A multi critria QoS Routing Protocol

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***Abstract*— The high mobility of the nodes , the reduced availability of the resources on the one hand and the rising needs of the real time applications made the provision of QoS compulsory in the ad hoc routing. Therefore the incorporating of QoS metrics in routing is very important in order to support any end-to-end QoS level. In this paper, we propose a routing approach which takes into account both the state of the nodes and the state of the links in determining the best routes and which guarantees a certain level of quality of service requested by the application.**

***Keywords — Mobile Ad Hoc Networks*, Routing, QoS, mobility, link quality, node state**

I. INTRODUCTION

The Mobile Ad hoc networks (MANETs) are made of mobile nodes connected by wireless links playing router role and which have random movement. The topology of such a network can change rapidly in an unpredictable way. In such networks inter node communications are made via single-hop or multi-hop paths. The MANETs technology can apply in numerous fields: setting up a network during military operations; installing a network during rescue operations in hostile environments; setting up a common interest network for workshops, conferences, university campus. A MANET has specific constraints linked to the nature of that kind of networks: radio links, limited energy, limitation of the bandwidth, reduced calculation power, broken connectivity between nodes. Due to these characteristics the reliability of data transmission cannot be guaranteed.

Quality can be defined as the capacity that has a node to offer a level of guarantee in the routing of packets [1]. It can also be defined as the needs to be fulfilled in order to permit the end-to-end traffic [2].

The multimedia and real time applications require many network resources and therefore require high flows and reduced transfer deadline [3]. It is a real challenge to guarantee the QoS in the MANETs in order to assure a good functioning of such applications.

There are intensive research activities on QoS, mainly the routing which is fundamental in a mobile ad hoc network. The specificities of the wireless links and the mobility make the achievement of the QoS difficult in those networks. This quality of service is available in terms of bandwidth, deadline, loss rate and jig.

The remainder of paper is organized in the following way. The second section presents some related works on the routing with QoS. In the third and the fourth section, we present our approach in order to improve QoS at the routing level in the mobile ad hoc networks. The fith section is focused on the analysis of the performances. We finish by a conclusion and research perspectives.

II. RELATED WORKS

Most of the QoS routing protocols focus on some of the standard parameters and rarely on many at the same time. The problem of the routing with numerous constraints is reputed NP-complete [3]. The approaches used to find out solutions can broadly be gathered in two main classes. The protocol class which takes into account the energy and mobility, and those using metric as the bandwidth, the deadline and the loss rate.

In the first class, the AODV protocol is a representative which was subject to different approaches for QoS. In [4] authors suggest the metrics both the deadline and the bandwidth whereas [5] uses the links' stability, the number of hops, the bandwidth and the deadline. The choice of the best quality path here is based on a probabilistic function. The [6] introduces an approach similar to that of [5] but it uses in addition metric of loss and cost rate. However, since both approaches are not concerned by the energy factor, the routes of high quality may no more exist for lack of energy.

The second protocol class uses both energy constraint linked metrics and the network links stability. In [7] the optimal route is chosen according to residual nodes energy and the link stability after the route discovery phase. That approach plans a local repair step of the routes when a link cut off occurs. That approach is limited in terms of offered services since it does not take into account the standard parameters of QoS. In the QoS routing of [8], the route is selected when it has a higher energy level and matches the bandwidth constraint. Among several candidate routes, the one with the highest energy level is selected. In [9] H. Labiod and A. Quideller, define QoS-ASR, a routing protocol which is one of those using simultaneously the standard QoS metrics and the metrics linked to energy, nodes mobility and the links stability. That is an extension of the DSR protocol.

The density of a node is a fundamental parameter, which permits to avoid collisions on a route and therefore to increase the routing performances. The route stability also influences quality of service, but highly depends on the selected model of mobility. Most of the protocols above provide QoS guarantees specific to well determined applications. But we think that a protocol which adapts to the application or the type of flow will be more interesting for the user because offering many more services.

III. PROPOSED MODEL

Our proposed scheme aims at to jointly take into account the metrics: deadline, the bandwidth, the loss rate, the neighbor number, the hop number on the route, the quality of the route and the links stability. Next it is concerned about minimizing a function. The last one is guided by the network parameters.

A. *Network model*

A MANET with n nodes can be represented by a graph $G = (N, A)$ with N representing the set of the nodes and A the set of the links between network nodes. Let us note S (source node) and D (destination node) 2 nodes such as $S \in N$ and $N \backslash \{S, D\}$ is the set of other nodes. The following notations will be used: $ch(S, D)$ is the route from S to D; $l = (i, j)$ is a link with i and j as two nodes.

The QoS metrics connected to each link are: -delay $Delay\ (l)$, -the available bandwidth $BP(l)$, -the packet loss rate P_l, - and the quality of the link $LQ_{(l)}$.

We also define different parameters for a node: the packet treatment time $Delay(n)$, the number of its neighbors $V(n)$, and its lifetime D_vie^n.

B. *Network linked constraints*

For a given route ch(i,j), the calculated metrics are: -its delay (1), -the loss rate (2), - the available bandwidth (3), - the lifetime (4), - the hops number (5), - the number of neighboring nodes to the route (6), and the quality of the route (7).

The delay of the route:

$$Delay\left(Ch(i,j)\right) = \sum_{l \in Ch(i,j)} Delay(l) + \sum_{n \in Ch(i,j)} Delay(n) \quad (1)$$

The loss rate on this route:

$$Loss(ch(i,j)) = 1 - \prod_{l \in ch(i,j)} (1 - P_l) \quad (2)$$

The band-with available:

$$BW\left(ch(i,j)\right) = Min_{l \in Ch(i,j)} \{BP(l)\} \quad (3)$$

The lifetime of the route:

$$D\_vie\left(ch(i,j)\right) = Min_{n \in Ch(i,j)} \{D\_vie\}^n\} \quad (4)$$

The number of hops on the route:

$$Nb_{hops(ch(i,j))} = \left|\left(ch(i,j)\right)\right| - 1 \quad (5)$$

The neighbors number of this route:

$$Nneighb\left(ch(i,j)\right) = \left|V\left(ch(i,j)\right)\right| \quad (6)$$

The route quality:

$$LQ\left(ch(i,j)\right) = \sum_{l \in ch(i,j)} LQ_l / Nbhops\left(ch(i,j)\right) \quad (7)$$

The QoS routing purpose is to find out a route matching the following constraints:

$Delay\left(ch(i,j)\right) \le Dl$

$Loss\left(ch(i,j)\right) \le P$

$BW\left(ch(i,j)\right) \ge B$

With Dl, P and B represent respectively the constraints of deadline, loss rate and band-with for a given application. Now we can define the cost function as follows:

$$Cost\left(Ch(i,j)\right) = \alpha * Cost(Delay\ ch(i,j)) * f\left(Dl - Delay(ch(i,j))\right) + \beta * Cost(Loss(ch(i,j)) * f\left(P - Loss(ch(i,j))\right) + \lambda * Cost\left(BW\left(ch(i,j)\right)\right) * f\left(BW\left(ch(i,j)\right) - B\right) + Cost\left(Nneighb\left(ch(i,j)\right)\right) + Cost\left(D\_vie\left(ch(i,j)\right)\right) + Cost\left(LQ\left(ch(i,j)\right)\right) \quad (8)$$

Where $f(x) = \begin{cases} 1 & if\ \ x \geq 0 \\ \infty & else \end{cases}$
And $\alpha, \beta, \lambda \in \{0, 1\}$ according to the application type.

This cost function includes the cost related to the constraints defined in previous section (1) to (7): cost(Delay), cost(BW), cost(Loss), cost(Nneighb), cost(D_vie) and cost(LQ).The use of a multiple constraint cost function during route discovery permits to come near an optimal solution that is to find a satisfying route. F(x) infinite means that the requests of QoS required by the application cannot be matched. The different costs used in (8) are defined as follows:

The cost relating to the deadline is directly proportional to the route deadline of the route and inversely proportional to the delay required for a new application.

$$Cost\left(Delay(ch(i,j)\right) = \frac{Delay\left(ch(i,j)\right)}{Dl} \quad (9)$$

The cost relating to the loss rate is proportional to the loss rate of the route and inversely proportional to the loss rate required by a new application.

$$Cost\left(Loss\left(ch(i,j)\right)\right) = \frac{Loss\ (ch(i,j))}{P} \quad (10)$$

The cost related to the bandwidth permits to measure the traffic load at a node and thus the traffic load in the whole network [10].

$$Cost\ \left(BW\left(ch(i,j)\right)\right) = \frac{B}{C_l - (C_u - B)} \quad (11)$$

The cost relating to a node lifetime is proportional to its initial energy and its transmission power and, inversely proportional to the energy consumption in this node (12).

$$Cost\ (D\_vie\ ch(i,j)) = \sum_{n \in ch(i,j)} \frac{E^n_{init}}{E^n_{res}(t)} \quad (12)$$

The cost relating to the neighborhood of a route is linked to the hop number and the number of the neighbors of this route.

$$Cost\ \left(Nneigh\left(ch(i,j)\right)\right) = \frac{Nb\_hops\left(ch(i,j)\right) + Nneighb(ch(i,j)}{Nneighb(ch(i,j) * Nb\_hops\left(ch(i,j)\right)} \quad (13)$$

The cost relating to the lifetime of a link is inversely proportional to this time.

$$Cost\left(LQ(ch(i,j)\right) = \frac{1}{LQ\left(ch(i,j)\right)} \quad (14)$$

In the preceding formulas, C_l represents the full capacity of the link, C_u represents the bandwidth used by the applications in progress, B represents the bandwidth requested by a new application and Nb_hops the number of nodes on the route.

C. Energy metric

This metric integrates the calculation of different parameters as well as the power consumption, the residual energy, and the lifetime of the node.

Consumed energy: the energy consumed at a node at a given time is defined as follows:

$$E^n_c(t) = \sum_{j \in L_n} E_{elec}\left(T^r_{n,j} + T^{tr}_{n,j}\right) + E_{amp} * T^{tr}_{n,j} * d^2_{n,j} \quad (15)$$

Where $L_n = \{i/i \in\ V(n)\}$ and
$E^n_c(t) : energy\ consumption\ of\ node\ n\ at\ \ t$

$T_{n,j}^{tr}: size\ of\ data\ transmitted\ on\ link\ (n\ ,j)$
$T_{n,j}^{r}: size\ of\ data\ received\ via\ link\ (n,j)$
$E_{elec}: energy\ consumption\ per\ bit$
$E_{amp}: energy\ of\ amplification$
$d_{n,j}: euclidean\ distance\ between\ n\ and\ j$

Node residual energy: If E_{init}^{n} be the initial energy of node n, its residual power E_{res}^{n} at one moment t is:

$$E_{res}^{n}(t) = E_{init}^{n}(t) - E_{c}^{n}(t) \quad (16)$$

Node lifetime: a node i belonging to a route calculates its lifetime at one moment t_2 according to the formula (17)

$$D_{vie}{}^{n}(t_2) = \frac{E_{res}^{n}(t_2)}{\Delta E_{res}^{n}(t_2)} \quad (17)$$

With $\Delta E_{res}^{n}(t_2) = \left|\frac{E_{res}^{n}(t_1) - E_{res}^{n}(t_2)}{t_2 - t_1}\right|$
and
t_2 : $current\ transmitting\ duration$;
t_1: $preceding\ transmitting\ duration$;
ΔE_{res}^{n}: $rate\ of\ variation\ the\ waste\ energy\ of\ n$;
D_vie^{n}: $lifetime\ of\ node\ n.$

D. Mobility metric

The mobility of nodes can significantly affect the link quality. We admit the following properties:

Property 1: the quality of a link decreases when the distance between the nodes which made increases.

Property 2: the quality of a link deceases when the lifetime of the nodes that it is made up decreases.

R represents the communication range of a node. Let x_i, y_i and x_j, y_j be the respective coordinates of nodes $i\ and\ j$.

The Euclidean distance between $i\ and\ j$ at a time t_1 is defined as follows:

$$d_{i\leftrightarrow j}(t_1) = \sqrt{\left(x_j^{t_1} - x_i^{t_1}\right)^2 + \left(y_j^{t_1} - y_i^{t_1}\right)^2} \ (18)$$

The transmission delay over the link (i,j) can be defined by formula (19):

$$delay_{(i,j)}(t_1) = \begin{cases} \frac{d_{i\leftrightarrow j}(t_1)}{v_p} + \beta \ if \ d_{i\leftrightarrow j} < 2R \\ \infty \quad else \end{cases} \quad (19)$$

With
v_p represents the signal propagation velocity and β a factor linked to the transmission environment ($\beta \geq 0$).

The minimum lifetime of link (i, j) is obtained by the formula (20).

$$D\_vie_{(i,j)}(t_1) = Min\{D_{vie}{}^{i}(t_1); D_{vie}{}^{j}(t_1)\} \quad (20)$$

The quality of the link (i,j) is obtained as follows:

$$LQ_{(i,j)}(t_1) = \frac{D\_vie_{(i,j)}(t_1)}{delay_{(i,j)}(t_1)} \quad (21)$$

$$LQ_{(i,j)}(t_1) = \begin{cases} \dfrac{D\_vie_{(i,j)}(t_1)}{\dfrac{d_{i\leftrightarrow j}(t_1)}{v_p} + \beta} \quad if \quad d_{i\leftrightarrow j}(t_1) < 2R \\ 0 \quad else \end{cases} \quad (22)$$

This formula can be rewritten as follows (23).

$$LQ_{(i,j)}(t_1) = \begin{cases} \frac{v_p * D\_vie_{(i,j)}(t_1)}{d_{i\leftrightarrow j}(t_1) + \beta * v_p} & if \quad d_{i\leftrightarrow j}(t_1) < 2R \\ 0 & else \end{cases} \quad (23)$$

IV. METHOD SUGGESTED

Our approach the best route finding is based on multi criteria and on a cost function related on metrics as deadline, the bandwidth, the loss rate, the neighbor number, the hop number on the route, the quality of the route and the links stability. The functioning of suggested algorithm relies on two procedures (route discovery, route maintenance) and three types of messages which are: the Route Request (RREQ), the Route Reply (RREP) and the Hello packets.

A RREQ packet contains the following fields:

- Source address
- Destination address
- Sequence number of the source
- Number of hops
- Required bandwidth
- Available bandwidth on the route
- Requested deadline
- Route delay
- Requested loss rate
- The route quality
- The route lifetime
- The route cost

A RREP request made by a node contains the following fields:

- Source address
- Destination address
- Sequence number of the source
- Cost of route
- Link lifetime
- The available bandwidth
- The delay of the route
- The packet loss rate on the route
- The number of two-hop neighbor on route.

A. *The hello packet*

That packet permits to check the topology of the network. Its characteristic differs from one protocol to the next according to the parameters used and it permits to assure the detection or the loss of a link. It, therefore, permits to know the number of neighbor of a link a given time. Moreover, that packet will permit to determine the quality of a link.

Let i and j be two nodes. To know a neighbor j, node i, sends the following message:

$Hello\_rq\ (adresse\_i, Nb\_hop = 1, (x_i; y_i), (D\_vie^i), t_1)$

where t1 represents the sending time. When any node *j* receives the message Hello_rq, it answers by the following acknowledge message:

$Hello_{ack}\left(adresse_j, adresse_i, \left(x_j; y_j\right), \left(D_{vie}{}^j\right), \quad t_2\right).$

The process to detect the neighborhood, to calculate the quality of the links is described in figure 1.

B. *Route discovery*

The route discovery process is based on RREQ message sending and RREP message reception. It consists to find a way between a source and a given destination. The corresponding algorithm through the source is represented by figure 2.

The behavior of an intermediary node changes according to the packet type received and the concerned application. Figure 3 shows the synoptic.

On receiving the first RREQ packet a timer is activated by the destination node. It is only when the deadline is over that the destination launches a RREP, choosing the minimum cost route. The related behavior is shown in the figure 4.

C. *Route maintenance*

A node must know its two-hop neighbor ahead towards the destination if the later really exist. That will be made by the RREP message transmission generated by the destination. For the instance when a node i receives

RREP from j and that it must transmit that packet to k, it has to save j in the RREP so that k knows j is its two-hop neighbor ahead on the destination route. Otherwise, the field will mark NULL. Likewise k on his turn will save i in RREP so that the next node on the reverse route knows that i is its two-hop neighbor away. That process is repeated by all the nodes on the reverse route till the source. In such a way, when a node fails to match the QoS requirements, its neighbor is next informed on the route so that the latter sets up locally a route search in order to reach its two-hop neighbor ahead.

When a node remarks another is off the route, it launches a local search in order to find a way towards its two-hop neighbor away if the latter exits, if not it keeps the original source aware so that the latter launches a new route discovery if necessary.

V. ANALYTIC RESULTS

Let k_i be the neighbor number of i and k_{i1} be the number of its neighbors towards the destination. So k_{i1} represents the number of neighbors for which i will transmit a RREQ local message. With the QoS-AODV protocol the number of message to send for a local search in the best is:

$k_i + \sum_{l \in N\{i\}} (k_l - k_{l1})$.

Our approach in the best of the cases emits $k_{i1} + \sum_{i \in L_j} (k_i - k_{i1})$ messages, with $L_j = \{j \in N / j \in V(i)$. In the best of cases, we have $L_j \subseteq N \backslash \{i\}$, so $|N \backslash \{i\}| \geq |L_j|$. Consequently the number of local RREQ message sent by our algorithm is less than that of QoS-AODV in the case of a route rediscovery. In the worst case, our approach permits to send the same number of message as the QoS-AODV protocol.

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1. Any node within the network broadcast a message:
      Hello_rq (adresse_i, Nb_hop = 1, (x_i ; y_i), (D_vis^i), t_1) every seconde.
2. If a node j receives a Hello_rq at a time t Then
          Delay (i,j) ← t − t_1
      nœud j sends Hello_ack (adress_j, adress_i, (x_j ; y_j), (D_vis^j), t_2) to i.
   If adresse_i don't exist in the neighborhood cache of j Then
          Insert j in the neighborhood cache
          Nvois (j) ← Nvois (j) + 1
          Determine the link quality
   Fi
Fi
3. IF a node i recieves Hello_ack at t' Then
     Delay(i,j) ← t' − t_2
       Determine the link quality
       If adress_j don't exist in the neighborhood cache of i Then
             Insert j in the neighborhood cache
             Nvois (i) ← Nvois (i) + 1
       Fi
   Fi
```

Figure 1. Neighborhood and link quality calcuation

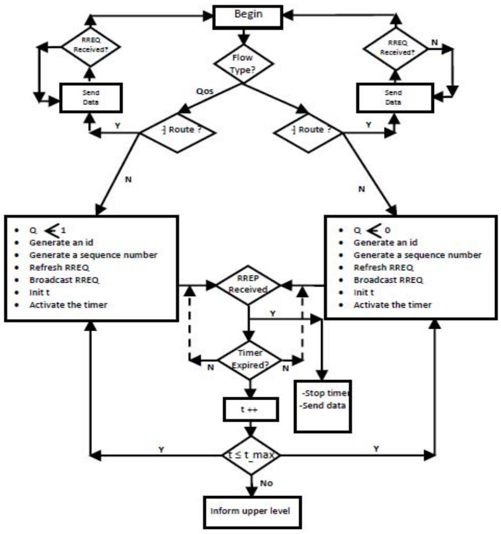

Figure 2. Behavior of the source node

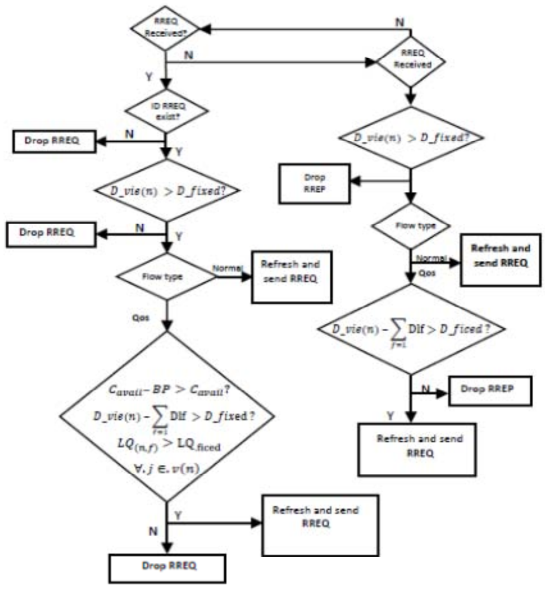

Figure 3. Behavior of an intermediary

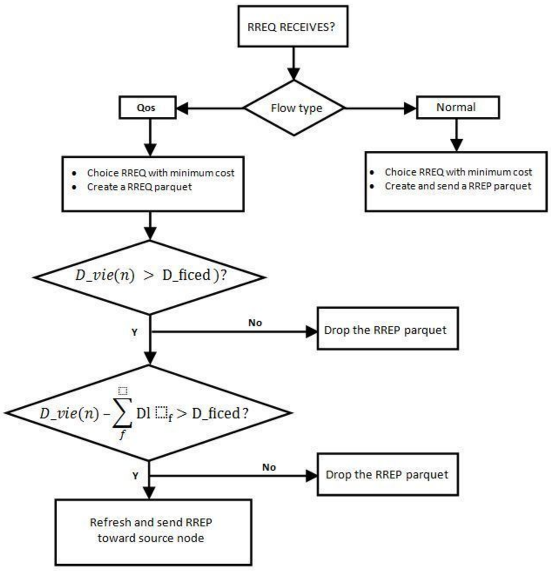

Figure 4. Behavior of the destination node

VI. CONCLUSION AND PERSPECTIVES

Most protocols of routing with QoS focus on some of the standard parameters and rarely on many at the same time. The mainstay of this work is that a protocol which adapts to the application or the type of flow will be more interesting for the user because offering many more services. From this point of view, we present a QoS routing method with multi criteria for MANETs. We defined a cost function related on several metrics as deadline, bandwidth, loss rate, the neighbor number, the hop number, the route quality and the link lifetime. Next it was concerned about minimizing this function.

That approach, mainly its adaptation to the application and the flow, offers interesting perspectives. It reduces the number of message sent. Therefore, we can hope to save energy, since message transmitting is power consuming, and reduce the loss rate. To attest these theoretical results, we plan numerous simulations under NS2. The results of these simulations will be published in a next paper. This projection could allow more flexibility in ad hoc routing such as in inter vehicles communication, communication between scientists, sharing of service in social networks.

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