OLSR-H: A Satellite-Terrestrial Hybrid Broadcasting for OLSR Signaling

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Abstract. Mobile ad hoc networks (MANETs) are proposed for emergency situations because they are self-organized and infrastructure-less. However, the mobility of the nodes and the lack of infrastructure pose challenges to the routing protocols. The signaling of these protocols is affected by the same problems as the data traffic: a multi-hop environment with limited bandwidth, collisions and bit errors. This paper proposes a modification of the Optimized Link State Routing (OLSR) protocol to combine satellite and terrestrial broadcasting for their signaling and evaluates its performance in a forest fire fighting scenario.

Keywords: Routing, ad hoc networking, emergency, satellite.

1 Introduction

Mobile ad hoc networks have awoken the interest of the research community in the last decade. The mobility of the nodes produces frequent topology changes that should be reflected in the routing tables. For that reason, routing protocols exchange network state information to achieve proper routing of data packets to their destinations[1].

Satellites can play an important role in the distribution of routing signaling by offering a broadcast medium ensuring quality of service. This contribution is based on the Optimized Link State Routing OLSR[2] protocol. We chose a link state protocol because the route computation and topology discovery phases are well separated and therefore subject to different optimizations. Finally OLSR is among the popular and standardized routing protocols. OLSR-SAT[3] proposes to modify OLSR to distribute the broadcast signaling messages over satellite. It shows an improvement in packet delivery ratio for data packets traversing several hops.

However, this modification requires all nodes to have a satellite interface. In this paper we relax this constraint by combining satellite broadcast with the default OLSR terrestrial broadcast. This solution is called Optimized Link State Routing-Hybrid (OLSR-H).

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The broadcasting procedures of OLSR, OLSR-SAT and OLSR-H are explained in Section 2. A forest fire scenario is described in Section 3 and the simulation results of the protocols in this scenario are presented in Section 4.

2 OLSR Hybrid Broadcast

Proactive routing protocols such as OLSR broadcast network state information in order to support the computation of routing tables. However, broadcasting in a multi-hop wireless network as a MANET is not a trivial task[4].

The main broadcast signaling messages of OLSR are topology control (tc) messages. OLSR broadcasts these messages using multipoint relays (MPRs). The rationale is to reduce signaling overhead by using selective flooding. Each node selects a set of neighbors as multipoint relays. These neighbors will be the only ones allowed to forward broadcast messages from the node. This set of neighbors must be selected so to cover all the 2-hop neighbors.

In OLSR-SAT a geostationary satellite is used to broadcast the tc messages instead of MPRs in OLSR. It mitigates the impairments caused by partition, bit errors and collisions on the wireless medium. It also sets a constant travel delay of ca. 250 ms in place of variable travel delays caused by the multiple hops of the MPR broadcast. However for OLSR-SAT to be operational, all nodes must have a working transmission and reception satellite interface.

A more realistic approach is taken in this paper. A hybrid system combining both MPRs and satellite broadcasting systems is devised as OLSR-H. A node originating a broadcast message always sends it via terrestrial wireless and via satellite

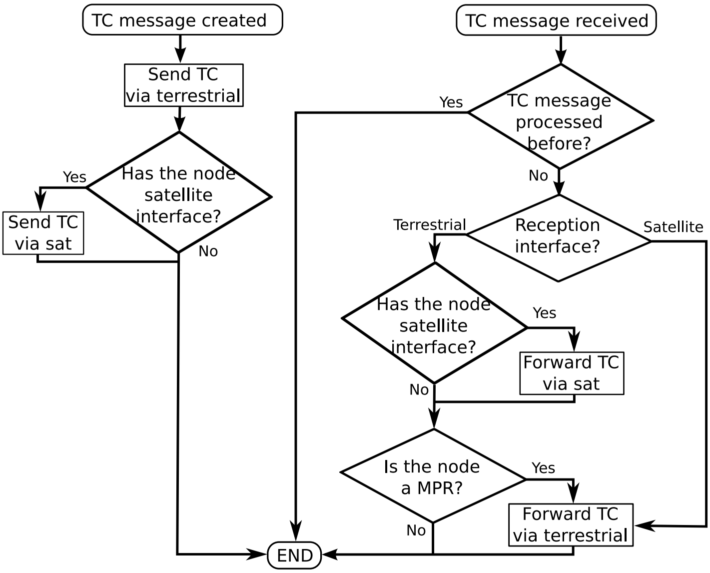

Fig. 1. OLSR-H broadcasting flow chart

if possible. When a node receives a broadcast message it checks if the message was already processed. If not, it continues the process. On the one hand, if the message was received via satellite, it is always forwarded via terrestrial link. On the other hand, if it was received via terrestrial link it is forwarded via the terrestrial network if the node is a MPR and via satellite if the node has a satellite interface. Figure 1 represents a flow chart of OLSR-H broadcasting process.

3 Scenario

The chosen scenario is a forest fire fighting mission. In this context, firemen share information about the fire advance, the topography of the intervention area or their own locations. However a network infrastructure may not exist because of the environment or it may be down because of the fire. The establishment of a MANET among the firemen units offers a primitive data network for these purposes.

The forest fire scenario was described in [3] and implemented using the OMNET++[5] simulator. The same implementation is used in this work (see Figure 2), but not all the nodes feature a satellite interface. Three configurations with 4, 7 and all (28) nodes with a satellite interface are summarized in Table 1. Using command cars as the units carrying satellite dishes is a sensible choice considering energy supply and antenna mounting constraints. Table 2 summarizes the simulation input parameters.

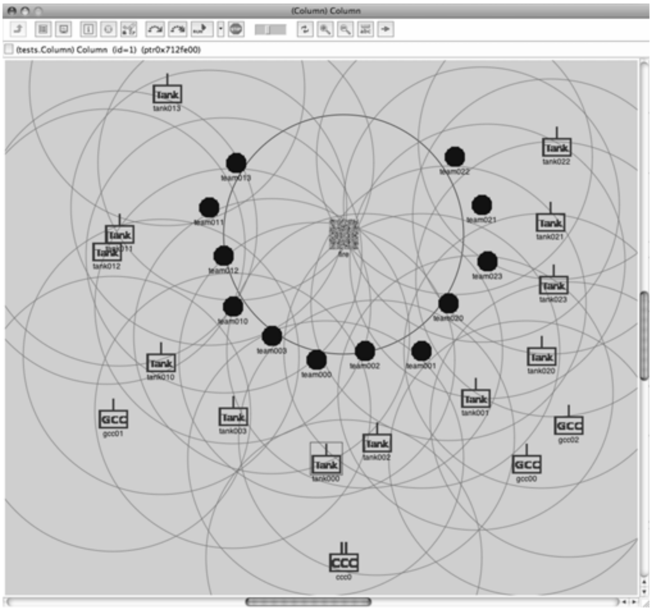

Fig. 2. Snapshot of the forest fire fighting network layout in OMNET++ simulator

Table 1. Forest fire scenario configurations

Name	Broadcast characteristics and nodes with satellite facilities
OLSR	Only tc terrestrial broadcast No node with satellite i/f
OLSR-SAT	Only tc satellite broadcast All nodes with satellite i/f
OLSR-H $r = 4$	Hybrid tc terrestrial and satellite broadcast Column command car + all group command cars (3) with satellite i/f
OLSR-H $r = 7$	Hybrid tc terrestrial and satellite broadcast Column command car + all group command cars (3) + one tanker per group (3) with satellite i/f
OLSR-H $r = n = 28$	Hybrid tc terrestrial and satellite broadcast All nodes with satellite i/f

Table 2. Simulation input parameters

Parameter	Forest Fire Fighting
Attenuation model	Path loss reception
Mobility model	FireMobility
Number of nodes	28
Path loss alpha	3
Transmission power	1 mW
Receiver sensitivity	-90 dBm
Channel model	Rayleigh
Radio technology	802.11g
Radio range (R)	46.25 m
Playground size	$5R \times 5R$
Data packet interval	Exp(100 ms)
Data packet size	1 KB

4 Simulation Results

Simulations were performed to compare the behavior of OLSR, OLSR-SAT and OLSR-H. As in [3], the packet delivery ratio of three data streams was chosen to measure the routing performance. The traffic flows vary in distance (i.e., the number of hops) between the source and destination representing short, medium and long distance communications.

The data packet delivery ratio is shown in Figure 3. As already noticed in [3], the improvement in data packet delivery achieved by OLSR-SAT depends on the distance between source and destination, with higher improvements for long distance communications (>4 hops). Focusing on the OLSR-H results, a similar improvement is achieved if only four nodes are equipped with satellite facilities. The performance achieved in such a configuration is close to the ideal situation where $r = n = 28$.

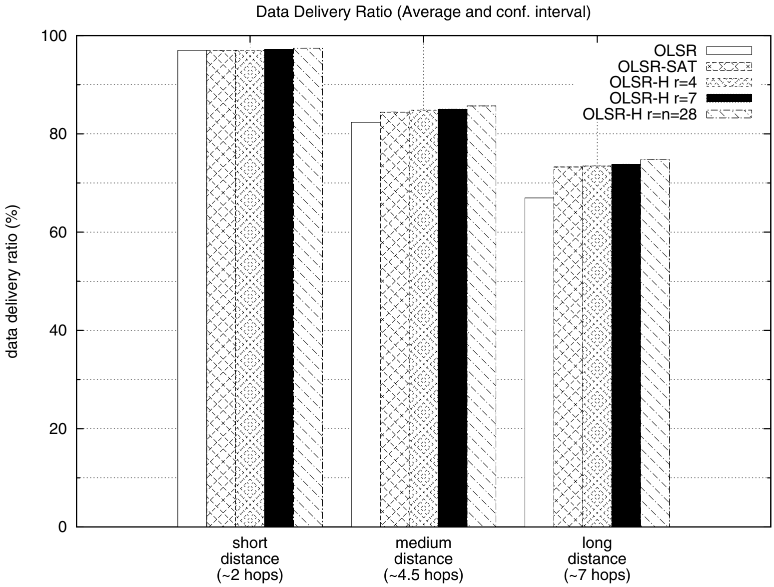

Fig. 3. Data packet delivery ratio comparison among OLSR, OLSR-SAT and OLSR-H

The difference among the three routing protocols is the broadcasting process for the topology control (tc) messages. The delay and the delivery ratio of these messages are therefore analyzed to find the reason of the improvement.

The average and standard deviation for the travel delay of the tc messages are shown in Figure 4. One reason for the data delivery ratio improvement could be the constant tc travel delay of the satellite transmission, allowing the nodes to have a consistent view of the network topology. However, the tc delay of OLSR-H with $r = 4$ is similar to OLSR but the data packet delivery is still improved.

The delivery ratio of tc messages is shown in Figure 5. The tc delivery ratio is improved without a large number of satellite equipped nodes (r). There is a relation between the tc delivery ratio and the quality of the routing decisions and therefore the data packet delivery ratio.

4.1 Detailed Evaluation of the Communication Errors

The tc message delivery ratio was computed at the routing level. The tc message delivery is the relation between the number of tc messages created and the number of tc messages processed. In an ideal situation each tc message created should be processed by all the other nodes ($n - 1 = 27$). The *tc message delivery* is therefore defined as:

$$\textbf{tc delivery ratio} = \frac{\textit{(tc msgs processed)}}{(n-1) \cdot \textit{(tc msgs created)}}$$

An analysis of terrestrial tc transmissions is performed at the link level (that is, WLAN) to classify the source of errors. Only the frames with at least one

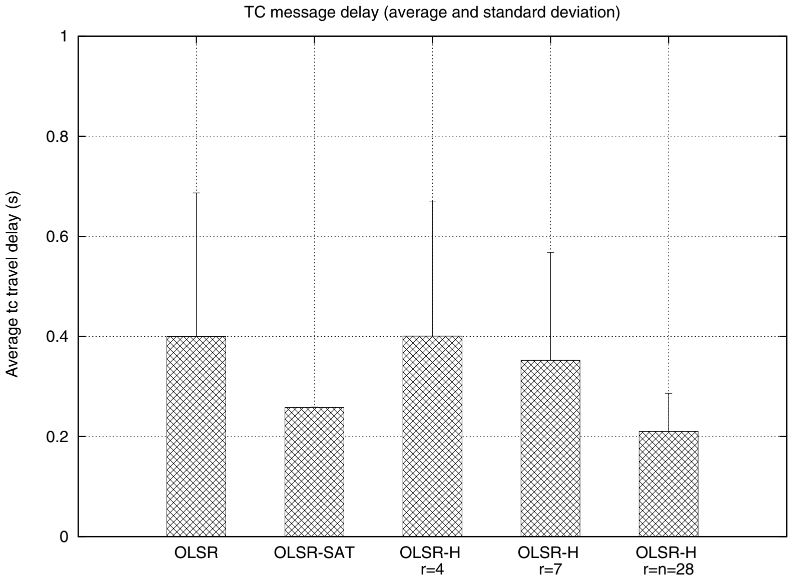

Fig. 4. Comparison of tc message travel delay of the studied routing protocols

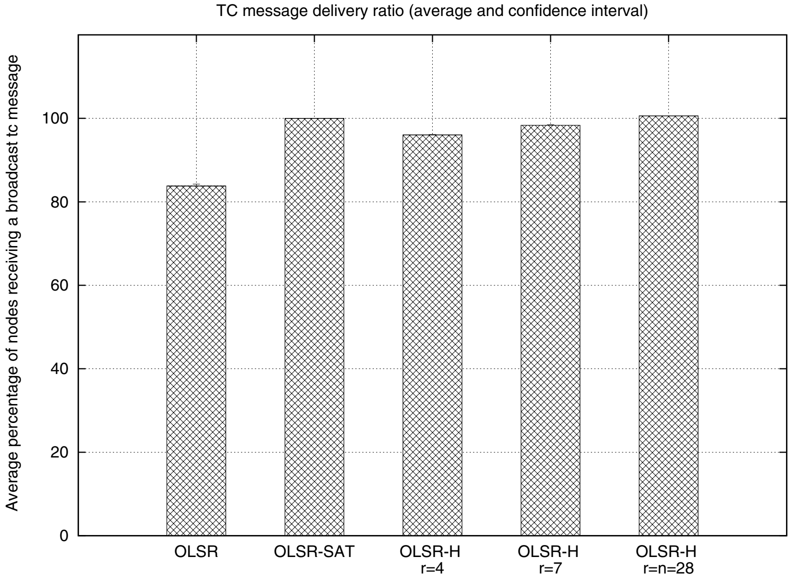

Fig. 5. Comparison of tc message delivery ratio of the studied routing protocols

tc message inside are taken into account. Four counters are set up: *sent frames*, *correctly received frames*, *received frames with bit errors* and *received frames with collisions*. In this case the relation between sent frames and received frames depends on the number of neighbors of each frame source.

The results obtained do not depend on the routing protocol: 94% of the frames were correctly received, 4.5% were received with bit errors and 1.5% were received after collisions. These two error indicators are linked to the traffic intensity going through the WLAN medium. It is therefore likely that in real-world conditions, the number of errored frames will be larger. On the other hand, sending tc messages through the satellite link makes it unaffected by the data traffic load.

4.2 Overhead Evaluation

Several frame transmissions are needed to broadcast a single tc message. The number of transmitted frames per tc message created defines the overhead of the broadcast system. Table 3 shows this relation for the terrestrial and the satellite broadcast.

The overhead in the satellite transmissions is due to the satellite propagation delay. While the satellite transmission of a frame is not over, a copy of the same frame could arrive via WLAN to a satellite node. The WLAN frame is then processed and forwarded again via satellite.

The overhead in the WLAN transmission increases with the number of nodes equipped with satellite facilities. The reason is that some nodes have an independent broadcast channel (the satellite) and the MPR algorithm does not take this into account, therefore the MPRs election is not optimized.

Table 3. Broadcasting overhead: transmitted frames per tc message created

	OLSR	OLSR-SAT	OLSR-H(r=4)	OLSR-H(r=7)	OLSR-H(r=n=28)
WLAN	6.51	0	8.41	9.44	14.51
satellite	0	1	2.19	3.36	10.93
total	6.51	1	10.6	12.80	25.44

5 Conclusions

Signaling traffic is a key component of routing. We demonstrate that improving the reliability of signaling communication yields better routing decisions and therefore improves the delivery of data traffic. OLSR-SAT and OLSR-H with $r = n$ are not realistic solutions because they require all nodes to be equipped with satellite terminals. However they yield the maximum improvement we could reach. Then we showed that a similar improvement can be achieved with a lower number of satellite terminals (OLSR-H $r = 4$ out of 28 nodes).

The hybrid broadcast solution produces larger overhead for both terrestrial and satellite systems. Future work should investigate the integration of information about which nodes have satellite facilities in the OLSR MPR election so to mitigate the signaling overhead in hybrid configurations. Also, increasing the traffic load of the network will favour the hybrid broadcast system with respect to OLSR.

Two future directions are worth mentioning. First, OLSR-H impacts two properties of the signaling distribution: the delay required to distribute the signalling and the reliability of the process. The results show that both properties are relevant however reliability seems to be the most significant of the two. This has to be further investigated. Second, while the hybrid signaling distribution scheme was presented in the context of OLSR, it might be used in another context and even help to optimize the route discovery process in protocols such as AODV.

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