Journal of Theoretical and Applied Information Technology
15th December 2020. Vol.98. No 23

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

ANALYSIS OF AD-HOC NETWORK ROUTING METRICS EFFICIENCY

[1]TIGUIANE YÉLÉMOU, [2]BOUREIMA ZERBO, [1]MESMIN TOUNDÉ DANDJINOU, [1]DODA AFOUSSATOU ROLLANDE SANOU

[1]University Nazi BONI, School of Computer Science, Bobo-Dioulasso, Burkina Faso

[2]University Thomas SANKARA, Department of Science and Technology, Ouagadougou, Burkina Faso

E-mail: tyelemou@gmail.com, bzerbo@gmail.com, dandjimes@yahoo.fr, afoussatous0@gmail.com

ABSTRACT

In the current context of ubiquitous computing, the contribution of ad hoc networks is strongly awaited. To enable these networks to play their full role, research is being actively carried on improving their Quality of Service (QoS). We focus on an improvement that considers link quality in route choice. In this paper, we analyze effectiveness of usual metrics and QoS methods used to improve routing in ad hoc network when considering the erroneous nature of radio links. We are particularly interested in costs of estimating the quality of the links, accuracy of measured value, relevance of the metric contribution in the choice of better paths. We carry out a detailed study on the metrics Hop count, Expected Transmission Count (ETX), Bit Error Rate (BER), number of Packet Retransmissions (PR), Delay and their derivatives. To test the efficiency of these metrics and compare their efficacy, we have implemented them into the well-known Optimized Link State Routing protocol. Realistic simulation results show that number of retransmissions-based metric outperforms traditional metrics based on delay, BER or Expected Transmission Count.

Keywords: *Wireless Networks, Routing Metrics, Number Of Retransmissions-Based Metric, Qos Routing Protocols Efficiency, Olsr Protocol*

1. INTRODUCTION AND MOTIVATIONS

In ad hoc networks, routing is still an issue. It remains hazardous to guarantee any quality of service (QoS) for such networks. Routing metrics are a critical part of routing protocols. They are used to quantify paths connecting communicating nodes. Most QoS algorithms establish paths by relying on a selected metric. This allows them to compare different paths and find the best. Routing metric must consider all specific characteristics of ad hoc wireless networks such as instability of links, interference, etc. In this erroneous-links context, a node may need several attempts to transmit data successfully. Unfortunately, retransmissions imply additional delays, decrease throughput and increase communication overhead in the network. In critical cases, the communication fails after several attempts. The choice of the metric, the cost of its estimation and the efficiency of the algorithm allowing its exploitation are determinant for the achievement of good performance of a network.

To analyze links quality of wireless networks, most protocols use probes [1], that are small messages (such as hello messages). However, small messages are less subject to errors compared to large multimedia packets [2], [3]. Therefore, the analysis of the network is biased. Shortest paths in terms of packet loss rate or round trip time (delay) estimated with probe packets, may include bad links where large data packet successful transmission may need retransmissions. Therefore, this induces longer delay than expected. In short, using usual metrics, algorithms fail at finding the actual shortest path, that is, the one that, somewhat, guarantees delivery.

In order to guarantee a certain level of QoS, routing protocols should be smart enough to pick a stable and good quality communication route in order to avoid retransmission and packets loss. In recent years, many QoS approaches have been proposed that consider link quality in the choice of routes. Nevertheless, these methods arise many issues. Some approaches rely on link estimation that are hard to measure in practice (for instance, the bit error rate). Others require costly analysis of the network and imply a substantial communication overhead. Finally, some approaches choose routes that maximize packet delivery ratio, but at the cost of a high number of intermediate nodes and then long delay. The efficiency of such routing protocols is not guaranteed in ad hoc networks characterized by link instability.

To make protocols more reliable, we need effective and easy link quality estimation and link quality-aware computation of shortest paths. In this paper, we focus on QoS metrics related to the packet loss rate criterion. First, we present the traditional ETX metric and its derivatives. We highlight their characteristics, strengths and weaknesses. Then, we analyze Bit Error Rate (BER) as QoS link criterion and design a BER-based metric as an additive metric. Thereafter, we propose a new metric similar to hop-count metric where Packet Retransmissions (PR) at MAC level are accurately taken into account.

These different metrics (number of hops, ETX, BER, PR, delay-based ones) are integrated into the Optimized Link State Routing (OLSR) protocol. The choice of route is based on the best paths in terms of these criteria. Our choice of the well-known OLSR protocol is justified by the fact that, as a link state routing protocol, it facilitates the tracking of the paths chosen proactively by the different algorithms. In a realistic environment, taking into account obstacles in the propagation medium, we test and compare these five variants of improved OLSR.

As contributions, this paper questions the efficiency and highlights the limits of different routing approaches considering link quality. We also propose a new metric based on the number of retransmissions. Estimating the number of retransmissions does not generate additional routing load and estimating the metric using it is simple and less expensive in terms of computing power and computing time. The enhanced protocol is tested in realistic conditions.

The remainder of this paper is organized as follows. In Section II, we analyze inconvenient of different QoS routing approaches where we highlight shortcomings of QoS metrics usage. In Section III, we conduct a thorough study of QoS metrics. In Section IV, we present performance results of the standard OLSR protocol enhanced with these different metrics. These different QoS OLSR are analyzed and compared with each other. We conclude and present some prospects in Section V.

2. ANALYSIS OF QOS ROUTING APPROACHES

Due to erroneous nature of wireless links, interference and limited bandwidth capacities of radio channel, wireless networks offer a lower QoS compared to wired ones. To address the QoS requirements of multimedia applications, several algorithms aiming at choosing better paths for data transmissions were proposed. Many research works consider quality of links in route choice process. Several metrics have been proposed and incorporated into routing protocols. The provided performances have been mixed. In this section, we make a critical overview of the most encountered metrics. We analyze the cost (in terms of routing load and additional time) generated by link quality measurement processes and uses of these metrics in routing protocols.

Packet loss in Mobile Ad hoc NETwork (MANET) [4] is due to many factors. Among them, buffer overflow, transmission loss and link breakages are the most dominant. In addition, a received packet whose delay is over tolerable threshold is also treated as a lost packet. Loss caused by over-threshold delay can only be monitored at the receiver, requiring a feedback message be sent to the source for QoS purpose. Packet loss caused by buffer overflows and maximum retransmissions exceeding, are the only information that can be obtained from intermediate nodes. Successful design of a metric that considers all of these components is very delicate.

Many approaches measure the packet loss rate by injecting probing packets into a network. A large number of sample packets are required to accurately estimate a highly variable link. Shi et al. [5] evaluate the number of probing packets needed to get an accurate result as follows: $N=\frac{1-p}{m^2 * p}$ where p is the packet loss probability and m the coefficient of variation. According to this formula, we see that this active measurement scheme is not suitable for MANETs. For example, for a link with 10% mean packet loss rate (p= 0.1), 900 samples must be sent on that link to get a measurement result where standard deviation is within 10% of the loss probability (i.e. m= 0.1). When each node should send probe packets, these can cause a large overhead in MANETs, thus skewing the obtained results. Furthermore, it takes some time for measurements. For example, if one sample packet is sent every 1 second, 15 minutes are needed to send 900 samples. Which shows that the active measurement scheme is obviously not suitable for

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

wireless network particularly in mobility context. In order to overcome this dilemma (amount overhead), Link Quality Ranking (LQR) [6] uses the following trade-off: Instead of estimating a link-layer metric for each link, LQR performs a pairwise comparison of the physical-layer metrics and selects the best link. One problem faced when broadcasting probe-based estimators such as ETX, is that they decouple link estimation from data traffic: If a link goes bad and packets are lost, the link estimate will not reflect this change until the next routing beacon is dropped [7].

The average rates of ink packet loss are commonly used. Link quality of a route is evaluated by summing the metric value of each link on the route [8], [9]. This way of using this metric is questionable. The average or sum of link quality measurements along one route may ignore the worst link. Indeed, if the quality of a link among one route is rather bad, the packets cannot be delivered successfully although the average or sum value is rather good.

The Packet Delivery Ratio (PDR) metric is often used as a multiplicative metric [10]. A blind multiplication applied to this metric strongly favors long paths. In this case, inter-hop interference may be significant. Indeed, the intermediate node cannot simultaneously receive a packet from a neighbor upstream and send another to a downstream neighbor. Additional delay due to intra-communication interference is often not taken into account. It has an impact on throughput but not necessarily on packet delivery ratio.

In addition to the sensitivity of the link quality criterion measurement, many authors have questioned the use of these QoS values. In [5], [11], [12], [13], [14], the authors highlight the complexity and exorbitant cost (overhead and computing time) of route-discovery approach with admission control processes.

Often, feasible paths under QoS metric requirement are based on a blacklisting method [15]. Link estimators consider only links with quality above a certain threshold. This minimizes the potential costs for low quality link estimation that should not be used for routing. However, a blacklisting policy could filter routing options, severely limiting the efficiency of the routing algorithm if an improper threshold is chosen [16]. Some work like [17], [18], [19] use a composite metric. It is shown that taking into account several metrics simultaneously is NP-complete [13].

3. QOS METRICS

In this section, we analyze four metrics commonly used in wireless networks and a new one based on number of retransmissions. Their features and limits are detailed.

A. Basic metrics: Hop-count metric and Delay-based metrics

Hop-Count metric is the natural metric used in most of native multi-hop routing protocols. This metric privileges paths having the minimum number of hops. It is a very stable metric and has the isotonicity characteristic [20]. Its measurement generates additional routing load. In some unstable contexts like mobility situations, it may be more efficient than metrics inducing long paths. The weakness of this metric is that it does not address interference, channel diversity, varying load on the link and capacity of the link. Thus, during the route establishment, algorithms implementing this metric do not consider the characteristics of the network. They treat all the links identically. These algorithms are likely to generate overloads in the center of the network because the shortest path passes through this center. Thus, in the case of multicommunication, interference may be very frequent.

Delay-based metrics are also questionable. Delay at each node is composed of input queuing, processing, output queuing, transmission, propagation, and retransmission ones. Most of QoS-based delay metrics focus only on transmission delay at MAC layer [21], [19], while the other components of delay take a significant portion of the total hop-to-hop delay. Li et al. [18] consider queuing delay at network layer, but their estimation method is complex. In practice, it is not easy to obtain the number of packets waiting in network-layer buffer.

Delay is closely related to packet loss rate. Packet loss that induces retransmissions grows significantly delay and also network congestion. These network performance parameters depend on the quality of used links and ambient flow. Delay and link loss ratio are often subject to high variation. End-to-end delay changes with network load as interface queue lengths vary. This can cause routes to oscillate away from a good path once the path is used. This increases the number of route changes and can lead to instability in communication and degrades performance.

B. ETX metric

ETX [9] routing metric is one of the most popular classes of packet-loss-based metrics. It is developed to improve the performance of routing in static wireless mesh networks where hop count is not suitable. The *ETX* of a link is calculated using the forward and reverse delivery ratios of the link. These delivery ratios are measured using probe packets. For two adjacent nodes X and Y, X measures probe delivering rate by determining the ratio between the number of probes received from Y and the number of expected ones. When X sends a probe, it includes the calculated ratio in the message. Y does the same. Hence, each node knows the ratio in both directions of a link (one is calculated, the other is provided by the neighbor). The metric is then obtained by :

$$ETX = \frac{1}{PDR_{X\to Y} * PDR_{Y\to X}}$$

We note that, although ETX distinguishes two PDR values for respectively upstream and down-stream direction, the obtained link metric is the same for both directions. ETX is therefore symmetric. We consider this point as a drawback of the approach. Indeed, if a link is asymmetric, we thing that this link should be used but only for traffic in the reliable direction. Only ACK messages should be sent in the unreliable direction, since these messages are small and consequently are more likely to be transmitted correctly. Besides, this metric is independent on network load. Detailed analysis of OLSR [22] with the original hysteresis [23] and ETX routing metric revealed that the original hysteresis performs better than ETX-based protocols in a large dense mesh network. An analysis was then carried out on the ETX protocols. It revealed that in realistic networks, the predicted losses using the ETX algorithm are twice the actual losses that are experienced even in ideal lab conditions for 802.11 [22]. Shi et al. [24] present the design and selection of appropriate routing metrics as the principal issue to guarantee efficient routing in self-organizing networks. They attempt to analyze, compare and summarize traffic-based routing metrics in the Expected Number of Transmissions (ETX) family. Several studies [25], [26], [27] have been proposed to improve the metric, but its fundamental limits remain.

C. BER-based metric

In this section, we, first, present a design of BER-metric, then, we present some limits of BER-based metrics. Finally, we show the relationship between BER criterion and expected number of retransmissions needed for a successful transmission.

The BER criterion characterizes a network at the lowest level of the transmission chain. Measuring the error rate at physical layer provides a more refined estimation of quality of radio links. It allows the study of physical phenomena that influence the quality of communication. This link quality criterion has a direct impact on packet delivery rate and average communications delay. BER-based metric has been used in QoS routing as additive metric [28],[29]. Yélémou et al. [30] formally prove that this metric can be used as additive metric.

In [28], the authors used a BER-based approach to improve delay performance of on-demand routing protocol (not specified) but the used BER metric is too simplistic. BER depends on the Signal-to-Noise Ratio (SNR) at the receiving node. For simplicity, it has been assumed that the transmitted signal is affected only by free space loss. Reserve-and-go (RESGO) MAC protocol [31] was used. It is very simplistic and is based on the assumption of immediate relaying at intermediate nodes, without any anti-collision mechanism. RESGO MAC protocol is known as a low-delay MAC protocol and is relatively weak in reducing the inter-node interference. This performance of the proposed approach is limited to low interference wireless networking scenarios. The measurement of this metric has not been detailed.

Delahaye et al. [32], [33] use a ray-tracer propagation model CRT for a better estimate of the radio channel in Network Simulator (NS). The BER used in [29], [34] is the result of simulation of this realistic channel model. The use of this metric in MANET routing protocols (OLSR, AODV, ZRP) has significantly improved Packet Delivery Ratio (PDR) and delay. However, this metric has many drawbacks in actual implementation. Indeed, the BER metric is quite hard to measure in practice. A first method consists in injecting probe packets in the network. Knowing every binary element that a packet should contain; the receiver is able to evaluate the bit error rate by counting how many bits are erroneous. Nevertheless, the packet should be large enough to allow a precise measure of BER, but its size is in practice limited to the maximal transfer unit of the network. Note that control packets are too small and cannot be used to evaluate BER. So, this method generates an additional load for the network [35]. Another approach consists in sending impulses and

Journal of Theoretical and Applied Information Technology
15th December 2020. Vol.98. No 23

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

measuring the impulse response associated with a transmission. The main drawback is that this method requires an adapted physical layer. An estimation of all these disadvantages is presented in [5]. Moreover, using BER as an additive metric induces long end-to-end transmission paths [34]. These long paths with an overall good BER value would potentially permit a better packet delivery ratio, but they generate long delays and induce poor throughput. Indeed, first, long paths increase intra-communication interference. Second, they also increase the vulnerability of established routes, particularly in mobility or dense networks and multi-communication contexts. For all these reasons, the BER-based metrics remain theoretical.

Against these BER metric limits, we invested a new metric based on the number of retransmissions required to make a data transmission over a link successful. We can note that the number of packet retransmissions is highly related to the bit error rate *ber*. If we suppose a multimedia stream with constant packet size of *n* bits, the packet error rate is

$$per = 1 - (1 - ber)^n .$$

Furthermore, the expected number of transmissions to get a successful packet can be computed as the mathematical expectation of the stochastic variable *per*, that is $\frac{1}{(1-per)}$. Therefore, the expected number of transmissions is equal to:

$$nb_{transmissions} = \frac{1}{(1-ber)^n}$$

Table 1 shows how the expected number of transmissions depends on the BER, for 512-byte-long packets (n= 4096).

Table 1: Center Table Captions Above The Tables.

ber	$nb_{transmissions}$
10^{-5}	1.05
10^{-4}	1.56
2.10-4	2.27
3.10^{-4}	3.42
4.10^{-4}	5.15
5.10^{-4}	7.76

We see that when a BER equals 4.10^{-4} or above, the expected number of transmissions is beyond the number of attempts that a default MAC layer allows to successfully deliver a packet. If possible, these links should not be used. We therefore propose a new metric based on the number of transmissions and more precisely the number of retransmissions (that appear when the first attempt is not successful). As shown in Table I, this metric is highly related to BER, but, it does not require to be measured. It appears as a low-level but effective measure of the quality of links. This metric only requires that each MAC layer computes a mean value of the number of transmissions required to send packets to each neighbor, including the large ones. It is therefore not a costly measure. The next subsection is devoted to this metric.

D. Retransmissions-based metric

In this sub-section, first, the choice of route when intra communication interference (different transmissions for the same communication) is considered is discussed. In a second step, the design of our number of retransmissions-based metric is presented. In a third step, this metric is compared with the ETX metric.

In this new metric, the estimated cost of retransmission, compared to the cost of the first attempt, must be evaluated, and delay seems a convenient way to evaluate it.

Let us evaluate the transmission time between a source S and its neighbor D. Let's consider a given constant timet1corresponding to a successful first transmission. If transmission fails, the additional time for each retransmission ist2. For more details on different timing at MAC level see [36][11]. To simplify, *t1* is supposed to include processing time to pass from routing level to MAC level, Request To Send / Clear To Send (RTS/CTS) mechanism [37] time and propagation time, and *t2* includes additional ACKnowledge (ACK) packet waiting timeout, RTS/CTS mechanism time and propagation time (hence *t2>t1*).

Thereby, the delay is:

$$t = t1 + n - 1 \times t2$$

where *n* is the total number of transmissions. We normalize this equation to get our new metric (called PR for Packet Retransmission) as follows:

$$PR = \frac{t}{t1} = 1 + (n - 1) \times a$$

with $a = \frac{t2}{t1}$.

Note that this metric appears as the number of hops penalized by a weighted number of

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

retransmissions $a \times (n-1)$. It equals 1 if no retransmission is needed, but it may have a greater value if retransmissions occur. This value may be consider as an equivalent (but not integer) number of intermediate hops. *PR* is therefore an additive metric, since equivalent number of hops can be accumulated. In a sense, it is an alternative to the simple number of hops metric: this new metric is based on the number of intermediate nodes to access a recipient, but unlike the standard number of hops, it takes into account the quality of links.

To evaluate this metric, the number of packet transmissions must be determined. This information is available at the MAC level (it is a part of the communication statistics at the MAC layer) and, by a cross layer approach, is operated at routing level. There is no need to use special probes contrary to what is required in most metrics. When the used packet size is small (such as hello packet), the number of transmissions is almost always 1 (no retransmission) when the used link exists. On the contrary, large packets allow a better estimate of the quality of a link with this metric. In our protocols, all packets are considered.

Note that a is a mean value that represents retransmission cost. To calibrate the value of a, we use a statistical approach. A realistic propagation model taking into account the obstacles, with data packets in a multi-communication context, allowed us to find the value 1.65 for a with 0.1 as standard deviation. In-depth study could better refine the value of a. This parameter may vary depending on the nature (dense or less dense) and congestion level of the studied network.

To test the effectiveness of this new metric, it has been incorporated in OLSR as the metric used for path selection. At each node, the metric is calculated from the number of retransmissions required to make data transmissions successful over a given link. The obtained information is recorded as a new field in the record of neighbors and is disseminated through the network thanks to Topology Control (TC) messages. As it is an additive metric, a path length is computed as the sum of the metric of each of its links.

4. PERFORMANCE EVALUATION

In this section, we briefly present the five different protocols implementing the metrics we analyze. Then, we present our experimental setup and simulation conditions, specifically our realistic propagation model and realistic mobility model. We conclude the section with an analysis of simulation results.

A. Routing protocols

We compare performance of five routing protocols, the standard one OLSR-3626 and four modified ones, OLSR-delay, OLSR-ETX, OLSR-BER and OLSR-PR. OLSR-3626 refers to the standard OLSR described in RFC-3626 [23]. Route selection criterion used in this protocol is the minimum number of hops needed to reach the destination. The four other protocols are based on standard OLSR. Basically, they consider another metric than the number of hops. These metrics are additive: the distance of a route is the sum of the distances of all elementary links on the route. A node computes the shortest path, in term of the considered metric, toward each destination and records it in its routing table. OLSR-delay chooses delay as metric. Link delay measures are based on Hello messages. Considering OLSR-ETX, ETX metric is implemented like in [1]. The delivery ratio is based on Hello messages. OLSR with BER consideration (OLSR-BER) consists in selecting the path with the lowest global BER described in Section III-C. OLSR-PR is based on PR metric as described in Section III-D.

B. Experimental setup

To show effectiveness of new QoS approaches for protocol enhancements, in most studies, evaluations rely on simulation. Most of the time, experiments do not take into account any environment parameters when modeling the propagation channel. They often consider only the direct ray between transmitter and receiver considering that no obstacle disturbs transmissions. Furthermore, other effects such as multiple paths induced by the environment are not taken into account although they highly influence the quality of the received signal [38], [39], [40]. If the environment is not considered, the obtained results are biased and rather optimistic. The influence of bad links is thus highly underestimated. To compute more convening simulations, we must use a realistic model of wave propagation taking into account the environment characteristics. Therefore, we enhanced NS2 [41] with a communication ray-tracer (CRT) simulator that has been developed at the XLIM-SIC laboratory [32]. Our BER-based protocol directly relies on BER values computed by this CRT software.

Another important simulation parameter to consider is the mobility model. A mobility model reflects the spatio-temporal behavior of mobile

Journal of Theoretical and Applied Information Technology
15th December 2020. Vol.98. No 23

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

nodes in a network, aiming at reproducing the best motion and travel conditions of the nodes in a real-world context. Several studies such as [42], [43] have shown that the mobility model can significantly affect the performances of a simulated protocol. Therefore, special attention should be paid in the design and definition of mobility model considering the characteristics and constraints of the modeled environment. In this respect, most commonly used models are not realistic [44], [45]. To realistically model the movement of a node, the VanetMobiSim software is used [46]. Our choice fell on this simulator mobility due to its realism and the control it provides to define paths in correlation and consistency with our environment model. VanetMobiSim is also easily interfaced with NS2. Specifically, it uses a mobility file in XML format, which contains all the details of the microscopic and macroscopic models that govern the node mobility information. The mobility model set nodes in the software and takes into account the environmental parameters of mobile nodes (traffic lights, speed limits, etc..) and possible interactions between mobile nodes. A node may thereby accelerate or decelerate according to the constraints of the environment.

The global parameters for the simulations are given in Table II.

Table 2: Simulation parameters.

Parameters	Values
Network simulator	NS2
Simulation time	100s
Simulation area	1000m*1000m
Maximun number of transmissions	4
Transmission power	0.1w
Data types	CBR
Data packet size	512 bytes
MAC layer	IEEE 802.11a

We have also used a realistic model of the Munich town (urban outdoor environment, see Figure. 1), obstacles (building, etc) are printed red. Points rep-resent nodes.

C. Simulation results

We simulate OLSR protocol based on our new metric and compare results with standard and the most common enhanced ones. Communication concern ten source-destination pairs simultaneous transmissions during 100s. They are visible in Figure 1: 2–9, 4–6, 7–8, 18–2, 5–19, 3–0, 8–10, 1–5, 17–12,14–15. The number of hops between the transmitters and receivers varies from 2 to 6. To compare the obtained results, we consider two criteria: packet delivery ratio (PDR) and average end-to-end delay. PDR is the ratio of the number of successfully delivered data packets over the number of sent data packets. Average end-to-end Delay concerns only successfully delivered packets. The transmission delay of a packet is determined by the difference between the date (at the application layer) of receipt (at the destination) and the date of issue (at the source). An average is then calculated from these delays. Our metric considers both quality of links in terms of transmission error and any kind of delay estimation to select shortest paths. It is important to note that, for these results, BER estimation time is not taken into account. The BER measurement is supposed for all links completed before the packet transmission begins. We compare different protocols, first, in fixed-nodes context, then we analyze them with mobile nodes.

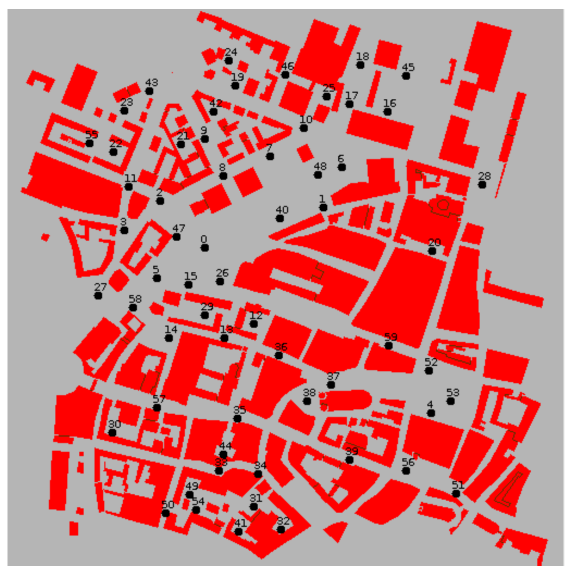

Figure 1: Simulation environment when number of nodes=60. Obstacles are printed red.

1) Fixed-node context

In this set of simulation scenarios, the number of nodes increases from 10 to 50. We study the protocols' performance under the influence of path breakages in low densities, routing overhead and new paths in high densities (high network connectivity).

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Figure 2 shows that all these enhanced OLSR outperform the standard one (OLSR-3626) in delay. This means that the shortest path based on the number of hops metric is not suitable for communications in realistic environment. (Couto et. al have produced the same result [1]). These results show that our approach (OLSR-PR) always finds best paths in term of end-to-end delay than other protocols. Considering PDR criterion, OLSR-BER and OLSR-PR outperform the others (Figure 3). Very often the OLSR-BER is slightly better than OLSR-PR. The difference does not exceed 10 points. Analysis of simulation trace files (statistical results) shows that the paths found by OLSR-3626 is shorter (in terms of number of hops), followed by OLSR-PR. The average length of the paths used by OLSR-BER and OLSR-ETX are the longest.

The best performance of OLSR-PR against OLSR-BER and OLSR-ETX is due to the intra-communication interference effect and additional processing time at the intermediate nodes that are larger for the latter. Our new approach allows to better optimize the number of hops. But the poorer performance of OLSR-3626 is because some of the used links have a very poor quality, resulting in too many retransmissions.

Regarding PDR parameter, as shown in Figure 3, although OLSR-PR often seems less efficient than OLSR-BER, a thorough analysis shows that it has delivered more packets (it provides the best throughput). This has an impact on the end-to-end delay. Since additional packets sent using OLSR-PR require longer delays, so the average delay is degraded.

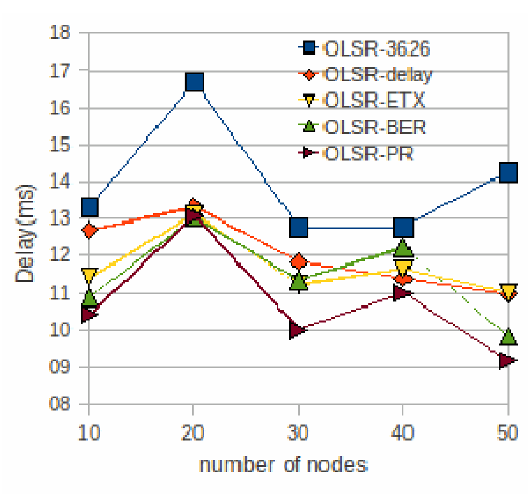

Figure 2: Delay evolution with number of nodes.

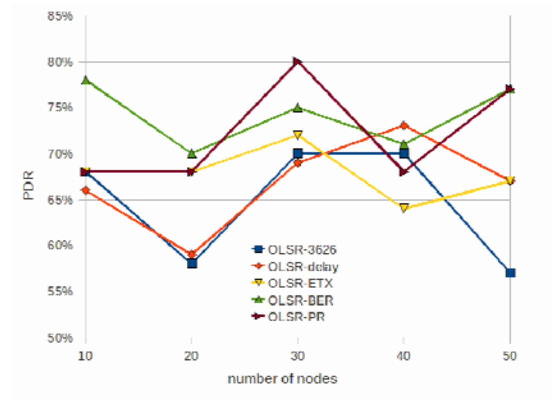

Figure 3: PDR evolution with number of nodes.

2) Mobile-node context

In this section, we want to study the impact of rapid change of network topology on the performance of our new metric. We vary the average speed of nodes from 4 m/s to 20 m/s. We explained in Section III the highly volatile nature of delay and ETX values in a mobile context. In Figure 4, we compare average delays for OLSR-PR, OLSR-3626 and OLSR-BER with mobile nodes. For low speeds (below 12 m/s), OLSR-PR and OLSR-BER outperform OLSR-3626. OLSR-PR seems not always better than OLSR-BER. In fact, for 12 m/s and 15 m/s, OLSR-BER has better delays than OLSR-PR. An analysis of received packets shows that, for these speeds, OLSR-PR was able to successfully transfer more packets (1956 packets against 1911 for OLSR-BER at 12 m/s and 1871 packets against 1740 for OLSR-BER at 15 m/s). Nevertheless, these additional successful packets imply a significant increase of the average delay, since longer paths are found. Figure 5 illustrates better this point. We consider the delay corresponding to the *n %* best packet transmissions among emitted packets for different values of *n* (that is necessary less than PDR). Here, we find that OLSR-PR provides faster paths globally, for a large amount of transmissions. The increase of delay is caused by the additional packets that the protocol manages to send (where OLSR-BER fails).

Considering PDR criterion for high node speed, OLSR-3626 protocol outperforms the enhanced ones (Figure 6). The difference between OLSR-BER and OLSR-PR does not exceed 5 points.

The poorer performance of QoS protocols is due to the long paths that they select. When network topology changes too rapidly, transmissions success hardly on long paths. Most the paths over four hops are not allowed to have more than 50% success rate in the packet transmissions. Thus, more transmissions failed with OLSR-BER compared to the other two protocols.

In mobility context, the drawbacks of topology changing dominate. For a significant improvement in performance, it would be better to reconsider the neighborhood much more frequently through the reduction of various timers.

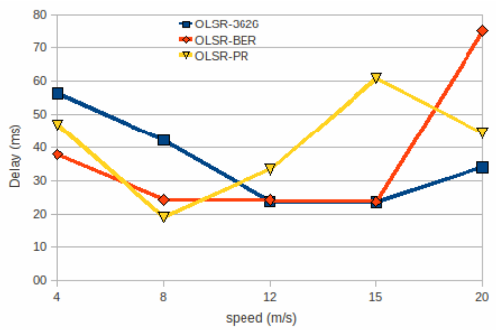

Figure 4: Delay evolution with nodes average speed.

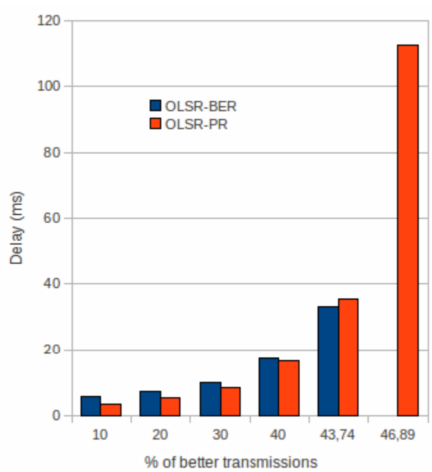

Figure 5: Delay of better transmissions when node speed is 15 m/s.

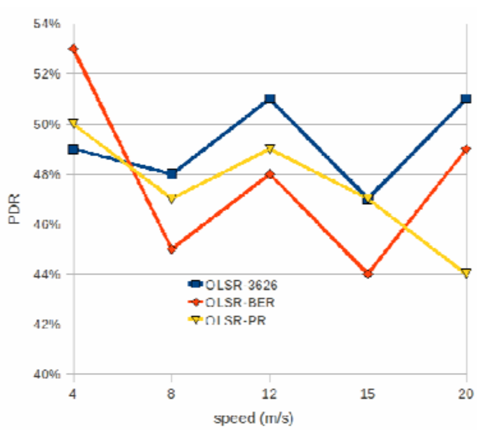

Figure 6: PDR evolution with nodes average speed.

5. CONCLUSION AND PROSPECTS

We first conduct a critical analysis of several routing approaches which take into account quality of links in the choice of route. We highlight their strengths and disadvantages. To be efficient, QoS metric-based algorithms must use a light and immediate way to evaluate link quality. It should not induce significant additional load. Then, we reviewed various link quality metrics. We compared their performance. The PR metric outperforms the other ones. With PR-metric-based OLSR, the distance be-tween a node and its neighbor will not be 1 but $1 + a \times (n - 1)$ where n represents the average number of transmissions required to make transmissions successful and a is a parameter to weight retransmission cost. We choose to base a on expected transmission delay, that is, the ratio between the average delay required for a retransmission over the delay necessary for an initial successful transmission. This metric indirectly relates to BER, since this latter affects the number of retransmissions. In addition, it takes into account the real-time network load. Its estimation does not induce additional routing load or a large computation time. This number of retransmision-based metric is a compromise between the number of hops metric that does not consider the quality of links and metrics based on packet delivery ratio that induce too long paths. We retain that, to be efficient, the metric used to quantify link must not induce more instability in the routes used for data transmission. In the context of ad hoc networks, it must not lead to too long paths. The number of hops must be judiciously exploited. For better PDR and delay performance, neighbor links and MPR node selection should be reconsidered. When node speed is very high (too dynamic network topology), the results are mixed. These allow us to say that the main issue in high mobility context is not to consider link quality, but rather control of neighborhood information. A node should more frequently inventory its links and routes.

REFRENCES:

[1] A[1] D. S. J. de Couto, D. Aguayo, J. Bicket, and R. Morris, “Ahigh-throughput path metric for multi-hop wireless routing,”in Proceedings of the 9th Annual International Conference on Mobile Computing and Networking, MobiCom ’03, (New York,NY, USA), pp. 134–146, ACM, 2003.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[2] G. Anastasi, M. Conti, and M. Di Francesco, “A comprehensive analysis of the mac unreliability problem in ieee 802.15.4wireless sensor networks,” Industrial Informatics, IEEE Transactions on, vol. 7, pp. 52–65, Feb 2011

[3] J. Whitbeck, V. Conan, and M. Amorim, “Tuning message size in opportunistic mobile networks,” in Proceedings of the1st ACM workshop on Networking, systems, and applications for mobile handhelds, MobiHeld’09, (New York, NY, USA),pp. 75–76, ACM, 2009.

[4] I. Chlamtac, M. Conti, and J. J. N. Liu, “Mobile ad hoc networking: imperatives and challenges,” Ad Hoc Networks,vol. 1, no. 1, pp. 13 – 64, 2003.

[5] L. Shi, A. Fapojuwo, N. Viberg, W. Hoople, and N. Chan, “Methods for calculating bandwidth, delay, and packet loss metrics in Multi-Hop IEEE802.11 ad hoc networks,” in IEEE Vehicular Technology Conference (VTC), pp. 103–107, May2008.

[6] M. Zuniga, I. Irzynska, J. Hauer, T. Voigt, C. A. Boano, andK. Roemer, “Link quality ranking: Getting the best out of unreliable links,” in IEEE International Conference on Distributed Computing in Sensor Systems and Workshops (DCOSS), pp. 1–8, June 2011.

[7] R. Fonseca, O. Gnawali, K. Jamieson, and P. Levis, Four-Bit Wireless Link Estimation. 2007.

[8] G. Karbaschi and A. Fladenmuller, “A link-quality and congestion-aware cross layer metric for multi-hop wireless routing,” in IEEE International Conference on Mobile Ad hoc and Sensor Systems Conference, IEEE, Nov. 2005.

[9] D. S. J. d. Couto, D. Aguayo, J. Bicket, and R. Morris, “a high-throughput path metric for multi-hop wireless routing”, Wireless Networks, vol. 11, pp. 419–434, July 2005.

[10] F. Ingelrest and D. Simplot-Ryl, “Maximizing the delivery of *mpr* broadcasting under realistic physical layer assumptions, ”Journal of Computer Science and Technology, vol. 23, no. 3,pp. 451–460, 2008.

[11] S. Su, Y. Su, and J. Jung, “A novel QoS admission control for ad hoc network”, in IEEE Wireless Communications and Networking Conference (WCNC), pp. 4193–4197, Mar. 2007.

[12] B. Bakhshi and S. Khorsandi, “Complexity and design of QoS routing algorithms in wireless mesh networks”, Computer Communications, vol. 34, no. 14, pp. 1722 – 1737, 2011.

[13] Z. Wang and J. Crowcroft, “Quality-of-service routing for supporting multimedia applications”, IEEE Journal on Selected Areas in Communications, vol. 14, pp. 1228–1234, Sept. 1996.

[14] K. A. Al-Soufy and A. M. Abbas, “A path robustness-based quality of service routing for mobile ad hoc networks,” in2010IEEE 4th International Conference on Internet Multimedia Services Architecture and Application (IMSAA), pp. 1–6, IEEE, Dec. 2010.

[15] J. Ledy, H. Boeglen, B. Hilt, A. Abouaissa, and R. Vauzelle, “An enhanced AODV protocol for VANETs with realistic radio propagation model validation,” in 2009 9th International Conference on Intelligent Transport Systems Telecommunications (ITST), pp. 398–402, 2009.

[16] O. Gnawali, M. D. Yarvis, J. Heidemann, and R. Govindan, “Interaction of retransmission, blacklisting, and routing metrics for reliability in sensor network routing,” in IEEE Conference on Sensor and Adhoc Communication and Networks, pp. 34-43.Santa Clara, California, USA, IEEE., May 2004

[17] K. Oudidi, A. Hajami, and M. Koutbi, “QoS routing using OLSR protocol,” in Proceedings of the 14th WSEAS international conference on Communications (ICCOM), pp. 165–171, 2010.

[18] H. Li, Y. Cheng, C. Zhou, and W. Zhuang, “Minimizing end-to-end delay: A novel routing metric for multi-radio wireless mesh networks”, in IEEE INFOCOM, pp. 46–54, Apr. 2009.

[19] Y. Yang, “Designing routing metrics for mesh networks,” in InWiMesh, 2005.

[20] M. Siraj, “A Survey on Routing Algorithms and Routing Metrics for Wireless Mesh Networks”, World Applied Sciences Journal, pp. 870–886, 2014.

[21] R. Draves, J. Padhye, and B. Zill, “Routing in multi-radio, multi-hop wireless mesh networks,” in Proceedings of the10th annual international conference on Mobile computing andnetworking, MobiCom ’04, (New York, NY, USA), pp. 114–128, ACM, 2004.

[22] D. Johnson and G. Hancke, “Comparison of two routing metrics in OLSR on a grid based mesh network”, Ad Hoc Netw., vol. 7,pp. 374–387, Mar. 2009.

[23] T. Clausen and P. Jacquet, “Optimized link state routing proto-col (OLSR),” Oct. 2003. IETF RFC 3626.

[24] F. Shi, D. Jin, and J. Song, "A survey of traffic-based routing metrics in family of expected transmission count for self-organizing networks", Computers and Electrical Engineering,vol. 40, no. 6, pp. 1801 – 1812, 2014.

[25] P. Esposito, M. Campista, I. Moraes, L. Costa, O. Duarte, and M. Rubinstein, "Implementing the expected transmission time metric for OLSR wireless mesh networks," in Wireless Days(WD), pp. 1–5, Nov. 2008.

[26] R. Draves, J. Padhye, and B. Zill, "Routing in multi-radio, multi-hop wireless mesh networks", in Proceedings of the10th annual international conference on Mobile computing and networking (MOBICOM), pp. 114–128, 2004.

[27] A. Cerpa, J. L. Wong, M. Potkonjak, and D. Estrin, "Temporal properties of low power wireless links: Modeling and implications on multi-hop routing", In ACM MobiHoc, pp. 414 –425, ACM Press, 2005.

[28] N. Wisitpongphan, G. Ferrari, S. Panichpapiboon, J. Parikh,and O. Tonguz, "QoS provisioning using BER-based routing in ad hoc wireless networks," in Vehicular Technology Conference(VTC), vol. 4, pp. 2483–2487, May 2005.

[29] T. Yélémou, P. Meseure, and A. M. Poussard, "A new ber-based approach to improve OLSR protocol", in 2011 Eighth Inter-national Conference on Wireless and Optical Communications Networks, pp. 1–5, May 2011.

[30] Tiguiane, Yélémou, P. Meseure, and A.-M. Poussard, "Taking Binary Error Rate into Account to Improve OLSR Protocol," International Journal of Computer Networks and Communications Security, pp. 276–285, 2016.

[31] G. Ferrari and O. Tonguz, "Mac protocols and transport capacity in ad hoc wireless networks: Aloha versus pr-csma", in Military Communications Conference (MILCOM), vol. 2,pp. 1311–1318, Oct. 2003.

[32] R. Delahaye, Y. Pousset, A.-M. Poussard, C. Chatellier, andR. Vauzelle, "A realistic physic layer modeling of 802.11gad hoc networks in outdoor environments with a computation time optimization," in Proceedings of the Eleventh World Multi-Conference on Systemics, Cybernetics and Informatics (WM-SCI), (Orlando, Florida, USA), 2007.

[33] R. Delahaye, A.-M. Poussard, Y. Pousset, and R. Vauzelle, "Propagation models and physical layer quality criteria in-fluence on ad hoc networks routing," inTelecommunications,2007. ITST '07. 7th International Conference on ITS, pp. 1–5,June 2007.

[34] T. Yélémou, P. Meseure, and A. M. Poussard, "Improving zrp performance by taking into account quality of links," in2012IEEE Wireless Communications and Networking Conference (WCNC), pp. 2956–2960, April 2012.

[35] J. Ledy, H. Boeglen, A. Poussard, B. Hilt, and R. Vauzelle, "A Semi-Deterministic channel model for VANETs simulations," International Journal of Vehicular Technology, vol. 2012, pp. 1–8, 2012.

[36] IEEE, "Wireless lan medium access control (MAC) and physical layer (PHY) specifications (IEEE standard 802.11, part 11)", June 1999.

[37] J. Weinmiller, H. Woesner, J. pierre Ebert, and A. Wolisz, "Analyzing the rts/cts mechanism in the dfw mac media access protocol for wireless lans," 1995.

[38] J. Gozalvez, M. Sepulcre, and R. Bauza, "Impact of the radio channel modelling on the performance of vanet communication protocols," Telecommunication Systems, pp. 1–19, 2010.

[39] W. Hamidouche, R. Vauzelle, C. Olivier, Y. Pousset, andC. Perrine, "Impact of realistic mimo physical layer on video transmission over mobile ad hoc network," in Personal, Indoor and Mobile Radio Communications, 2009 IEEE 20th International Symposium on, pp. 187–191, 2009.

[40] M. G¨unes, M. Wenig, and A. Zimmermann, "Realistic mobility and propagation framework for manet simulations," in Pro-ceedings of the 6th International IFIP-TC6 Conference on AdHoc and Sensor Networks, Wireless Networks, Next Generation Internet, NETWORKING'07, (Berlin, Heidelberg), pp. 97–107,Springer-Verlag, 2007.

[41] L. Breslau, D. Estrin, K. Fall, S. Floyd, J. Heidemann,A. Helmy, P. Huang, S. McCanne, K. Varadhan, Y. Xu,and H. Yu, "Advances in network simulation," COMPUTER,vol. 33, May 2000.

[42] F. Bai, N. Sadagopan, and A. Helmy, "Important: a framework to systematically analyze the impact of mobility on performance of routing protocols for ad hoc networks," in22th Annual Joint Conference of the IEEE Computer and Communications, vol. 2,pp. 825–835, 2003.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[43] G. Marfia, G. Pau, E. De Sena, E. Giordano, and M. Gerla, "Evaluating vehicle network strategies for downtown portland: Opportunistic infrastructure and the importance of realistic mobility models," in First International MOBISYS workshop on Mobile Opportunistic Networking, pp. 47–51, 2007.

[44] A. H. Fan Bai, "A survey of mobility models in wireless ad hoc networks," 2004. http://www.cise.ufl.edu/ helmy/papers/Survey-Mobility-Chapter-1.pdf.

[45] T. Camp, J. Boleng, and V. Davies, "A survey of mobility models for ad hoc network research," Wireless Communications and Mobile Computing, vol. 2, pp. 483–502, Aug. 2002.[46] J. H ̈arri, F. Filali, and C. Bonnet, "Mobility models for vehicular ad hoc networks: a survey and taxonomy," in IEEE communications surveys and tutorials, vol. 11, pp. 19–41, 2009.