Proceedings of the 5th WSEAS International Conference on Telecommunications and Informatics, Istanbul, Turkey, May 27-29, 2006 (pp207-212)

TUQR: A TOPOLOGY UNAWARE QOS ROUTING PROTOCOL FOR MANETs

IBRAHIM ZAGLI, MIN SONG
Department of Electrical and Computer Engineering
Old Dominion University
Norfolk, VA 23529
U.S.A.

Abstract: - The main issue addressed in this paper is the quality of service (QoS) routing protocol for mobile ad hoc networks (MANET). The objective is to improve the packet delivery ratio in QoS constrained communications in comparison to other well-known protocols that use distributed multi-path routing. To accomplish that, a new protocol is developed to reduce the effects of distrustful environment of MANET by keeping the number of suitable paths as high as possible and distributing the decision mechanism among the nodes on the path. The new protocol uses on-demand route discovery. The source node or the intermediate nodes have no knowledge about the path that will be followed by data packets. Instead, starting with the source node, each node just knows which neighbor declared to be capable of forwarding data packets under given delay constraint to the given destination. Simulations are performed to verify the performance improvement of the proposed protocol.

Key Words: - MANET, quality of service, routing protocol, delay.

1 Introduction

MANET (Mobile ad hoc network) is a dynamic multi-hop wireless network that is established by a group of mobile wireless hosts on a shared channel. In MANET, there are no fixed infrastructures to support routing and mobility issues. Because of that, each host has to act as a router when it is required. Each host's capabilities vary in time due to mobility and transmission environment restrictions. This situation makes routing maintenance a challenging task especially under QoS requirements.

The most important design criterion for any type of networks is guaranteeing QoS. QoS measures include bandwidth, delay, jitter, and delivery guarantee. With the emergence of bandwidth-greedy and/or time sensitive applications, the need for guaranteed QoS of those applications becomes prime importance in the networks. In order to design good protocols for MANETs, it is important to understand the fundamental properties of these networks:

- *Dynamicity:* Every host can randomly change position. The topology is generally unpredictable, and the network status is imprecise.
- *Non-centralization:* There is no centralized control in the network and, thus, network resources cannot be assigned in a predetermined manner.
- *Radio properties:* The channel is wireless, so it will suffer fading, multipath effects, time variation, etc.

Because of the negative effects of those properties, techniques that depend on resource reservation would have low packet delivery ratio especially under high traffic load. Multi-path and distributed routing algorithms may have increased chance to respond to route failures and resource diminishing caused by high traffic load. In this work, the main purpose is to design a new QoS routing protocol for mobile ad-hoc networks that improves *packet delivery ratio* in delay constrained communication in comparison to current well known protocols by using distributed multi-path routing.

The rest of paper is organized as follows. The related work is introduced in Section 2. The proposed routing protocol is presented in Section 3. The implementation and simulation results are provided in Section 4. Finally, Section 5 concludes the paper.

2 Related Work

Many approaches have been proposed to solve the routing challenge in MANETs. These previous works only provide a basic routing functionality that is sufficient for conventional applications such as file transfer or download. To support applications such as VoIP in MANETs, which have a higher requirement for delay, jitter and packet losses, support for QoS is needed in addition to basic routing functionality. Inspired by common techniques for QoS provision in Internet, some researchers proposed the integration of QoS provision into the routing protocols [1,2,5,6,7,8]. However, since most of them implicitly assumed the same link concept as the one in wired networks, they still do not address the QoS problem for MANETs.

In [9] Zhang and Mouftah presented an On-Demand Delay-Constrained Unicast Routing Protocol (ODRP) for wireless ad hoc networks. The design of ODRP focuses on the operations at the network layer and assumes the capabilities of determining resource availability on neighboring links and the availability of resource reservation functions at nodes.

ODRP is designed to effectively reduce the communication overhead consumed in acquiring a low-cost delay-constrained path while achieving high route acquisition success probability. The hybrid routing strategy works to first probe the feasibility of the min-hop path connecting the source-destination pair of an arriving QoS request. This path is returned if feasible; otherwise, a destination-initiated route searching process via restricted flooding is enforced. Directional search is employed to restrict the search range of the route-searching process.

In [3], Perkins *et al.* proposed a simple and efficient routing framework designed to reduce random and correlated packet loss, end-to-end delay, and routing overhead. The proposed scheme is called QoS-sensitive Multipath Routing with Packet level Redundancy (QMR/PR). By combining multipath routing, round-robin packet scheduling, and packet-level forward error correction, the QMR/PR framework is able to (1) reduce the effective route downtime (as perceived by the source application layer) (2) reduce the route discoveries required and (3) reduce correlated losses.

In [4], Liu *et al*. have proposed a new version of the self-organized Emergent Ad Hoc Routing Algorithm (EARA) enhanced with QoS. EARA is inspired by the foraging behavior of biological ants. The biological concept of stigmergy is used to reduce the amount of control traffic. Local wireless medium information from the MAC layer is used as the artificial pheromone (a chemical used in ant communications) to reinforce optimal or suboptimal paths without knowledge of the global topology. In addition, this algorithm adopts the cross-layer design approach by using metrics from different layers to make routing decisions. These multi-criteria routing decisions allow for the better usage of network characteristics in selecting best routes among multiple available routes.

EARA-QoS is an on-demand multipath routing algorithm for MANETs. This algorithm takes positive feedback, negative feedback and randomness into the routing computation. Positive feedback originates from destination nodes to reinforce the existing pheromone on good paths. Ant-like packets are used to locally find new paths. Artificial pheromone is laid on the communication links between nodes and data packets are biased towards strong pheromone, but the next hop is chosen probabilistically. To prevent old routes from remaining in the current network status, exponential pheromone decay is used as the negative feedback.

3 Topology Unaware Routing (TUQR) Protocol

In this work, a new protocol to the QoS routing in MANET is developed to reduce the effects of distrustful environment of MANET by keeping number of suitable paths as high as possible and distributing the decision mechanism among the nodes on the path.

To support the new protocol, each node is assumed to be capable of supplying:

- The information delay time to neighbours by checking periodically.
- The average time that an individual packet spends in outgoing packet queue.
- In outgoing packet queue, QoS constrained data packets have higher priority by having lower QoSParam value remaining in their header.

3.1 Design

In the proposed protocol, the source node and any other node have no idea about the path that will be followed by data packets. Instead, starting with the source node, each node just knows which neighbour(s) declared to be capable of forwarding data packets under given delay constraint to the given destination. Picks one of these neighbours according to current local connection status and given delay constraint and forwards the data packet to that neighbour. This process repeats on each node until the packet reaches to one of adjacent nodes of destination. This approach, as a whole, tries to avoid to be affected by wireless link status changes, by reacting them in a timely fashion and keep the packet on its way using all possible resources of the network.

3.1.1 Route Discovery

In this phase of proposed protocol, based on the limited knowledge about connection to neighbours, each node has no information about the topology beyond its 1-hop neighbours. Route Discovery begins when network layer on a node *s* receives a data packet with delay constraint from application layer destined to a node *d* other than itself ($d \neq s$). In this design, each node maintains a QoS Routing Table (QRT) that has an entry for each processed destination node.

When any node has a data packet with delay constraint;

- *If there is no information in its QoS Routing Table (QRT) related to Destination:*
  - *Stores data packet in a buffer place called Path Waiting Pool (PWP)*
  - *Broadcasts a QoS Route Request (QRRq) packet by pure flooding. (See Table* 1*).*
- *If QRT has a record indicates that there is a neighbour declares it could forward data packets to destination under given delay constraint;*
  - *Forwards data packet to neighbour node returned by QRT*

When a node receives a QRRq packet;

- *If it is destined to itself;*
  - *Set DelayRep field value to* 0
  - *Immediately broadcasts a QoS Route Reply (QRRp) packet with Hop_Count+*1.
- *If QRRq processed before;*
  - *Discards arriving QRRq*
- *If not;*
  - *if it has an entry in self QRT matches destination and satisfies requested delay constraint in QRRq;*
    - *broadcasts a QoS Route Reply (QRRp) packet with Hop_Count+1, setting DelayRep field to a value calculated using QRT records;*
  - *if it doesn't have;*
    - *broadcasts incoming QRRq with Hop_Count+1*

When a node receives a QRRp;

- *If this is a valid packet by sender and not processed previously;*
  - *if delay constraint still valid;*
    - *Broadcasts a new QRRp packet with new calculated delay value.*
    - *Registers included information in QRRp into QRT*
    - *Purges PWP to forward path waiting data packets*
- *If not;*
  - *Discards arrived QRRp*

When the source node gets a QRRp, then it has a neighbor to send the packets that satisfy requested QoS parameters. It immediately begins to send the data packets to that neighbor, while still gets new QRRp packets and constructs new alternative routes.

Table 1: QRRq and QRRp structure

Field Name	**Definition**
Type	The type of the packet. *QRRq, QRRp*
Source	Address of the source node
Hop_Count	Source node sets to 1 when initiates the request. Incremented by each node that forwards the request.
Destination	Points the address of the node that source node willing to have a QoS connection.
DelayReq	Indicates delay constraint requested.
DelayRep	Indicates the actual delay time supplied by network.

3.1.2 Path Selection

Each node purges PWP every time after an addition or update has been made to its QRT. Every data packet stored in PWP with its remaining delivery time, is checked against QRT records one by one. For each neighbor node *i* recorded in QRT related with the same destination node of data packet a new delay value is calculated using

$$S(i) = Q + P(i) + D(i) \quad (1)$$

where $S(i)$ is delay value of node i, Q is the current delay in outgoing queue, $P(i)$ is the propagation time to node i, and $D(i)$ is the delay to destination declared by node i.

Neighbor node i which gives smallest $S(i)$ is selected as next-hop node to forward data packet. This calculation enables data packets to be always forwarded to the currently best path.

Route maintenance is simply made by initiating a new route request using information stated in data packet when there is no available neighbour to forward data packet. This re-initiation broadcast alters preceding nodes on the path as not forwarding more data packets to that node until a fresh QRRp received from that node.

3.1.3 QoS Routing Table (QRT)

Each node individually constructs a QoS Routing Table (QRT). This table is used when forwarding packets to destination. The QoS Routing Table is constructed as a 3-level collection of linked lists, in order to remove information replication and reduce memory usage. At the top of the structure, the list of destinations takes place, followed by the list of delay constraints as a sub-level and Next-Hop Node List as the last level.

Destinations List: Keeps the list of destinations extracted from received QRRp packets

Proceedings of the 5th WSEAS International Conference on Telecommunications and Informatics, Istanbul, Turkey, May 27-29, 2006 (pp207-212)

Delay Constraints List: List of different actual delay values towards destination given in the Destinations List. *DelayReq* field in each element carries the value of *DelayRep* field of *QRRp* packet broadcasted. This list is maintained as sorted by the field of *DelayReq*.

Next-Hop Node List: Holds the list of neighbor nodes that declared to be having a way to forward data packets to the given destination under given delay constraint as in the upper level corresponding elements. Actually next-hop nodes are nothing but the nodes that *QRRp* packets received from.

Table 2: QoS Routing Table Structure

Destinations List	**QoS Params List**	**Gateways List**
Destination	DelayReq	Gateway Node
Delay Constraints List	Last Used	DelayRep
Pointer to other Destinations	Pointer to Next-Hop Nodes List	Pointer to other Destinations
	Pointer to other Delay Cosntraints List	

4 Implementation and Results

The proposed design has been evaluated by carrying out a series of simulations with the simulator NS-2 [14]. First, new agent implemented including Route Discovery, PWP, QRT and necessary modifications on NS-2 configuration files has been made to make all packets pass through new agent. After that, needed modifications have been made to Priority Queue module so that delay constraint data packets have highest priority according to required delay time information in their headers. QRRq and QRRp packets enter in head of the queue. Additionally, 802.11 module has been modified in order to calculate communication delay time to each neighboring node and make it available for new routing agent.

The performance of the proposed protocol has been compared to three of present routing protocols that are named as QMR/PR in [9], EARA-QOS in [4] and ODRP in [3]. For each of the present protocols a different simulation environment has been constructed as stated in [9,4,3] to evaluate and compare performance of the proposed protocol. Evaluation has been made with four metrics, namely

- ***Packet Delivery Ratio (PDR)*** is the percentage of data packets received by destination node to that sent by a corresponding source node.
- ***Average end-to-end (ETE) Delay*** reflects the total time needed to successfully deliver a packet by a source node till it is received by the corresponding destination node.
- ***Success Ratio*** is defined as the total number of arriving connection requests over the total number of routed connection requests.
- ***Routing Overhead*** is total number of all routing control messages produced during simulation divided by number of nodes in the network.

The *random waypoint mobility model* was used in the simulations. In this model, each node is placed randomly in the simulated area and remains stationary for a specified pause time and then randomly selects a destination in the physical terrain. The node then moves in the direction of the destination point at a speed uniformly chosen between a minimum and maximum speed (meters/sec). After reaching the destination, the node stays there for a time period (pause time).

4.1 TUQR vs. QMR/PR

Simulation setup

Number of Nodes : 50
Terrain Dimension : 1500 x 1500 m^2
Transmission range : 250 m
Average node speed : 20 m/s
Traffic : CBR with 500 data packets per session
Source nodes : 10,11,12,13,14
Destination nodes : 25,26,27,28,29
Delay constraint : 250 milliseconds.
Simulation time : 150 seconds

It can be seen from Fig. 1 that TUQR brings an explicit improvement comparison to QMR/PR under high mobility conditions. Results get closer under the conditions of lower mobility because the loss due to mobility decreases. When all nodes are fully mobile, connection between individual nodes is highly unstable and causes huge changes in delay times. And this situation causes high delay times and data packets to be dropped due to un-satisfied delay constraints. By design of proposed algorithm, each node using TUQR, can react those changes faster and always selects the best connection, so the number of drops due to delay constraint reduces.

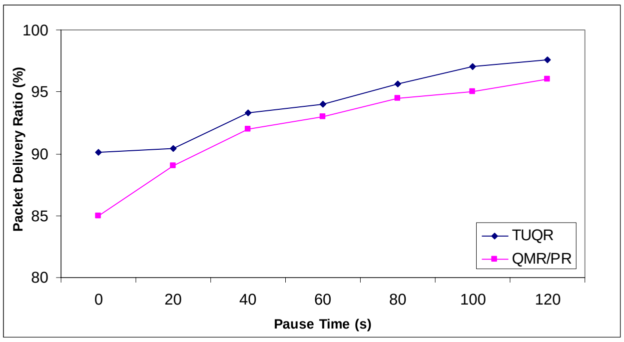

Fig.1: TUQR vs. QMR/PR in packet delivery ratio.

Fig. 2 shows that distributing routing decision helps reducing end-to-end delay time of successful packets. For QMR/PR, network environment changes rapidly enough to turn earlier decisions into mistakes, and, these mistakes get bigger as the mobility increases. Thus, performance gain realized by TUQR tends to increase as node mobility increases. And also, as TUQR always uses current active conditions to make decisions, mobility change does not make much effect on end-to-end delay times, unless, a relatively long term partitioning does not occur on the network.

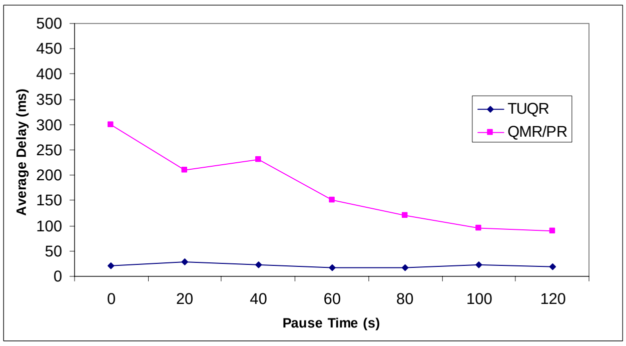

Fig.2: TUQR vs. QMR/PR in end-to-end delay.

Obviously, distributing routing decision over nodes in the network and trying to react changes as soon as possible can only be done by control messages broadcasted by intermediate nodes, naturally, this process increases the number of control messages relative to the other protocols. As seen in Fig. 3, as node mobility decreases, QMR/PR routing overhead decreases better than TUQR, this is because under low mobility rates, TUQR still needs to broadcast control messages in case that the delay times between nodes increase.

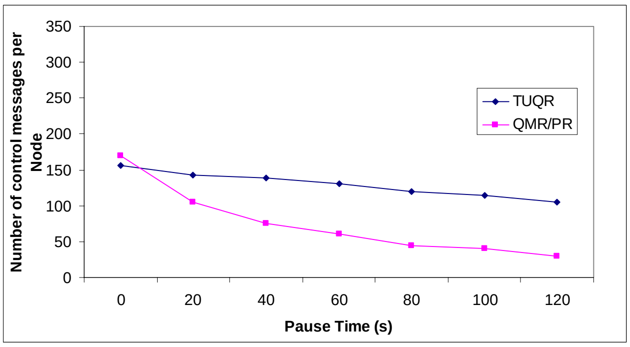

Fig.3: TUQR vs. QMR/PR in message overhead.

4.2 TUQR vs. EARA-QoS

Simulation Set 1

Number of Nodes : 50

Terrain Dimension : 1000 x 1000 m2

Transmission range : 250 m

Average node speed : 1.5 m/s

Traffic : CBR with 9.6 kbps, Simulating VoIP calls

Inter-arrival time of calls: average 10 secs.

Length of calls : average 40 secs.

Delay constraint : 250 milliseconds.

Simulation time : 500 seconds

Simulation Set 2 (differences to Set 1 only)

Terrain Dimension : 350 x 3500 m2

Average node speed : 5.5 m/s

In Fig. 4, with low node speed, both protocols have approximately the same simulation results but TUQR is slightly better in all mobility rates. In Fig. 5, with increasing average node speed, especially under high mobility conditions TUQR brings an explicit improvement comparison to EARA-QOS, under conditions of lower mobility, results are closer because loss due to mobility decreases. Trend between 0 second and 100 second pause time is lower comparing to EARA-QOS which shows that at higher mobility rates, scenario does not allow better connections. Same comments with Fig. 1 are also valid with this one.

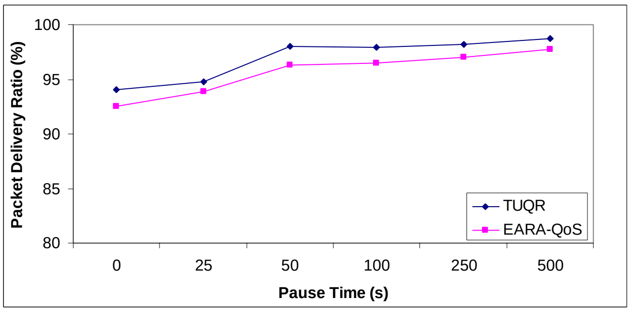

Fig.4: TUQR vs. EARA-QoS, Set-1 in PDR.

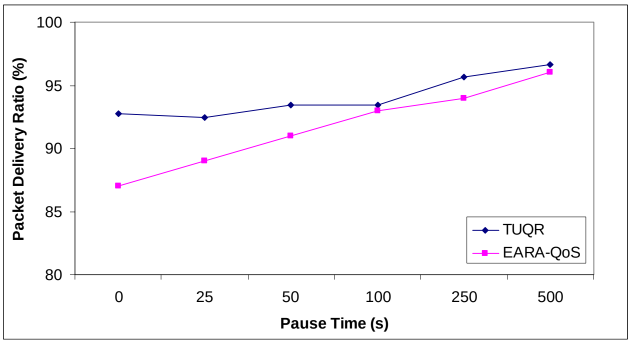

Fig.5: TUQR vs. EARA-QoS, Set-2 in packet delivery ratio.

Figs. 6 and 7 show that distributing routing decision helps reducing end-to-end delay time of successful packets. Even though EARA-QOS has a positive and negative feedback mechanism to react changes on network faster, it is still not good enough because time between two traveling packets is not enough to be absolutely aware of changes in connection environment. Thus, performance gain realized by TUQR under low speed tends to increase as node mobility increases.

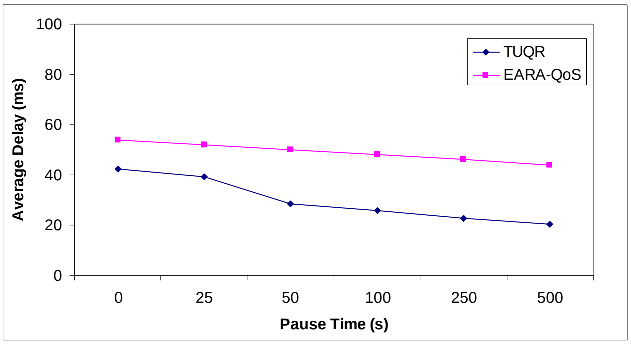

Fig.6: TUQR vs. EARA-QoS, Set-1 in end-to-end delay.

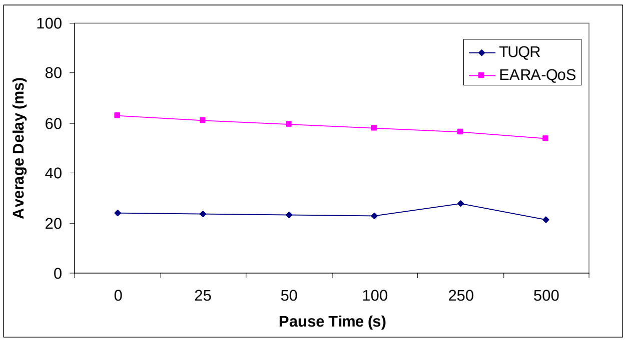

Fig.7: TUQR vs. EARA-QoS, Set-2 in end-to-end delay.

Fig.8 shows that TUQR realizes better Success Ratio than ODRP. The success ratio increases with the relaxation of delay constraint, because the number of nodes that are able to involve in routing increases. The major improvement of proposed protocol is with low delay constraint.

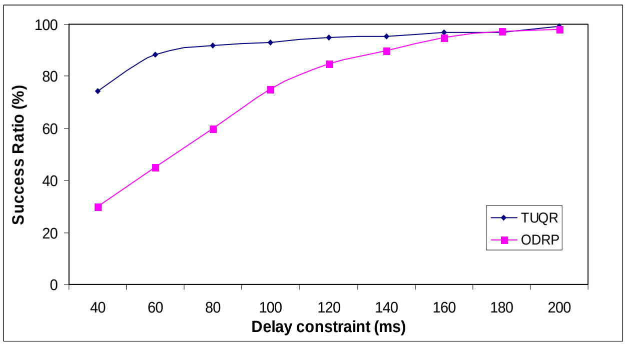

Fig.8: TUQR vs. ODRP in success ratio.

5 Conclusion

We have designed a new QoS routing protocol for mobile ad-hoc networks that improves the packet delivery ratio in delay constrained communication by using distributed multi-path routing. Simulations results suggest that TUQR gives better performance compared to the selected existing work for packet delivery ratio, end-to-end delay and success ratio. As expected, routing overhead is worse than others in an acceptable ratio.

References:

[1] Badis, H.; Al Agha, K. “An efficient QOLSR extension protocol for QoS in ad hoc networks”, *Vehicular Technology Conference*, 2004. pp. 2650 – 2653.

[2] Lei Chen; Heinzelman, W. “Network architecture to support QoS in mobile ad hoc networks [video streaming applications]”, *Multimedia and Expo, 2004. ICME '04. 2004 IEEE International Conference* on Volume 3, 27-30 June 2004. pp. 1715 – 1718.

[3] Perkins, D.F.; Jinping Yang; Hughes, H.; Owen, C. “Reducing the impact of mobility-induced route failures on QoS in MANETs”, *Global Telecommunications Conference, 2004. GLOBECOM '04*. IEEE Volume 6, 29 Nov.-3 Dec. 2004. pp. 3419 – 3425.

[4] Zhenyu Liu; Marta Z. Kwaitkowska; Costas Constantinou “A Biologically Inspired QoS Routing Algorithm for Mobile Ad Hoc Networks”, *Proceedings of the 19th International Conference on Advanced Information Networking and Applications (AINA’05)*, 2005. pp. 426 - 431.

[5] P. Sinha; R. Sivakumar; V. Bharghavan “CEDAR: A Core-extraction Distributed Ad Hoc Routing Algorithm”, *IEEE JSAC*, vol. 17, no. 8, Aug. 1999, pp. 1454–65.

[6] C. R. Lin; J.-S. Liu “QoS Routing in Ad Hoc Wireless Networks”, *IEEE JSAC*, vol. 17, no. 8, Aug. 1999, pp. 1426–38.

[7] S. Chen; K. Nahrstedt “Distributed Quality-of-service Routing In Ad Hoc Networks”, IEEE JSAC, vol. 17, no. 8, Aug. 1999, pp. 1488–505.

[8] B. Zhang; H. T. Mouftah “QoS Routing Through Alternate Paths in Wireless Ad Hoc Networks”, *Int’l. J. Comm. Sys.* vol. 17, no. 3, Mar. 2004, pp. 233–52.

[9] Baoxian Zhang; Hussein T. Mouftah “QoS Routing for Wireless Ad Hoc Networks: Problems, Algorithms, and Protocols”, *IEEE Communications Magazine*, pp. 110-117, October 2005. pp. 110 – 117.