Improving Topology-based Routing in High Mobility VANETs

Miguel Luis, Rodolfo Oliveira, Luis Bernardo, Rui Dinis and Paulo Pinto

FCT-Universidade Nova de Lisboa, Lisbon, Portugal

Abstract

In *ad hoc* networks the broadcast nature of the radio channel poses a unique challenge because the wireless links have time-varying characteristics in terms of link capacity and link error probability. In mobile networks, particularly in vehicular *ad hoc* networks (VANETs), the topology is highly dynamic due to the movement of the vehicles, hence an on-going session suffers frequent path breaks. In this work we present a method that uses the available knowledge about the network topology to improve the routing protocols performance through decreasing the probability of path breaks. We propose a scheme to identify long duration links in VANETs, which are preferentially used for routing. This scheme is easily integrated in the existent routing protocols. We describe how to integrate it in the Optimized Link-State Routing Protocol. Finally, we evaluate the performance of our method with the original protocol. Simulation results show that our method exhibits better end-to-end path delay, higher packet delivery ratio and higher path duration than the original protocol. This observation is even more evident when the nodes density increases.

Motivation and Problem Analysis

Motivation

Optimized Link State Routing protocol (OLSR) [1] has shown to outperform other ad hoc routing algorithms (even for vehicular environments [2] [3]), due to its topology optimization scheme. However, for vehicular ***ad hoc*** networks (VANETs), we argue that OLSR's performance can be improved. In the next table, the performance of OLSR routing protocol is evaluated for a highway scenario with an average density of six vehicles (each node is in range of the nearest five).

	Single way	Both ways
Packet delivery ratio (%)	68.8	47.1
Average end-to-end delay (ms)	66.9	99.1
Average path duration (s)	96.48	74.41

Table 1: OLSR performance evaluation in an highway mobility scenario.

As we can see, when OLSR routing protocol is applied to an highway scenario, with vehicles moving in both sides, the protocol's performance is seriously affected. This fact is observed because the routes are build with all vehicles traveling in highway.

This work characterizes and distinguishes the vehicles that travels on each side of the road, and modifies the MPR election process, and routing table computation, to use only the links between vehicles that travel in the same way.

Problem Analysis

The following developments were considered using a mobility model, with highway properties, where vehicles are traveling in both ways with a certain velocity given by $\vec{v}$. In this analysis we adopt the following assumptions: two vehicles are d length unities far away from each other; the radio communication range of each vehicle is expressed by r and a link is detected and subsequently sensed if $d \leq r$. Considering two vehicles n_a and n_b moving in the same way, the expected relative velocity yields:

$$E_{\text{same way}}(v_r) = \int_{V_{min}}^{V_{max}} \int_{V_{min}}^{V_{max}} f(v_a) f(v_b) \sqrt{v_a^2 + v_b^2 - 2 v_a v_b}\, dv_a\, dv_b. \quad (1)$$

However, if vehicles n_a and n_b move in opposite ways, the expected relative velocity is given by:

$$E_{\text{opposite way}}(v_r) = \int_{V_{min}}^{V_{max}} \int_{V_{min}}^{V_{max}} f(v_a) f(v_b) \sqrt{v_a^2 + v_b^2 + 2 v_a v_b}\, dv_a\, dv_b. \quad (2)$$

Assuming that at instant t the vehicles n_a and n_b form a link, and considering that vehicle n_a moves with velocity $\vec{v_r}$ relative to vehicle n_b, the link will be considered broken if $|\vec{v_r}| > 0$ after some time. We define that the probability of the link remains active in time $t + \Delta t$ is related with the spacial intersection of the covered areas at instants t and $t + \Delta t$ (the space covered at both instants), which is represented by the shaded area in Figure 1.

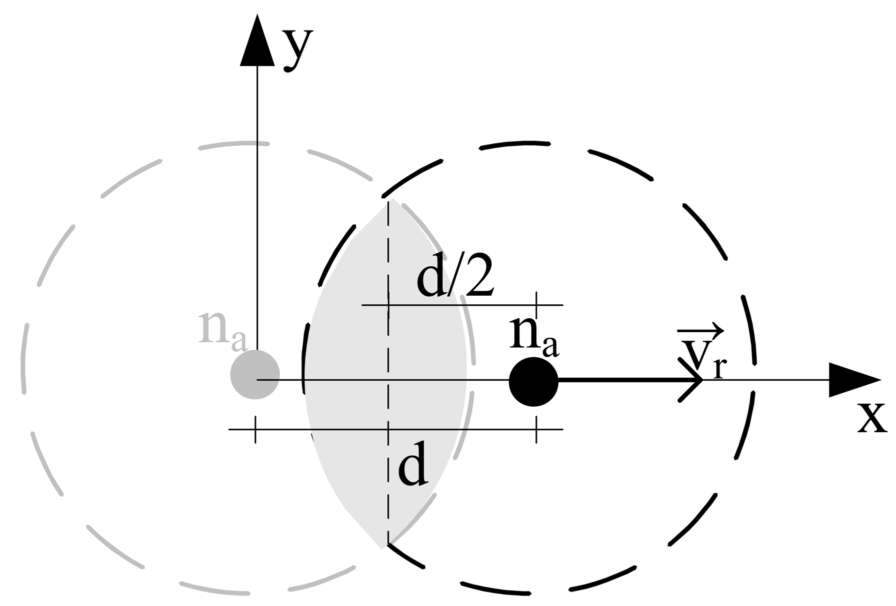

Figure 1: Position of the vehicle n_a in the time instants $t + \Delta t$ after moved d length units after the instant t.

The overlapped area in the instant $t + \Delta_t$ is a function of the distance $d \geq 0$ traveled by the vehicle n_a with velocity v_r in the interval $(t, t + \Delta t)$, and is given by

$$a_{t+\Delta_t}(d) = \begin{cases} \pi r^2 - \int_{-d/2}^{d/2} \sqrt{r_2 - x_2}\, dx & 0 \leq d \leq 2r \\ 0, & d > 2r \end{cases}. \quad (3)$$

Now, lets consider the case when HELLO messages are broadcasted every T_B seconds, to discover and/or maintain an active link. The distance traveled by the vehicle n_a, relative to the vehicle n_b during the period T_B, is given by $E(v_r)T_B$. Therefore, the probability of the link remains active during k T_B periods is given by

$$p_{link}(k) = \frac{a_{t+\Delta_t}(kE(v_r)T_B)}{\pi r^2}. \quad (4)$$

By (3) and (4), a link created by two nodes moving in opposite directions presents a null probability of remaining active when $d > 2r$. Thus, for a link created by two vehicles moving in opposite directions, the condition $p_{link}(k) = 0$ only holds when

$$k > \frac{2r}{E_{\text{opposite way}}(v_r) T_B}. \quad (5)$$

Problem Solution

Based on the description previously presented, we now introduce a solution to detect the links formed by two vehicles moving in the same direction. In topology-based routing algorithms, the links between the nodes are discovered and maintained through periodical HELLO packets exchange. The duration of the links is characterized by the number of HELLO packets uninterruptedly received (η). For example, the link duration between vehicles n_a and n_b, at instante t, is given by:

$$\eta(n_b) = 1 + (t - t_i(n_b)) \operatorname{div} T_B \quad (6)$$

where $t_i(n_b)$ represents the instante when the node n_a firstly receives an HELLO packet from it's neighbor node n_b. Links between vehicles are identified through the observation of each link duration. This way, links between vehicles moving at the same direction are the only links who can satisfy the following equation

$$\eta(n_b) \geq k_{est} > \frac{2r}{E_{\text{opposite way}}(v_r) T_B}, \quad (7)$$

because the links between vehicles moving in opposite directions never reach a stability $\eta(n_b)$ greater than the number of k of T_B periods given by $2r/(E_{\text{opposite way}}(v_r)T_B)$. In order to parameterize k_{est} is necessary to relate the relative velocity between two vehicles moving in opposite ways, preferably between the most slower vehicles.

The main changes in OLSR routing protocol were made in MPR nodes selection algorithm and in the routing table computation, in order to include the benefits of the longer link duration times:

- **MPR nodes selection algorithm:** MPR nodes selections rules previously based on energy were replaced by a set of rules based on link duration, in order to reduce the frequent topological changes. For example, the vehicle n_a can only select vehicle n_b for his MPR node, if n_b is traveling in the same way;
- **Routing table algorithm:** For routing purposes, only nodes traveling in the same way can be selected as "next hops". This way, path duration can be increased.

Performance Evaluation

The performance of OLSR and OLSR with our improvements (OLSR-FCT) (ns-2.33 [4] was used). We defined 3 different scenarios, with different vehicles density: 6, 8 and 10. The metrics used to evaluate the performance of both protocols were packet delivery ratio, end-to-end delay and path duration.

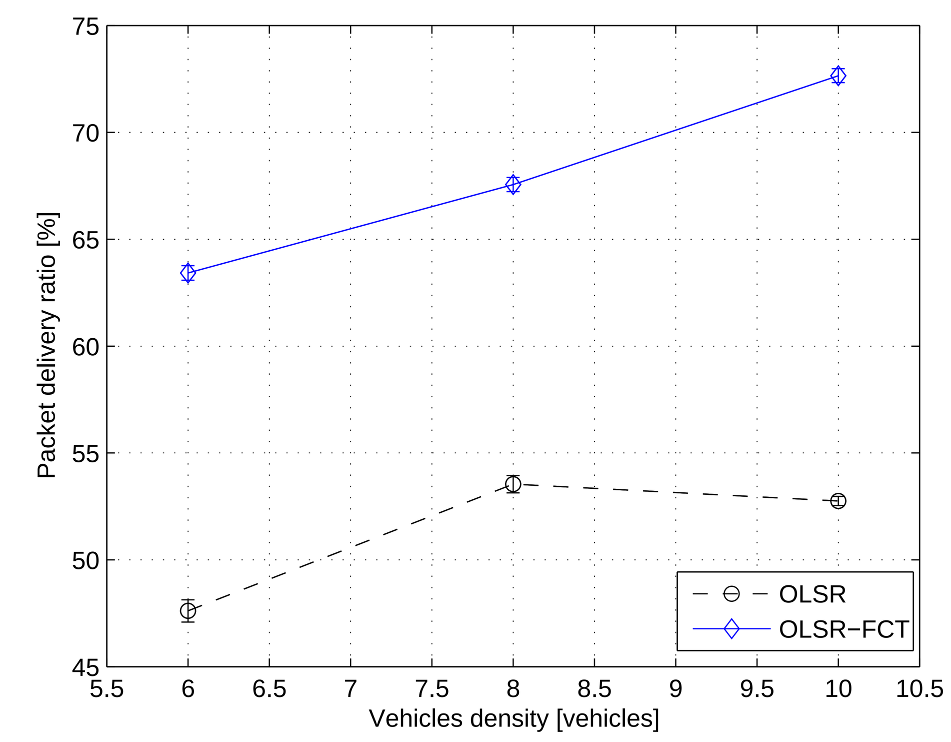

Figure 2: OLSR and OLSR-FCT performance evaluation: packet delivery ratio (%).

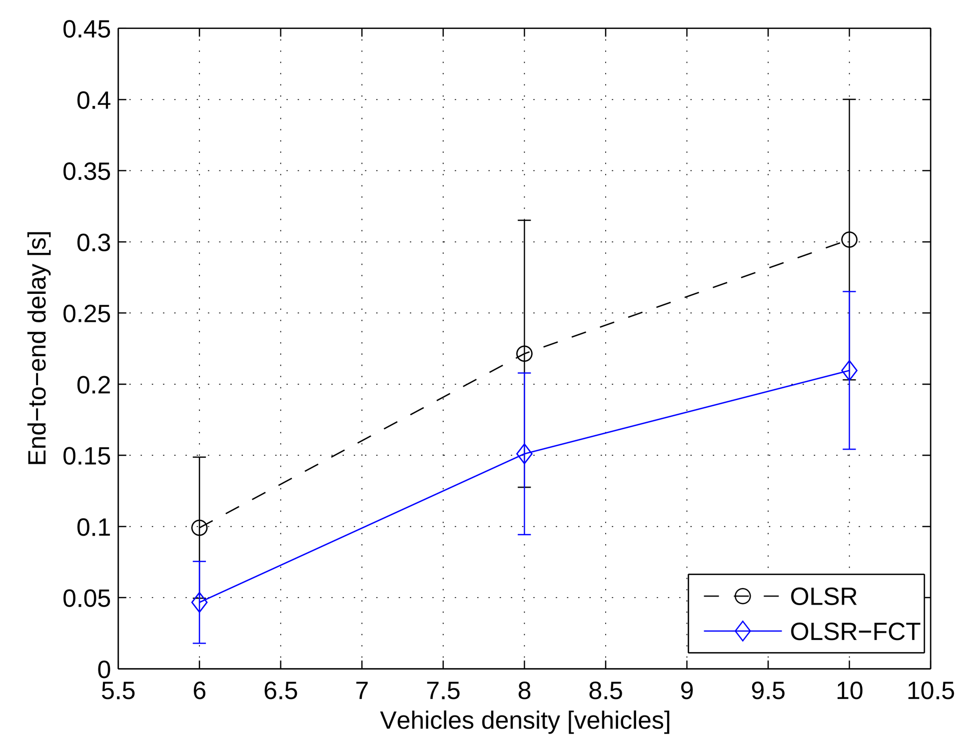

Figure 3: OLSR and OLSR-FCT performance evaluation: end-to-end delay (s).

Vehicles density	Packet delivery ratio gain (%)	End-to-end delay gain (%)	Path duration gain (%)
6	33.2	52.94	26.61
8	26.19	31.76	45.74
10	37.72	30.48	6.5

Table 2: OLSR-FCT experimental gains.

Conclusions

- This work presents a method that uses the available knowledge about the networks topology to improve the routing protocols performance, through decreasing the probability of path breaks;
- We integrate our improvements in the OLSR routing protocol, and the performance results explicitly confirms that our proposal outperforms the original protocol;
- Finally we recommend the use of protocol OLSR with our improvements in high mobility and high density scenarios.

References

[1] T. Clausen and P. Jacquet. "*Optimized Link State Routing Protocol*". IETF Internet Draft, http://www.ietf.org/internet-drafts/draft-ietf-manetolsr-10.txt, 2003

[2] T. Clausen, P. Jacquet, and L. Viennot. "*Comparative study of routing protocols for mobile ad-hoc networks*". The First Annual Mediterranean Ad Hoc Networking Workshop, 2002.

[3] Filali F. Haerri, J. and C. Bonnet. "*Performance comparison of aodv and olsr in vanets urban environments under realistic mobility patterns*". In Proceedings 5th IFIP Mediterranean Ad-Hoc Networking Workshop, Lipari, Italy, 2006.

[4] Network simulator (2.33). Retrieved from http://www.isi.edu/nsnam/ns/.