A New Scheme for Electing Stable MPR Nodes for the OLSR Protocol

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ABSTRACT: *Mobile Ad hoc networks are infrastructure less networks, which are formed by a number of autonomous wireless and mobile nodes. Many Ad hoc routing protocols are proposed, in the literature, for electing paths between communicating nodes. Due to the nodes mobility, these paths are unstable and must update them frequently. In this paper, we study the nodes stability and we propose a metric to asses the link stability between two adjacent nodes. To implement this metric, we have modify the MPR (MultiPoint Relay) scheme, in the OLSR (Optimized Link State Routing) protocol, to elect the most stable MPR nodes in the network. The election of stable MPR nodes in the network improves the quality of the established topology, which will be more stable. The simulation results show that the topology in our case is more stable and the quality of the selected paths is improved (decreasing in the end-to-end delay and the lost packets).*

Keywords: MANETs, QoS Routing, Link Stability, OLSR

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1. Introduction

Wireless networks are classified into tow classes: with fixed infrastructures and without fixed infrastructures [1]. MANET (Mobile Ad hoc NETworks) are a type of infrastructure less wireless networks. Each node, in MANET, can move freely and without any constraints [2]. Due to the nature of the network (wireless, mobiles and infrastructure less), several problems are emerged which are different from those exposed in the other types of networks. Among these problems, the routing problem. At the onset of Ad hoc networks, the routing problem was only to find paths between communicating nodes, without taking into account the quality of these paths (Delay, bandwidth, jitter, etc.). Some of routing protocols based on this strategy, proposed in the literature, are retained as a standard by IETF (Internet Engineering Task Force) such as AODV (Ad hoc On-demand Distance Vector) [3], DSR (Dynamic Source Routing) [4] and OLSR [5]. These protocols install the shortest path between communicating nodes. The shortest path does not guarantees, in the most case, the QoS (Quality of Services) required by the multimedia applications. For this, another class of routing protocols, called QoS routing protocols, are emerged [6]. Instead of the shortest path, this new class of protocols installs paths based on criteria of quality of services. Due to the nature of Ad hoc networks (wireless and mobility), another problematic is added to this class of routing protocols (QoS routing protocols): the stability and durability of the installed paths [7].

Several works focused on the QoS routing protocols based on the paths stability are proposed in the literature [8-11]. To address the path stability, the majority of these works try to minimize the distance between the nodes that constitute the installed path. However, this approach increases the hopcount which consequently degrade the QoS of the supported applications and affect the performance of the network at all (congestion, packets collision, etc.). Other works proposed complicated methods which it is difficult to implement and prove them.

The routing mechanism based on the link stability, which minimizes the frequent path disconnections and guarantees other QoS requirements such as the packet delivery ratio and the Delay, constitute the first motivation of this work. For this, we propose in this paper, a new metric to evaluate the link stability between two neighboring nodes. We consider the signal strength variation as a main indicator of the nodes' mobility. To implement our metric, we have modify the OLSR protocol to elect the most stable MPR nodes and called the new protocol SMPR OLSR (Stable MPR for OLSR). The election of the stable MPR nodes implies the establishment of a stable topology, which consequently affects the stability of paths and improve other QoS requirement such as the Delay and the lost packets.

The rest of the paper is organized as follows: The standard OLSR protocol is detailed in Section II. In Section III we describe the proposed mechanism to elect the more stable MPR nodes in the network. Section IV analyses the performance of the proposed approach and we conclude our work in Section V.

2. Optimized Link State Routing (OLSR) Protocol

Ad hoc routing protocols are classified into two classes: the proactive and the reactive protocols. The proactive protocols install and maintain at each node paths toward all nodes in the network. The disadvantage of this class of protocols is the excessive exchange of control messages. The main goal of OLSR protocol is the minimization of the number of control packets exchanged. For this, only the nodes elected as MPR exchange between themselves the control packets to establish the topology at these nodes. The MPR node is responsible to relay the data, for the nodes that have elected it as MPR, toward other nodes in the network. Only the MPR nodes are involved in the routing process. Then, the main problem is to elect the MPR set nodes that cover the entire network. Authors of OLSR protocol proposed a heuristic method ,based on the degree of reachability, for electing the MPR set. In this method, each node elects its one-hope neighbor node as MPR if : the link to this neighbor is symmetric and this neighbor covers the maximum number of two hop neighbors of the node (degree of reachability). The MPR node elected and the two-hop nodes covered by this MPR will not be considered in the next iteration of the algorithm. This algorithm is repeated until all the two-hop neighbors will be covered by the selected MPR nodes. Authors in [12] showed that the calculation of a minimum set of multipoint relays using this algorithm is a NPcomplet problem.

3. Our Proposed Algorithm For Electing More Stable MPR Nodes in The Network

The notion of node stability, in Ad hoc networks, does not exist. All nodes can move freely and without any constraints. We mean by the nodes stability, the estimation of the link lifetime between the adjacent nodes. This notion of stability allows us to classify the candidate paths , between communicating nodes, according to their stability and durability.

In this paper, we present a new metric to assess the link stability between two adjacent nodes. For this, we have developed two concepts : the SND (Stability of NoDes) concept and the FND (Fidelity of NoDes) concept. Those two concepts are used to elect the most stable MPR nodes set in the network. In what follows, we present the SND and the FND concepts, followed by their integration in the OLSR protocol to elect the stable MPR nodes set.

3.1 Stability of NoDes (SND)

The notion of stability that we present in this paper is based on statistics collected by a node on its neighbor to estimate the durability of the connection. In Figure 1, the node A, and after the reception of messages received from *B*, calculates the stability of the link joined it with *B*.

To estimate this stability, we have proposed a function based on bienayme- chebyshev inequality. [13].

3.1.1 Bienayme- chebyshev inequality

In probability theory, Bienaym´e-chebyshev inequality guarantees that in any data sample or probability distribution: whatever the discrete variable X, the strictly positive expectation $E(x)$, and the variance $V(x)$ we have the following inequality:

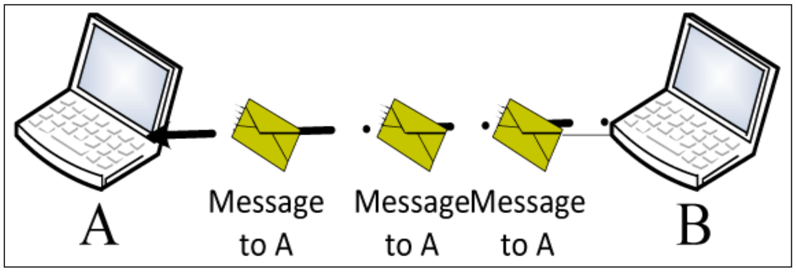

Figure 1. Archiving process of received messages for calculating SND

$$P\{|X - E(X)| < \varepsilon\} \geq 1 - \frac{VAR(X)}{\varepsilon^2}$$

The probability:

$$P\{|X - E(X)| < \varepsilon\}$$

is always true if the variance tends to zero

$$1 - \frac{VAR(X)}{\varepsilon^2} \text{ tends to } 1 \Rightarrow V(X) \text{ tends to } 0$$

This also reflects the probability that the value of the random variable X is always close or equal to its expectation (Little change in the future)

$$P\{|X - E(X)| < \varepsilon\} \text{ Little change in the future}$$

By definition

$$V(X) = E(X^2) - E(X)^2$$

And

$$E(X) = \sum_i \frac{X_i}{n}$$

$$V(X) = \left(\sum_i \frac{X_i^2}{n}\right) - \left(\sum_i \frac{X_i}{n}\right)^2 \qquad (1)$$

3.1.2 Stability Function of a node

In our proposal (based on Bienayme-chebyshev inequality) instead of taking the X_i as the actual positions of the nodes (absence of this information in Ad hoc networks without the localization systems), we will take the values of the received signal power from a neighboring node in different intervals of time. Otherwise (see Figure 1), the link between the node *B* and the node *A* is stable if the values of the signal power are very close to their expected value. In a particular case, if the mathematical variance of these signal power values is equal to zero, we can say that the node *B* is strictly stable with the node *A*. The function of stability that we propose consists on calculating the stability of a neighbor *B* by a node A (Figure 1) as follows:

$$SND_{AB} = V(X_B) \qquad (2)$$

According to (1) and (2)

$$SND_{AB} = \left(\sum_i \frac{X_{Bi}^2}{n}\right) - \left(\sum_i \frac{X_{Bi}}{n}\right)^2$$

$$SND_{AB} = \left(\sum_i \frac{Value\_signal_{Bi}^2}{n}\right) - \left(\sum_i \frac{Valuesignal^2\_Bi}{n}\right)^2$$

3.2 Fidelity of NoDe (FND)

The graph in Figure 2 represents an Ad hoc network where the weights of edges are the SND and the weights of vertices are the FND. In the case of OLSR, for example, the FND is the degree of reachability. In the case of our proposal, it is the degree of reachability with only the stable nodes. For example, in Figure 2, the node 8 has two links with two nodes: the node 3 with SND equal to 2.3 and the node 2 with SND equal to 1.6. The node 8 chooses the node 2 as the most stable (minimum SND) where it gives it a token. Similarly, the node 7 gives its token to the node 2. We conclude that the fidelity FND of the node 2 is equal to 2.

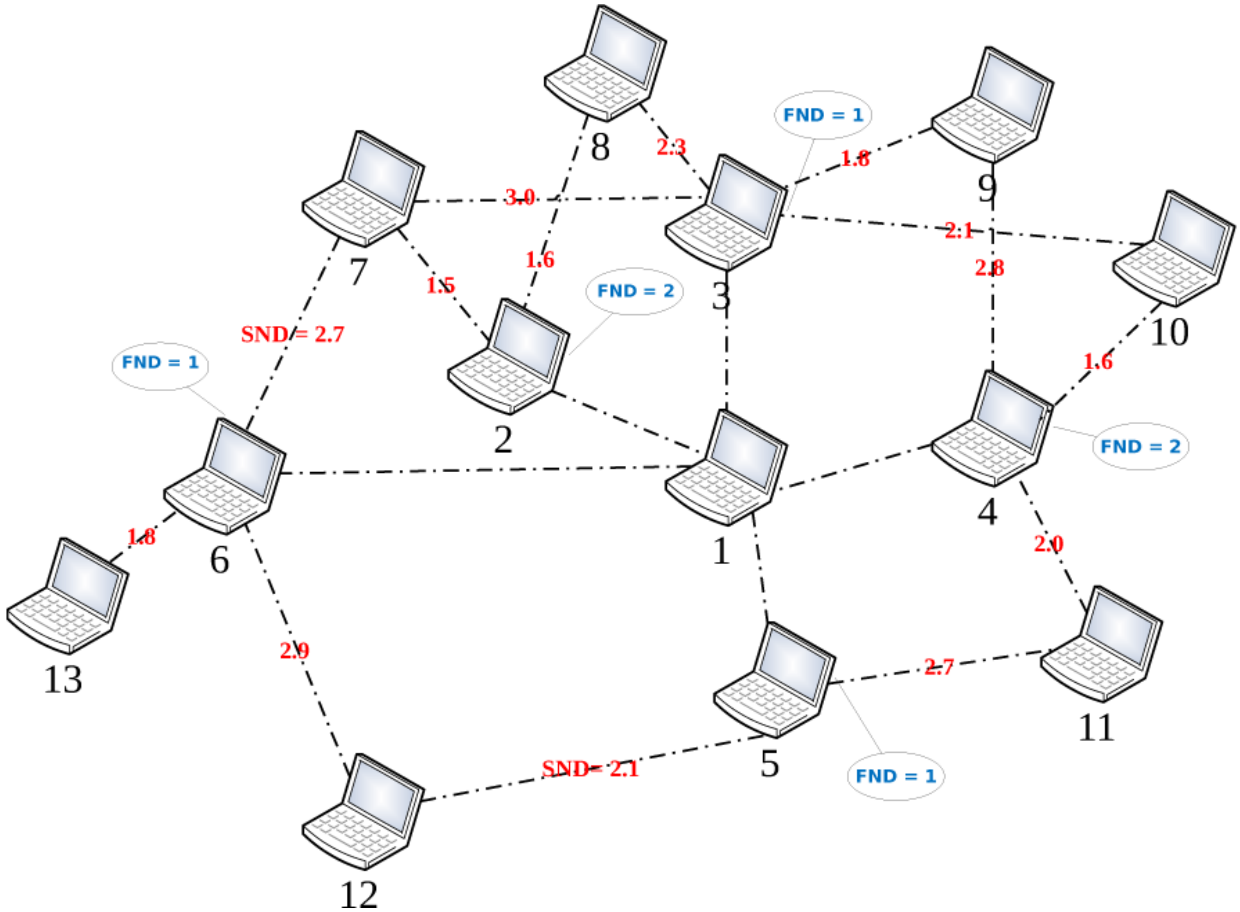

Figure 2. Illustrative example of the Fidelity notion

3.3 Integration of the SND and the FND concepts in the MPR calculation algorithm

The standard mechanism of MPR set calculation is based only on the degree of reachability. So, this mechanism tries only to minimize the flooding in the network by using a proactive protocol. Our proposal is still based on this principle but it selects the set of more stable MPRs in order to keep the network topology stable as long as possible. This stability leads to a significant reduction of the MPR computation time, the frequent disconnection of paths and the number of recalculated routing tables. Therefore, we present the new format of Hello messages as well as our proposed algorithm for the MPR calculation.

3.3.1 Format of the Hello message

For our proposal and with respect to the standard Hello message, we introduce the value of stability SND for each neighbor node as shown in Figure 3.

3.3.2 New MPR selection algorithm

The election of MPR in our proposal is based on the FND concept. For this, we have introduced changes to the algorithm described in Section II for the election of stable and durable MPR. In our algorithm, a neighbor node is selected as MPR if the link to this neighbor is symmetric and it has the greatest FND value compared to the others. In the case of equal FND values for several nodes, the node which has the largest degree of reachability (which covers a large number of two-hops neighbors) will be elected as MPR. The following algorithm (Algorithm 1) describes the process of stable MPR election. In this algorithm, we note that:

$N(x)$: is the set of direct neighbors of x.

$N2(x)$: is the set of neighbors of the second level.

MPRset (x) : is the set of multi-point relays of x.

<table>
<tr><td colspan="10">0</td><td colspan="10">1</td><td colspan="10">2</td><td colspan="2">3</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td></tr>
<tr><td colspan="16">Reserved</td><td colspan="8">Htime</td><td colspan="8">Willingness</td></tr>
<tr><td colspan="8">Link Code</td><td colspan="8">Reserved</td><td colspan="16">Link message size</td></tr>
<tr><td colspan="32">Neighbor interface address</td></tr>
<tr><td colspan="32">SND</td></tr>
<tr><td colspan="32">Neighbor interface address</td></tr>
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Figure 3. New format of hello message in SMPR OLSR

Algorithm 1 New MPR selection algorithm

1. Start with an empty multipoint relay set.
2. Calculate the degree $D(y)$ of each node in $N(x)$.
3. Calculate the fidelity $F(y)$ of each node in $N(x)$.
   $F(y)$ is the number of the obtained tokens.
4. Select the nodes of the neighbors set $N(x)$, which are the only connected with a neighbor of the second level. Add these selected nodes of $N(x)$ for all MPRset (x) and remove all nodes of the second level covered by them of all $N^2(x)$.
5. While ($N^2(x)$ is not empty) Do
   {
   a- Calculate reachability $R(y)$ of each node in $N(x)$.
   b- Add the node (y) of $N(x)$ with $F(y)$ maximum to MPRset (x).
   If the values are the same, take the node with the highest degree of reachability $R(y)$.
   If they are equal then we take the node with the maximum degree $D(y)$.
   Remove all nodes of the second level covered by this node in the set $N^2(x)$.
   }

4. Analysis of the Simulation Results

To show the effectiveness of the protocol SMPR_OLSR, we proceed to compare it with the standard OLSR using the OPNET simulation tool [14].

In what follows, we proceed to explain the network model, that summarizes the different network parameters used in thesimulation, followed by the simulation results, to show and analyse the obtained simulation results.

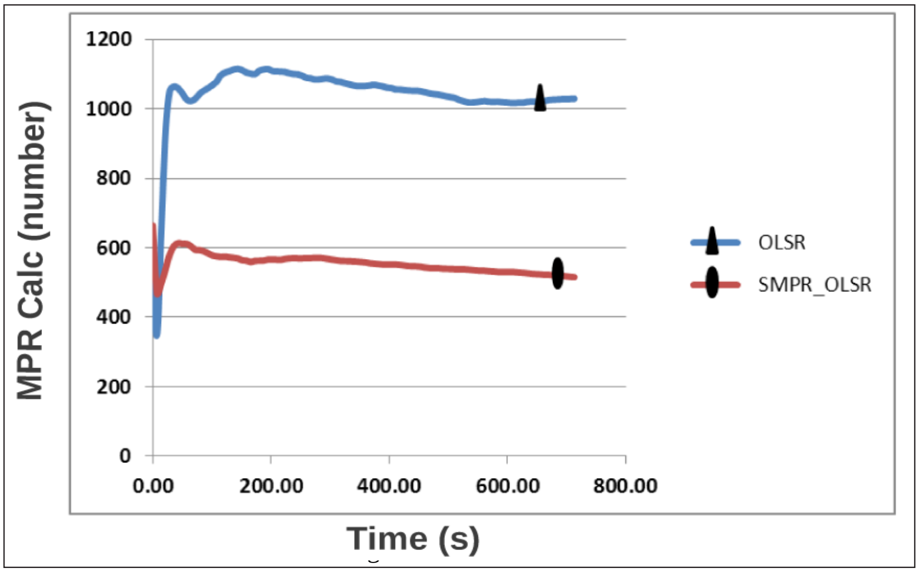

Figure 4. MPR Count

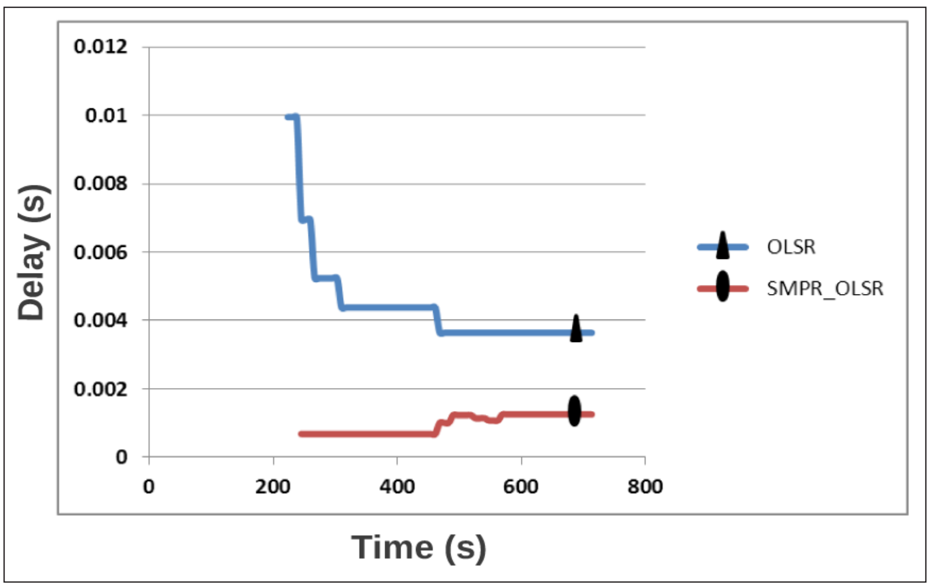

Figure 5. Delay

4.1 Network model

The evaluation of our protocol is done on a network area of 1000m x 1000m with 100 nodes. The mobility model used in the simulation is the RWP (Random Way Point) with a speed of mobility varied between 0 and 20 m/s for each node. The Topology Hold Time (the expiry time for entries in the topology table) is fixed to 15s. The Table 1 summarizes the different network parameters used in the simulation.

4.2 Simulation results

In our simulation, three metrics are chosen to show and evaluate the effectiveness of the SMPR OLSR protocol as follows:

- **MPR count:** this metric shows the number of MPR in the network.

- **Delay:** this metric shows the end-to-end delay for successful transmitted packets.

- **Packets dropped:** this is a most important QoS metric that shows the impact of the stability on the total number of lost packets in the network.

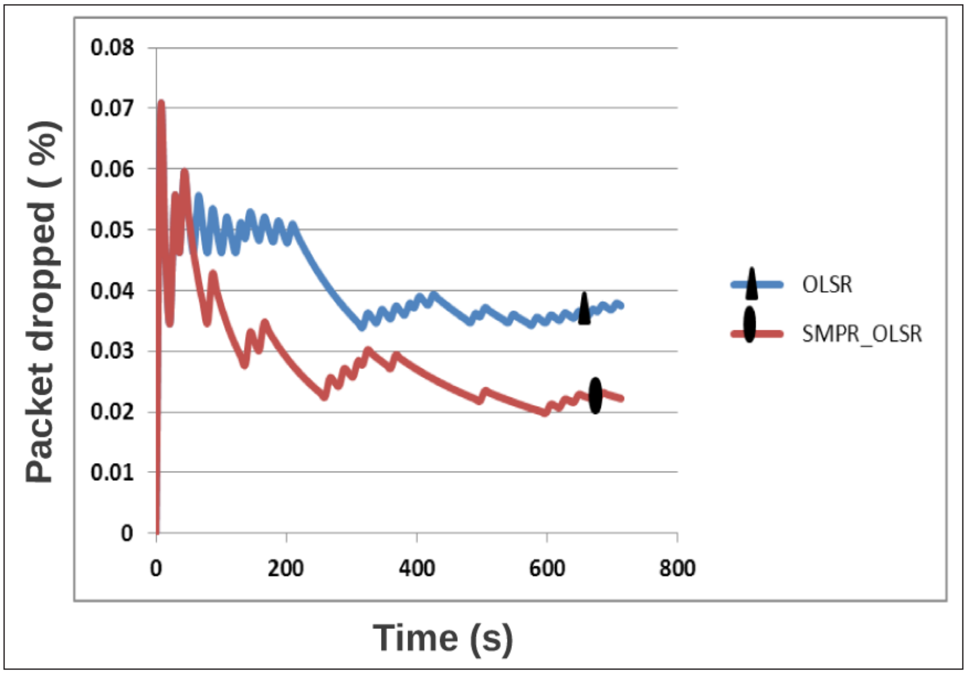

Figure 6. Packet dropped

Parameter	Value
Simulation area	1000m × 1000m
Mobility model	RWP model
Node speed	20 m/s
Pause time	5s
Hello interval	2.0s
TC interval	5s
Topology Hold time	15.0 s (3 × TC_INTERVAL)
Physical layer	IEEE 802.11
Transmit power	0.001w
Simulation time	1500 seconds (25 minutes).

Table 1. Simulation Parameters

4.2.1 MPR_Calc

The SMPR_OLSR protocol elects the MPR nodes based on the nodes stability instead of the degree of reachability as is the case in the standard OLSR protocol. The selection of stable MPR nodes implies the minimisation of MPR set recalculation in the network, which also improves the stability of the established topology. The Figure 4 shows that the number of MPR recalculation in the case of SMPR_OLSR is significantly less than in the case of OLSR protocol. This proves that the SMPR_OLSR protocol elects the most stable MPR nodes compared to the OLSR protocol.

4.2.2 Delay

The topology in the OLSR protocol is based on the shortest path between the MPR nodes. Then, electing the most stable MPR set affects the quality of paths elected which will be more stable and durable. This stability of paths minimizes the frequent path disconnections which decreases the end-to-end delay and the number of lost packets.

The Figure 5 shows that the end-to-end delay in SMPR_OLSR is significantly lower than in OLSR protocol.

This is due to the quality of MPR nodes elected which are more stable in the case of SMPR_OSR than in the case of OLS.

4.2.3 Packet dropped

As shown in Figure 6, the SMPR_OLSR presents less packets dropped than the OLSR protocol. This is due to the election of the more stable paths in SMPR_OLSR compared to the OLSR protocol.

5. Conclusion

The QoS routing in Ad hoc networks is among the most challenges for multimedia applications. Another problem is added to this challenge, the stability and the durability of paths. QoS routing based on link stability minimizes the frequent path disconnections and improves the QoS required for multimedia applications such as the Delay and the lost packets.

In this paper, we have proposed a mechanism to assess the link stability between two adjacent nodes. We have introduce this mechanism in the MPR selection algorithm to elect the most stable MPR nodes in the network. The simulation results have confirmed the effectiveness of our proposed mechanism in terms of Delay and lost packets.

The estimation of the link stability is not the unique parameter to evaluate the durability and the availability of the path. For this, and as future works, we plan to improve our work to support other parameters like: the overload of the path, the remaining energy of the nodes constituting the path, etc. On the other hand, we plan to adapt our mechanism to integrate it in other routing protocols, such as: AODV or DSR, and implement it in a real experiment.

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