studies to get an indication of the feasibility of the approach of combining temporal and spatial partial topology.

### A. Paper Outline

The remainder of this paper is organized as follows: section II and section III outline the core features of OLSR and FSR. Following, section IV specifies how features from FSR can be incorporated into OLSR, specifically with the aim of improving scalability to geographically very large networks. In section V, we subject OLSR with the FSR inspired extension to simulation studies, and compares the achieved performance to that of basic OLSR. We specifically conduct these simulations so as to expose the advantages (if any) of the combined approach. Finally, section VI concludes the paper and outlines directions for future work.

## II. OLSR

OLSR is a proactive link-state routing protocol, employing periodic message exchange to update topological information in each node in the network. OLSR is specifically designed to operate in the context of MANETs, i.e. in bandwidth-constrained, dynamic networks.

In this section, we present the architecture and optimizations of the OLSR protocol with the purpose of exposing necessary details for integrating the optimizations from FSR into OLSR.

### A. Protocol Architecture

Conceptually, OLSR contains three generic elements: a mechanism for neighbor sensing, a mechanism for efficient diffusion of control traffic to nodes in the network, and a mechanism for selecting and diffusing sufficient

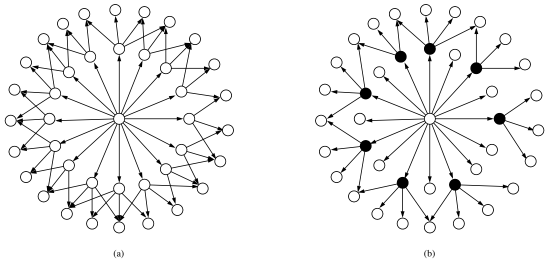

Fig. 1. *Example of pure flooding (a) and diffusion using Multipoint Relays (b). The source of the message is the node in the center. Each arrow pointing to a node, indicates that a node receives a copy of the message. The filled nodes are selected by the center node as Multipoint Relay.*

topological information in the network in order to provide optimal routes. These elements are described in briefly in the following.

All information, stored in a node, is considered valid for a limited period of time, and must be refreshed at least periodically to remain valid. Invalid (expired) information is purged, and not used.

### *B. Neighbor Sensing*

A node in OLSR uses neighbor sensing for three purposes: (i) to detect changes to its neighborhood (ii) to check bi-directionality of links to neighbor nodes and (iii) to acquire topology information up to two hops away. This is achieved through periodic emission of HELLO messages by each node. A HELLO message contains a list links of its neighbors as well as their associated link status (*asymmetric*, *symmetric*).

### *C. MPR flooding*

OLSR applies an optimized flooding mechanism, MPR-flooding, to minimize the problem of duplicate reception of message within a region. The optimization is simple: each node must select the minimal set (called the MPR set) from among its symmetric neighbors such that a message relayed by the MPR set will be received by all symmetric 2-hop neighbors.

Symmetrically, each node has a (possibly empty) set of MPR selectors (neighbors, which have selected the node as MPR). A node, selected as MPR, has the responsibility of relaying flooded messages from its MPR selectors. A message emitted by node *a* is thus only retransmitted by node *b* if node *a* is in the MPR selector set of node *b*. As illustrated in figure 1b,"careful" selection of MPRs (the filled nodes) may greatly reduce duplicate retransmissions – compared to figure 1a, illustrating full flooding with many "duplicate receptions" (with potential collisions) of a flooded message.

Nodes select their MPRs independently, based on information acquired through neighbor sensing. [8] presents an analysis of MPR selection algorithms.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Packet Length         |    Packet Sequence Number     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Message Type |     Vtime     |         Message Size          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Originator Address                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Time To Live |   Hop Count   |    Message Sequence Number    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
:                            MESSAGE                            :
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Message Type |     Vtime     |         Message Size          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Originator Address                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Time To Live |   Hop Count   |    Message Sequence Number    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
:                            MESSAGE                            :
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
           (etc)
```

Fig. 2. *Generic OLSR control traffic packet format. The MESSAGE field will typically contain a HELLO or TC message from OLSR.*

### *D. Control Message Transport*

[1] defines a generic message format and an algorithm for processing OLSR control messages. This packet format is illustrated in figure 2. Notice that time-to-live (TTL) considerations, limiting the number of hops a packet is transmitted, a validity time field (vtime) indicating the duration after receipt of the packet for which a node should consider the information in the packet is valid, sequence numbers *etc*. are included. For the purpose of the FSR inspired extension described in this paper, it is worth noticing that this specification, without modifications, allows for hop-limited distribution of manet-wide messages. Indeed, this is used by OLSR to limit HELLO message distribution to the neighborhood of the originator only.

### *E. Topology Information*

In OLSR, a partial topology-graph is build in each node, containing all reachable destinations in the network and a partial set of the links. To construct this graph, nodes with a non-empty MPR selector set per periodically generate TC-messages, listing their own address and the address of each node in its MPR selector set. This TC-message is diffused to all nodes in the network using MPR flooding and provides the link-state information required for building the topology graph.

Since all nodes must select a non-empty MPR set (assuming that all nodes can not reach each other directly), reachability to all nodes will be announced through the network. The result is that all nodes will receive a partial topology graph of the network, made up by all reachable nodes in the network and the set of links between a node and its MPR selectors. Using this partial topology graph, it is possible to apply a shortest path algorithm for computing optimal routes from a node to any reachable destination in the network [1]. A noticeable result is that the shortest path obtained from the partial topology yielded by the TC-messages have the same length as the shortest path from the full topology [2].

### F. OLSR optimizations

OLSR thus employs partial spatial topology through (i) building a partial broadcast tree for efficient MPR flooding, (ii) allowing only subset of nodes to issue TC messages, thereby (iii) maintaining a partial topology graph in each node for route calculation.

OLSR thus employs partial topology for handling dense networks by ignoring redundant links in a region.

## III. FSR

FSR is a proactive routing protocol, in which each node maintains complete link-state information about the network (as in a link-state protocol), however exchange topological information only between neighbor nodes, employing destination sequence numbers for ensuring freshness of information (as in a distance-vector protocol). In FSR, neighbor nodes exchange their topology graphs periodically.

In a large network, periodic exchange of complete topology graphs, even between neighbor nodes, could introduce a significant control traffic overhead. Hence, FSR introduces the concept of temporal partiality, whereby not all topology exchange messages from a node contain information about all the destinations known by the node. Rather, in FSR, a node advertises information about closer nodes, more frequently than it does about nodes farther away. The aim is at reducing the size of LSA messages. Thus, each node gets accurate information about its direct neighbors, with the accuracy of information about destinations decreasing as the distance from node increases.

Thus, considering figure 3, node *d* will include the nodes in scope 1 in all its topology exchange messages, nodes in scope 2 included less frequently and so on.

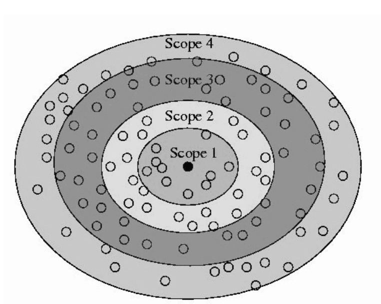


Fig. 3. *Information about node* d *(solid circle) is maintained with decreasing accuracy as the distance increases.*

The assumption behind FSR is that for a node to route data correctly to a far-away destination, accurate topology information is not required. Rather, the "general direction" in which data is to be sent suffices. As the data approaches the destination, the topology information becomes increasingly more accurate, thus allowing that the data is eventually delivered to the destination. This corresponds well with hop-by-hop routing, where the main issue for any node is to identify the next hop which will bring a data packet closer to the destination – rather than identifying the exact path a packet will take towards the destination.

### A. FSR optimizations

FSR maintains, through periodic exchange of topology information between neighbor nodes, a constant number of control messages, proportional to the number of nodes in the network. FSR also maintains a full topology graph in each node in the network. The size of the topology exchange messages is sought optimized through reducing the frequency at which far-away destinations are updated. Thus, FSR employs temporal partial information, maintaining an "approximative" topology graph in each node, with topological information about a destination becoming less and less accurate as the distance to the destination increases. Or, in other words, FSR optimizes towards the diameter of the network.

[6] presents studies of the performance of FSR under different conditions.

## IV. MERGING OLSR AND FSR

Section II described OLSR as a link-state protocol, in which neighbor nodes exchange local topological information and select nodes periodically diffuse local such link-state information globally through an optimized manet-cast mechanism. Thus, OLSR optimizes specifically towards dense networks, employing spatial partiality: each node maintains partial topological information (all destinations, subset of links), and topological information is exchanged through transmission over a partial broadcast tree, spanning all destinations and a subset of links in the network.

Section III described FSR as a link-state protocol, employing periodic exchange of routing tables between neighbor nodes. The optimization employed in FSR is one of temporal partiality, whereby a node includes information of nearby nodes often and far-away nodes rarely – the frequency at which information about a node is included depending on the distance to that node.

In this section, we will describe one way in which the ideas from OLSR and FSR can be combined. The resulting protocol is based on OLSR, incorporating the idea of, from each nodes perspective, dividing the network into separate "scopes" and of maintaining information in far-away scopes less frequently than in neighbor nodes.

In FSR, a node would *report far-away nodes less frequent* than nearby nodes in its topology exchange messages. In OLSR, since a node reports only local information (links between a node itself and neighbor nodes) in TC messages, this is adopted such that a node *reports local information to far-away nodes less frequent*. Also notice, that the optimization achieved in FSR is one of reducing the *size* of the topology exchange messages, whereas the optimization achieved when applying the ideas from FSR to OLSR is one of reducing the number of retransmission of TC messages.

The remainder of this section will discuss the introduction of "scopes" in OLSR, as well as detail the FSR inspired extension to OLSR further.

### A. Scopes in OLSR

Basic OLSR does, in a very simple fashion, employ scopes: HELLO messages are exchanged frequently to verify local connectivity, however do also update topological information about a node up to two hops away. TC messages are sent at a lower frequently, updating topological information to the rest of the network. Thus, OLSR does without modifications employ two scopes: a local and a *global* scope. The interval between two TC messages is, typically, 2.5 times the interval between HELLO messages. Referring to figure 3, this corresponds to HELLO messages updating scope 1, with TC messages updating the remaining scopes.

A simple way of adding further scopes to OLSR is through controlling the distribution of TC messages. Referring again to figure 3, using hop-limited distribution of TC-messages, node *d* transmits TC messages "frequently" to nodes in scope 2, "less frequently" to nodes in scope 3 and so on. This causes information about links between node *d* and its neighbors to be more up-to-date to those nodes in scope 2 than scope 3 – and at the same time, reduce the control traffic overhead that incurs from forwarding control traffic messages.

Scope-delimited TC messages are possible using mechanisms already present in the OLSR protocol. Section II introduced the general message format for OLSR control traffic, noting the presence of a TTL field and a Vtime-field in the OLSR packet format. Thus, for scopes close to a node, TC messages can be generated and transmitted frequently, with a small TTL and a vtime set accordingly, while for scopes farther away, TC messages can be generated at a lower frequency and transmitted with a higher vtime.

For the purpose of this paper, we define a simple scoping and timing rule: a "scope" is 2 hops, the interval between TC messages increase by 3 seconds for each scope and the validity time for information received in a message is 3 times the message interval. This is consistent with the difference in basic OLSR between HELLO and TC messages: HELLO messages are updating topology up to two hops from a node and are sent every 2 seconds. TC messages update topology beyond 2 hops, and are sent every 5 seconds. Thus scope 2 will be nodes from 3-4 hops away, and will be updated every 5 seconds. Scope 3 will be nodes from 5-6 hops away, and will be updated every 8 seconds etc.

We notice that this is a very primitive rule, not taking the network topology and dynamics into account.

We also notice, that this does not change anything in the OLSR protocol as such. Rather, it uses the mechanisms provided in form of hop-limited message diffusion and per-message validity times. Thus a network would remain functional, even if the nodes participating do not agree on scoping and timing rules, as long as all nodes set the vtime and TTL correctly.

## V. Simulation Comparison

This section subjects OLSR with the FSR inspired extension to simulation studies, and compares the achieved performance to that of basic OLSR. The simulations are specifically conducted so as to expose the advantages of the combined approach, i.e. the simulation scenarios are chosen explicitly to uncover if introduction of temporal partial topology is beneficial in large networks.

For each sample point presented, 30 random scenarios are generated, corresponding to the parameters describing that point. The simulation results presented are an average over these 30 scenarios. This reduces the chance that results are dominated by a single scenario which, accidentally, favors one protocol over another. We emphasize, that the same set of 30 scenarios are used for all simulations in a given sample point, hence the different protocol options are evaluated under identical conditions.

For the simulations, the ns2 simulator is used. We keep the density of nodes constant to 100 nodes/$km^2$ and vary the geographic size of the network. The shape of the network is a square, and the wireless interfaces have a transmission range of 250m. We inject a small number of low-intensity CBR data streams in order to monitor if the data delivery rate and path lengths vary, depending on protocol[1]. The nodes move according to the random way-point model [4] at speeds from 0-10 $\frac{m}{s}$.

Figure 4 shows the amount of control traffic generated with basic OLSR and with OLSR combined with the FSR-inspired extension. We notice, that for smaller network sizes, the two protocol performs identically. When networks increase in size, the positive benefit of introducing temporal partial topology becomes apparent.

Our low-intensity CBR data streams allow us to compare the path lengths and the data delivery rates achieved. The results were found to differ consistently less than 2%, indicating that no degradation in data delivery reliability was observed, and that the temporal partial topology does not introduce additional overhead in form of longer paths for data traffic.

[1]In proactive protocols, the control traffic overhead is independant of the traffic patterns, hence a very light traffic load is introduced solely in order to be able to measure the protocols ability to construct routes and deliver data.

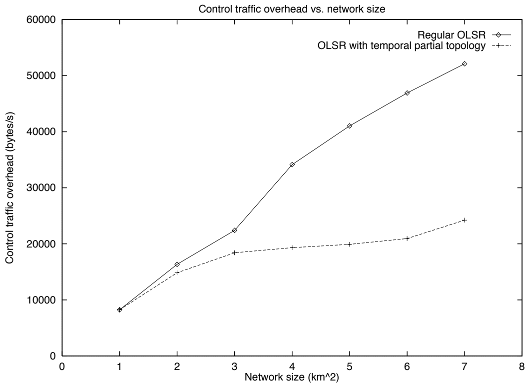


Fig. 4. *Control traffic overhead of basic OLSR and OLSR + temporal partial topology.*

## VI. CONCLUSION AND FUTURE WORK

In this paper, we have introduced a simple way of incorporating the ideas of partial temporal topology from FSR into OLSR, thereby combining partial temporal and spatial topology into one routing protocol. We note that this combined protocol is completely compatible with basic OLSR, allowing nodes running basic OLSR to coexist with the FSR-extended version of OLSR.

Simulation studies indicate, that for moderately-sized networks, the temporal partial topology has little impact on the amount of control traffic, whereas for very large networks, the impact of is significant.

In the future, these simulation studies should be extended to include those in [6] to investigate if the performance of OLSR with the temporal partial topology extension proposed in this paper is comparable to that of the original FSR. Also, future studies should be considering the performance in specific scenarios (such as large networks with local mobility) and with more realistic traffic patterns.

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