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Partial Topology in an MPR-based Solution for Wireless OSPF on Mobile Ad Hoc Networks

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Abstract: Using reduced topology within link state routing has proven to be an efficient way to decrease routing overhead while still providing sufficient route quality. There are various ways to achieve topology reduction, based on different ways to form a backbone in the network – this backbone usually originates from the flooding optimization scheme in use, such as MPR or CDS. In case of mobile ad hoc networks, flooding using MPR backbones is preferable as it is more robust in face of topology changes, compared to flooding using CDS backbones. This text therefore describes several methods to enable the use of reduced topology in wireless OSPF for MANETs, when MPR-based flooding optimizations are used. The topology reduction methods that are proposed for MPR-based approaches perform at least as well as the similar schemes that were recently proposed for CDS-based apporaches.

Key-words: Mobile networks, connected dominating set, multipoint relays, stability, collisions, partial topology

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Topologie Partielle Basée sur les MPR pour OSPF Sans-Fil dans les Réseaux Mobile Ad Hoc

Résumé : L'utilisation de la topologie partielle dans le cas du routage link state est un moyen efficace de réduire la quantité de bande passante requise par le protocole de routage, tout en gardant une qualité de route suffisante. Il y a plusieurs moyens d'extraire une topologie partielle, qui se basent essentiellement sur différentes façons de dégager une ossature dans le réseau. Cette ossature provient en général du méchanisme d'optimisation de flooding qui est utilisé dans le réseau, tels que les MPR ou autres CDS. Dans le cas des réseaux mobiles ad hoc, le flooding MPR est préférable aux autres flooding CDS, car plus robuste en cas de changements topologiques. Ce document décrit donc plusieurs méthodes afin d'introduire l'utilisation d'une topologie partielle dans sans-fil pour les Réseaux Mobile Ad Hoc, quand le flooding a base de MPR est utilisé. Ces méthodes de topologie partielles sont au moins aussi efficaces que les méchanismes similaires qui ont été proposé dans le cas de flooding à base d'autres CDS.

Mots-clés : Réseaux mobiles, ensembles dominants connectés, relais multipoint, stabilité, collisions, topologie partielle

1 Introduction

The most fundamental conlusion of the research accomplished so far in the field of MANETs (*i.e.* Mobile Ad hoc NETworks), is that the flooding overhead must be reduced, one way or another. The flooding optimization algorithms established by the MANET community are based on reducing the number of nodes actively participating in the forwarding of a given flood. Though there are many such different algorithms, they can nevertheless be classified in two main categories: (i) the algorithms that bring members of the set of forwarders to *select themselves* as part of this set, and (ii) the algorithms that bring members of the set of forwarders to *be selected* by their neighbors. CDS algorithms [1] are examples of (i) approach, while the MPR algorithm [7] is the archetype (ii) approach. However, going further than this classification, it is to be noted that the (i) approach is a special case of the (ii) approach.

Another fundamental conlusion of MANET research is that the use of partial topology, if done correctly, is an efficient way to help reduce the amount of bandwidth used by a routing protocol. An example of such a mechanism is the partial topology strategy developed with OLSR [7], enabling the use of reduced topology while still guaranteeing shortest paths and not impairing nework connectivity, or stability. Fig. 1 shows the substantial decrease in overhead with the use of partial topology schemes (bottom curves) compared to the full topology overhead (top curve).

Recent efforts in the IETF [14] [16] [15] attempt at designing an extension of the OSPF routing protocol [9] [10] for MANETs. Several proposals are being evaluated, including [12] and [11], aiming to converge to an extended OSPF standard.

The proposals for wireless OSPF on MANETs each feature an optimized flooding mechanism (based on CDS for [11], while based on MPR for [12]). MPR-based flooding is preferable as it is more robust than CDS-based flooding in face of topology changes and mobility [17]. However, partial topology schemes have been described in [11] for a CDS-based solution, while similar schemes are yet to be described for an MPR-based wireless OSPF. In the following we will therefore present approaches to partial topology for an MPR-based wireless OSPF solution, such as [12].

Section 2 will present methods to use reduced topology based on MPR backbones achieving at least as good results as the ones obtained using the CDS schemes described in [11].

However, based on MPR or CDS backbones, these schemes will produce slightly sub-optimal route quality: they introduce some route stretching, *i.e.* routes may include some unnecessary hops.

Therefore, Section 3 will present other partial topology methods based on MPR backbones, achieving optimal route quality: no route stretching, the shortest paths are used.

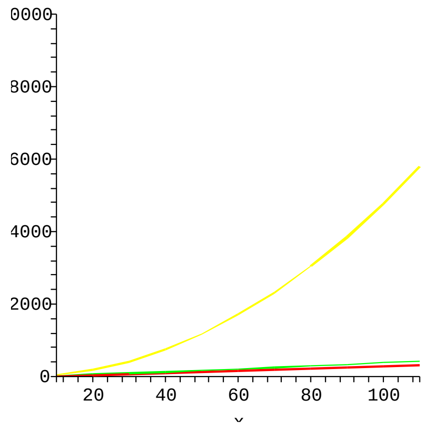

Figure 1: Full topology overhead (top) compared with partial topolgy overhead. Reduction to MPR selection links (bottom) and reduction to links to CDS nodes (middle). The overhead is measured in number of IP addresses (4 bytes per IP address), in function of the number of nodes in the network.

2 Approach with Route Stretch

In this section we will outline an approach to the use of reduced topology based on MPR backbones that achieves at least as good results as the ones obtained using the CDS schemes described in [11].

An MPR-based approach such as [12] can *decouple* its flooding mechanism from traditional OSPF Designated Routers mechanisms. Designated Routers are nodes that are given a special role of topology centralization and topology reduction in an OSPF network (see [9]). In that respect, an MPR-based approach can separate flooding optimization on one hand, and topology optimization schemes on the other hand.

A way to achieve this is to consider the MPR-CDS [8] laying naturally on top of the MPR selections. This CDS can be used, along with the same topology reduction techniques proposed in [11]. This approach then provides the same partial topology, and the same route quality properties (which means some amount of route stretching) as obtained with [11]. The advantage with the present solution is that the robustness of MPR flooding is kept, while still obtaining the same gains in topology reduction.

In fact, any other kind of CDS can be used on top of an MPR-based approach. The cost of using a different CDS is the additional complexity due to the computation of this specific CDS.

Furthermore, any other kind of topology reduction technique may be used along with the chosen

CDS, as long as it does not impair network stability, or connectivity.

The decrease in overhead with this method is shown with Fig. 1, comparing the middle curve to the full topology overhead (the top curve). In fact, the decrease in overhead may be slightly bigger, depending on the chosen topology reduction scheme.

However, wether they are used over an MPR approach or a CDS approach, the schemes proposed in [11], will produce slightly sub-optimal routes. These schemes introduce some route stretching, that is to say: routes may include some unnecessary hops (*i.e.* transmissions).

Route stretching is a concern in an environment where the number of transmissions are to be as limited as possible to reduce the bandwidth consumption, interference issues, number of collisions, or power consumption of the nodes in the MANET. In fact, route stretching really introduces some additional routing overhead, as it reduces the available bandwidth that can be used for data traffic. In other words, a 10% route stretch factor (*i.e.* routes being 10% longer) means a 10% decrease in available bandwidth for data traffic.

In the next section, we will therfore outline other approaches to partial topology based on MPR backbones, that do not introduce route stretching, and provide optimal routes.

3 Approach without Route Strech

In this section we will describe another partial topology method for MPR-based wireless OSPF solutions. Contrary to approaches described in [11] and in the previous section, this method does not degrade route quality.

Based on the approach developed in OLSR [7], and also taken by [13] for wireless OSPF, an MPR-based solution can provide partial topology without incuring any route sub-optimality, *i.e.* as if the full topology was indeed used.

Route optimality is achieved with the reduction of the flooded topology information to only the state of links between MPRs and their selectors, while still using the full topology information available locally. This approach provides shortest paths [3], as if the full topology was indeed advertized and flooded, while still drastically reducing the flooding overhead.

More precisely, in a wireless OSPF framework, [13] specifies that adjacencies are not to be formed between routers and that routing is done over any bi-directionnal link, as initially specified in [7]. Such an approach relies on periodic transmission of LSAs with short enough intervals so that it is more beneficial to just transmit updated information periodically, rather than to verify that the old information got through (through traditional adjacency OSPF mechanisms such as Acknowlegements or Database Exchange [9]).

The decrease in overhead with this method is shown with Fig. 1, comparing the bottom curve to the full topology overhead (the top curve).

However, if this approach to link state routing has proven to be the best in most MANET environments, in some cases it is not totally appropriate. These cases include scenarii targeted by the wireless OSPF design: mixing wired nodes and mobile nodes, or more generally, cases featuring more stable topologies, where updating topological information too often is wasteful. In these cases, the period with which different nodes update link information may vary greatly (from a few seconds, up to an hour), and this lack of homogeneity breaks the assumption that any update will come soon enough anyways.

In these cases, it is desireable to keep adjacencies and acknowledgements. Therefore an intermediate approach bringing optimal paths, but using partial topology, is to form adjacencies only between MPRs and their selectors. This yields more overhead than the approach described in Section 2 but the reward comes from being able to keep away from any route stretching and only use optimal, shortest paths.

4 Conclusion

In this paper, we have shown that partial topology mechanisms can be decoupled from the flooding mechanism, when an MPR-based solution is used for wireless OSPF in MANETs.

We have outlined several efficient ways to achieve topology reduction, including a simple technique that performs at least as well as the technique proposed in [11] for CDS-based approaches, in terms of overhead reduction.

We have also outlined other MPR-based techniques that perform better than the techniques proposed in [11], as they provide optimal paths while still drastically reducing the topology advertizement overhead.

The partial topology solutions described in this paper are advantageous compared to the solutions in [11], as they perform at least as well in terms of overhead reduction, while keeping MPR-based flooding, which is more robust than CDS-based flooding.

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