A New Composite Metric For QoS Satisfying Both Mobility And Bandwidth Constraints In Manets

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ABSTRACT. This paper proposes a novel routing metrics based on the residual bandwidth and mobility index of the nodes. The algorithms are designed to cope with high mobility and bandwidth constraints in order to find optimal paths that guarantee the QoS constraints. A maximizable routing metric theory has been used to develop a metric that selects, during route discovery process, routes that are more stable and offer a maximum throughput. The OLSR (Optimized Link State Routing) protocol, which is an optimization of link state protocols designed for MANETs (Mobile Ad hoc Networks) is used as a test bed in this work. We prove that our proposed composite metric (based on mobility and bandwidth) selects a more stable MPR set than the QOLSR algorithm which is a well known OLSR QoS extension. By mathematical analysis and simulations, we have shown the efficiency of this new routing metric in term of routing load, packet delivery fraction and delay

KEYWORDS: Mobile Ad hoc networks, quality of service, routing protocol, routing metric, mobility.

1. Introduction

A MOBILE AD HOC NETWORK (MANET) is a collection of mobile nodes working on a dynamic autonomous network. Nodes communicate with each other over the wireless medium without need of a centralized access points or a base station. Since there is no existing communication infrastructure, adhoc networks cannot rely on specialised routers for path discovery and routing. Therefore, nodes in such a network are expected to act cooperatively to establish routes instantly. Such a network is also expected to route traffic, possibly over multiple hops, in distributed manner, and to adapt itself to the highly dynamic changes of its links and the mobility patterns of its constituent nodes.

Providing QoS in MANETs is a tedious task. It's known that combining multiple criteria in the routing process is a hard problem (NP-Complet). A complete QoS model in MANETs will span multiple layers, however the network layer plays a vital role in providing the required support mechanisms. The goal of QoS routing is to obtain feasible paths that satisfy end-system performance requirements. In this paper we reiterate our proposed mobility metric. Based on the use of this mobility metric we propose a new composite metric, to find the optimal route given the QoS constraints. The objective of this metric is to find an optimal stable path with maximum available bandwidth .

Using the OLSR Protocol [1-2], we show that our proposed metric selects stable MPR set rather than the QOLSR [3-4] algorithm which is a well known OLSR QoS algorithm for MANETs.

2. QOS Routing problems

One of the key issues in providing end-to-end QoS in a given network is how to find a feasible path that satisfies the QoS constraints. The problem of finding a feasible path is NP-Complete if the number of constraints is more than two, it cannot be exactly solved in polynomial time and mostly dealt with using heuristics and approximations.

The computation complexity is primarily determined by the composition rules of the metrics [9]. The three basic composition rules are: additive (such as delay, delay jitter, logarithm of successful transmission, hop count and cost), multiplicative (like reliability and probability of successful transmission) and concave/min-max (e.g. bandwidth). The additive and multiplicative metric of a path is the sum and multiplication of the metric respectively for all the links constituting the path. The concave metric of a path is the maximum or the minimum of the metric over all the links in the path.

The proof of NP-Completeness relies heavily on the correlation of the link weight metrics. QoS Routing is NP-Complete when the QoS metrics are independent, real numbers or unbounded integers.

Based on maximizable routing metrics [6], it is shown that two or more routing metrics can be combined to form a composite metric if the original metrics are bounded and monotonic. Before we proceed to the mathematical proof, we give definitions [6] of maximal tree and the properties desired for combining metrics i.e. bounded- ness and monotonicity.

Definition 1: *Routing Metric*

A routing metric for a network N is six-tuple (W,Wf, M, mr, met, **R**) where:

1. M is a set of metric values
2. Wf is a function that assigns to each edge (i,j) in N a weight Wf((i,j)) in W
3. W is a set of edge weights
4. mr is a metric value in M assigned to the root.
5. met is a metric function whose domain is MxW and whose range is M (it takes a metric value and an edge value and returns a metric value).
6. **R** is a binary relation over m, the set of metric values that satisfy the following four conditions of irreflexivity,

Definition 2: *Boundedness*

A routing metric *(W, Wf, M, mr, met,* ***R*** *)* is bounded iff the following condition holds for every edge weight w in W and every metric value m in M.

$$met(m,w)\ \mathbf{R}\ m \lor met(m,w) = m$$

Definition 3: *Monotonicity*

A routing metric *(W,Wf, M, mr, met,* ***R*** *)* is monotonic iff the following condition holds hue for every edge weight w in W and every pair of metric values m and m' in M:

$$m\ \mathbf{R}\ m' \Rightarrow (met(m,w)\ \mathbf{R}\ met(m',w) \lor met(m,w) = met(m',w))$$

3. Our improvement

Our solution can be summarized as follows. Bandwidth is one of the most important factors required and requested by customer's applications. Mobility and bandwidth are crucial problem in MANETs, and until now, the majority of routing protocols have shown some weaknesses to face a high mobility and poor bandwidth resources in the network.

Our goal is to select the metric to maximize network throughput taking into account the key constraints of MANET environment (mobility). The idea behind the composite metric is that a cost function is computed locally at each node during the topology information dissemination during the flooding process. Once the network converges, each node runs a shortest path algorithm based on the calculated metric to find the optimal route to the destination. An underlying implication of this is that each node should also be able to measure or gather the information required. Bandwidth and mobility information's are available and could simply be gathered from lower layers. This paper is mainly focused on solving the routing issues based on the assumption that an underlying mechanism is there to gather the necessary information about the individual metrics.

We suggest the simple solutions already proposed in [5] to get available bandwidth at each node. Mobility estimation will be based on our proposed mobility measure [6-7] due to its simplicity and lightweight.

The proposed relationship for the composite metric is given below:

Comp_Met= $\left[\left(K0+\frac{K1}{M}\right)*BW+K2*(1-M)\right]$ [redacted] $*E$ (2)

Where

BW : Available Bandwidth in kilobits per second

E : residual energy of node (number in range 0 to 5; 0 refers no energy for node to perform)

The constants K0, K1, K2, will be set by the administrator based on network applications and required traffic class (conversational, streaming, background and interactive).

To the best of our knowledge, this work is amongst the first efforts to consider nodes with energy and mobility constraints in MANETs.

The proposed metric reflects a real dynamic environment where nodes have limited energy resources, and bandwidth constraints are crucial (streaming application). The idea behind the proposed metric is that in Manets environments, **durable-stable link with optimal bandwidth should never be omitted.**

Default metrics are defined for K1 to be set to 0, and K2 and node's energy resources are not limited:

Default metric1 = [redacted] $*BW+K2*(1-M)$ (3)

Default metric2 = $K0+K2\frac{BW}{M}$ (4)

3.1 Proprieties of the proposed metric

This paper mainly focused on solving the routing issues based on the assumption that an underlying mechanism exists to gather the necessary information about the individual metrics. In this subsection we prove that each of the individual metrics satisfies the conditions of houndness and monotonicity conditions then we prove the proposed metric.

The bandwidth metric represents the available bandwidth at the link. A simple technique proposed in [3], which computes available bandwidth based on throughput can be used to measure the bandwidth on any given node (respect. link *L(i,j))*.

Available bandwith "α" for each node could be estimated by calculating the percentage of free time T_L which is then multiplied by the maximum capacity of the medium Cmax as follows :

$$\alpha = T_L * C_{\max} \quad (5)$$

Let B_{av} (i,j) represent available bandwidth of the link then,

$$B_{av}(i,j) = \min\{B_{al}(i), B_{al}(j)\} \quad (6)$$

Where $B_{al}(i)$ is the available bandwidth of the node *i*

Also let $W_{i,j}$ be the edge weight on the link *L(i,j)*. $W_{i,j}$ can be estimated from the following relationship given below.

$$W_{i,j} = \frac{1}{B_{al}(i,j)} \quad (7)$$

The condition of boundness implies that along any path starting from root, the metric is non-increasing. The metric relation is given by: *met {m,W(i,j)}*.

Given *m* is the metric of the root. It is evident that this meets the boundedness and that monotonicity conditions hold for the selected metric. The available bandwidth is always positive, hence for any node located at distance *"d"* from the root *W(i,j)* would always be less than or equal to the metric value at the root. Since the bandwidth is always positive and greater than zero hence it satisfies the boundedness and monotonicity conditions.

The mobility metric represents the rate of link state changes in the network. Our simple technique proposed in [6] could be used to define mobility degree of a node and a link.

As *node's mobility* reflects how likely it is to either corrupt or drop data. It could be considered as reliability metrics [8]. Because the reliability metric is bounded and strictly monotonic, it may be sequenced with the partial metric while preserving boundedness and monotonicity.

Moreover, residual energy function is monotonic and bounded its value decreases in time. it also reflects how likely it is to either corrupt or drop data. Consequently, it can be sequenced with the partial metric while preserving boundedness and monotonicity.

3.2. Validation

To validate the robustness and efficiency of the proposed metrics, we use four models: bandwidth model, mobility model, sum_bandwidth-mobility Model and prd_bandwidth-mobility model.

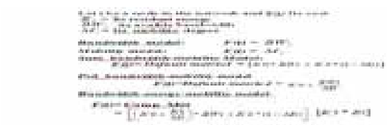
Metrics serves as *Cost-to-Forward* function . By exchanging Hello messages, every node is aware of its neighbor nodes and can simply compute its *Cost-to-Forward* value (i.e. to forward packet).

The Cost-to-Forward function (F(i)) for each of the four models can be defined as follows:

Let i be a node and F(i) its cost. Ei its residual energy, BWi its available bandwidth and Mi its mobility degree.

Bandwidth model : **F(i)=BWi** Mobility model: ***F(i)=Mi***

Sum_Bandwidth_Mobility model



Prd_Bandwidth_Mobility model

Bandwidth_energy_mobility model

4. Simulations and results

In this section we have compared the performance of the original OLSR protocol based on the MPR selection standard algorithm, and the two modified OLSR protocols related to different proposed model: bandwidth model (QOLSR) , mobility model (MobOLSR), sum_bandwidth-mobility Model (Met1OLSR) and prd_bandwidth-mobility model (Met2OLSR).

1.1. Simulation environment

For simulating the original OLSR protocol and the modified OLSR protocols related to our proposed criterions, we have used the OLSR protocol implementation [10] which runs in version 2.33 of Network Simulator NS2 [9].
We use a network consisting of 50 mobile nodes to simulate a high-density network. These nodes are randomly moved in an area of 800m by 600m according to the Random Waypoint (RWP) mobility model. Moreover, to simulate a high dynamic environment (the worst case), we have consider the RWP mobility model with a pause time equal to 0. Nodes can move arbitrarily with a maximum velocity of 140km/h. All simulations run for 100s.
A random distributed CBR (Constant Bit Rate) traffic model is used which allows every node in the network to be a potential traffic source and destination. The CBR packet size is fixed at 512 bytes. The application agent is sending at a rate of 10 packets per second whenever a connection is made. All peer to peer connections are started at times uniformly distributed between 5s and 90s seconds. The total number of connections and simulation time are 10 and 100s, respectively.
For each presented sample point, 40 random mobility scenarios are generated. The simulation results are thereafter statistically presented by the mean of the performance metrics. This reduces the chances that the observations are dominated by a certain scenario which favors one protocol over another. As we have interest in the case of high mobility (i.e. high link status and topology changes) we have reduced the HELLO interval and TC interval at 0.5s and 3s, respectively, for quick updates of the neighbors and topology data bases.

1.2. Results and discussion

With the supposed configuration cited above, we have run simulations in different mobility levels by varying maximum speed of nodes between 0km/h (no mobility) to 140km/h (very high mobility) in steps of 10km/h. To maximize performances we have chosen the mobility coefficient equal to λ =0.75.

1.2.1. Comparing MobOLSR to OLSR and QOLSR

Figure 4 shows that Mob-OLSR and QOLSR protocols ensure a good enhancement in terms of delay comparing to the original OLSR protocol for all maximum speeds. Precisely, the QOLSR and MobOLSR protocols delay is around 1.25 seconds (enhancement by 0.4s comparing to he original OLSR) with higher mobility rate (maximum speed equal to 140km/h) and decreases to almost 1.25 seconds (enhancement by 0.1sec comparing to he original OLSR) with static topology conditions. For the original OLSR protocol the delay gets more than twice as large being almost 2.1 sec for high mobility and surprisingly increasing to over 1.4 seconds when the mobility is decreased. For the intermediate speed (from 40m/s to 100m/s) a lightweight difference between MobLSR and QOLSR is shown (enhancement by 0.1sec for MobOLSR comparing to QOLSR for maximum speeds (0m/s and 30m/s)) . This allows us to conclude that MobOLSR performs better than QOLSR for intermediate speed.

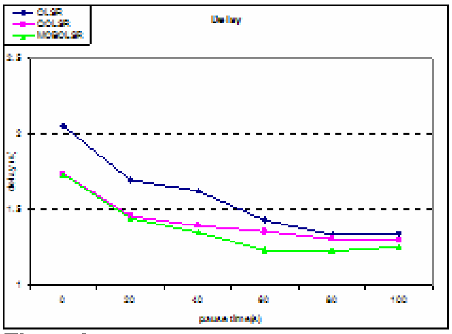


Figure 4. *Comparison of the three versions of the OLSR protocol in terms of delay*

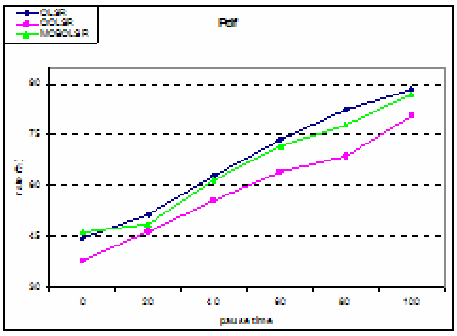


Figure 5. *Comparison of the three versions of the OLSR protocol in terms of packet delivery fraction*

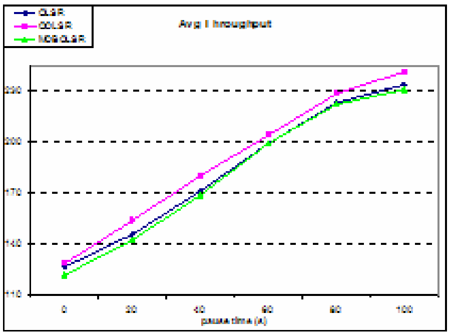


Figure 6. *Comparison of the three versions of the OLSR protocol in terms of Throughput*

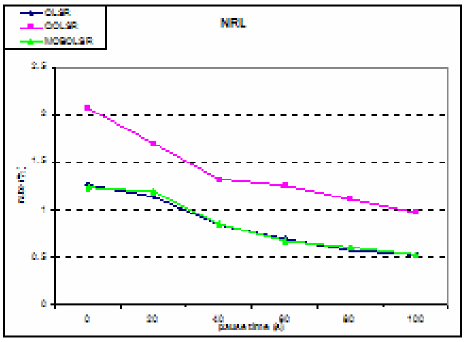


Figure 7. *Comparison of the three versions of the OLSR protocol in terms of NRL*

According to the Figure 5, the original OLSR and MobOLSR protocols ensure in the whole the same packet delivery fraction for all maximum speeds with a slight improvement in original OLSR for all maximum speed. Indeed, it can be seen that the number of packets dropped along the path is quite similar for all maximum speed being approximately 45% at worst for the original OLSR and MobOLSR and 35% for QOLSR. Moreover, the ratio is worse for a continuously changing network (i.e. high maximum speed) than for the static path conditions, because the number of link failures grows along with the mobility. However, it is interesting to notice that even with static topology conditions, sending nodes do not achieve 100% packet delivery but only 85%-89%. This clearly shows the impact of the network congestion and packet interference as the load on the network increases.

Moreover, compared to MobOLSR and original OLSR, QOLSR protocol presents a remarkable degradation in PDF for all maximum speeds. this is because QOLSR does not take into account the state of links in MPR selection process. In summary, we can say that the MobOLSR protocol is more adapted to all levels of mobility from 0m/s (no mobility) to 40m/s (very high mobility).

Figure 6, shows the average throughput for the three version of protocols. The original OLSR and MobOLSR protocols ensure in the whole the same average throughput for all maximum speeds being approximately 125 kbps at worst. Moreover, the ratio is worse for a continuously changing network (i.e. high maximum speed) than for the static path conditions, because the number of link failures grows along with the mobility. Moreover, it is interesting to notice that even with static topology conditions, network average throughput channel capacity (5Mbps) but only 230 kbps. This clearly shows the impact of the network congestion and packet interference as the load on the network increases.

QOLSR ensures an enhancement by 10kbps comparing to MobOLSR and the original OLSR for all

maximum speed. This is because OLSR select as MPR nodes with high throughput.
Figure 7 illustrates the normalized routing load (NRL) introduced into the network for the three versions of OLSR protocol, where the number of routing packets is normalized against sent data packets. A fairly stable normalized control message overhead would be a desirable property when considering the performance as it would indicate that the actual control overhead increases linearly with maximum speed of nodes due to the number of messages needed to establish and maintain connection. The original OLSR protocol and MobOLSR protocol produces the lowest amount of NRL when compared to QOLSR protocol during all maximum speed values. Moreover, original OLSR and MobOLSR protocol produce the same routing load for all the maximum speed.

1.2.2. Comparing OLSRMet1 and OLSRMet2 to QOLSR

Figure 9, 10, 11, 12 and 13 illustrate the average end to end delay for the proposed protocols (OLSRMet1 and OLSR Met2 MOBOLSR and QOLSR).

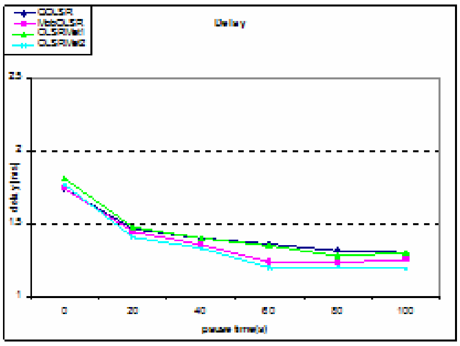


Figure 9. *Comparaison des of the four versions of the OLSR protocol in terms of delay*

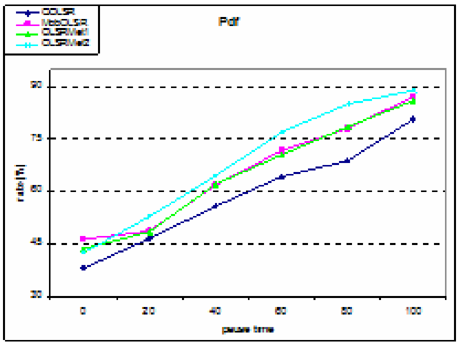


Figure 10. *Comparison of the four versions of the OLSR protocol in terms of pdf*

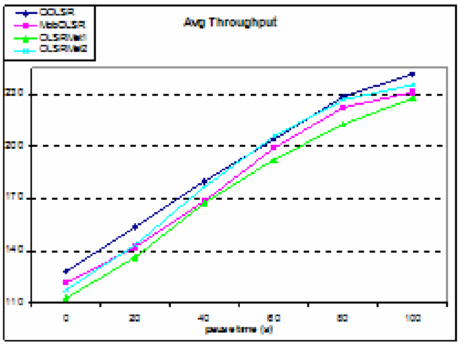


Figure 11. *Comparison of the proposed versions of the OLSR protocol in terms of throughput*

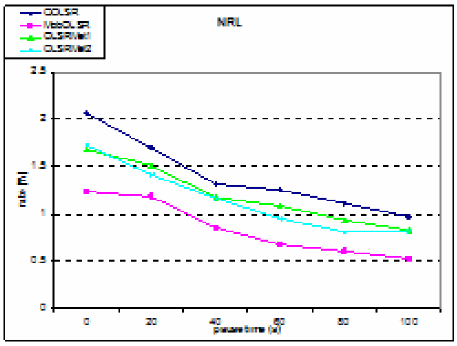


Figure 12. *Comparison of the four versions of the OLSR protocol in terms of NRL*

Comparing to QOLSR, it is interesting to notice that our proposed protocols MOBOLSR and OLSRMet2 perform better , in term of delay, in a dynamic topology (enhancement by 0.5 sec for maximum speed 40m/s to 80m/s). From figure 9, we can see that OLSRMet2 performs better in term of *Pdf*, comparing to the other proposed protocol (OLSRMet1 MOBOLSR and QOLSR) for all a maximum speed. OLSRMet2 gets more than twice as large comparing to QOLSR. A lightweight degradation in average throughput for OLSRMet2 protocol is shown in figure 11 comparing to QOLSR. However, we notice that OLSRMet2 performs better comparing to MobOLSR and OLSRMet1. This is because OLSRMet2 select stable routes offering an optimal bandwidth. This is

confirmed by the improvement seen in the *Pdf* parameter.
As shown in figure 10, MobOLSR protocol produces the lowest amount of NRL when compared to OLSRMet1 and OLSRMet2 protocols during all maximum speed values. Moreover, we notice that OLSRMet1 and OLSRMet2 protocols produce less amount of NRL compared to QOLSR for all the maximum speed.
This explains that our proposed criterion based on mobility parameter request less routing packets to establish and maintain routes in the network.
QOLSR produces an interfered environment in comparison with our proposed protocols.

5. Conclusion and future work

Satisfying QoS requirements of the traffic in MANETs are the key functions for transmission required for multimedia applications. In this paper we have discussed the different approaches used to provide QoS functionality in OLSR. Our proposed metric is an attempt to make use of the available resources and find the most optimal path based on multiple metrics taking into account mobility parameters. The proposed metric selects the most stable path based on mobility and energy information and QoS requirements on bandwidth. The proposed metric is expected to efficiently support real-time multimedia traffic with different QoS requirements. The next step is to show the gain made in term of energy. Then we plan to extend our metric to WSN routing protocol in order to reconfirm their efficiency.

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