International Journal of Soft Computing 4 (1): 49-55, 2009
ISSN: 1816-9503

Energy-Aware QoS Routing Protocol for Ad Hoc Wireless Sensor Networks: A Survey

[1]M.K. Jeya Kumar and [2]R.S. Rajesh
[1]Faculty of Computer Applications, Noorul Islam College of Engineering,
Kumaracoil, Thuckalay, India
[2]Faculty of Computer Science and Engineering,
Manonmaniam Sundaranar University, Tirunelveli, India

Abstract: For effective routing in wireless sensor networks many routing protocols have been implemented. Energy awareness is an essential design issue and almost all of these routing protocols are considered as energy efficient and its ultimate objective is to maximize the whole network lifetime. However, the introduction of video and imaging sensors have posed additional challenges. Transmission of video and imaging data requires both energy and QoS aware routing in order to ensure efficient usage of the sensors and effective access to the gathered measurements. In this study, the performance of the energy-aware QoS routing Protocol are analyzed in different performance metrics like average lifetime of a node, average delay per packet and network throughput. The parameters considered in this study are end-to-end delay, real time data generation/capture rates, packet drop probability and buffer size. The network throughput for realtime and non-realtime data was also has been analyzed. The simulation has been done in NS2 simulation environment and the simulation results were analyzed with respect to different metrics.

Key words: Cluster nodes, end-to-end delay, QoS routing, routing protocols, sensor networks, least-cost-path

INTRODUCTION

A wireless sensor network is one of the ad hoc wireless telecommunication networks (Singh *et al*., 1998), which are deployed in a wide area with tiny low-powered smart sensor nodes. An essential element in this ubiquitous environment, this wireless sensor network can be utilized in various information and telecommunication applications. The sensor nodes are small, smart devices with wireless communication capability, which collect information from light, sound, temperature, motion, etc. and process the sensed information and transfer it to other nodes. The sensor nodes senses accuracy and scalability of sensing areas. The most important networking factors influencing large scale networking environment are self-organizing capability (Sohrabi *et al*., 2000) for well adaptation of dynamic situation changes and interoperating capability between sensor nodes.

The challenging area in wireless sensor network is routing of sensor data. It usually use multi-hop communications for routing data. Despite the similarity between sensor and mobile ad-hoc networks, routing approaches for ad-hoc networks proved not to be suitable to sensors networks. This is due to different routing requirements for ad-hoc and sensor networks in several aspects. For instance, communication in sensor networks is from multiple sources to a single sink, which is not the case in ad-hoc networks. Moreover, there is a major energy resource constraint (Floyd and Jacobson, 1995) for the sensor nodes. As a consequence, many new algorithms have been proposed for the problem of routing data in sensor networks. Current research on routing of sensor data mostly focused on protocols that are energy aware to maximize the lifetime of the network, scalable for large number of sensor nodes and tolerant to sensor damage and battery exhaustion. Since, the data they deal with is not in large amounts and flow in low rates to the sink, the concepts of latency, throughput, delay and jitter were not primary concerns in sensor networks. However, the development of video and imaging sensors requires the consideration of quality of service (QoS) (Lin, 2000) in sensor networks, which magnifies the difficulties associated with the energy efficiency and awareness.

Real time target tracking in battle environment is 1 of the important applications of the sensor networks and it is crucial to locate. To detect and identify a target in this environment imaging and/or video sensors should be used. It requires a real-time data exchange between sensors and controller to take the proper actions. So, for the usage of real-time multimedia data, required certain bandwidth with minimum possible delay and jitter is

Corresponding Author: M.K. Jeya Kumar, Faculty of Computer Applications, Noorul Islam College of Engineering, Kumaracoil, Thuckalay, India

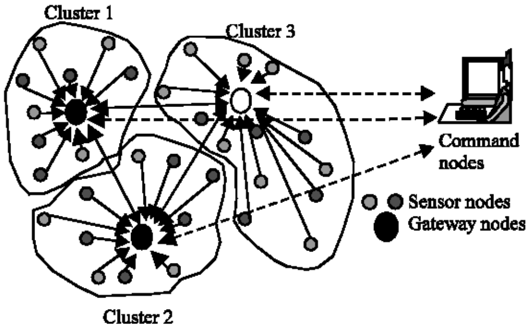

Fig. 1: Multi-gateway clustered network sensors

required. The service differentiation mechanism is needed to guarantee the reliable delivery of the real-time data.

The sensor network architecture shown in Fig. 1 is taken into consideration. In this architecture, sensor nodes are grouped into clusters (Lin and Gerla, 1997) controlled by a single command node. Sensors are only capable of radio-based short-haul communication and are responsible for probing the environment to detect a target/event. Every cluster has a gateway node that manages sensors in the cluster. Clusters can be formed based on many criteria such as communication range, number and type of sensors and geographical location (Buczak and Jamalabad, 1998; Lin and Gerla, 1997).

In this study, it is assumeed that sensor and gateway nodes are stationary and the gateway node is located within the communication range of all the sensors of its cluster. Clustering (Lin and Gerla, 1997) the sensor network is performed by the command node. The command node will inform each gateway node of the ID and location of sensors allocated to the cluster.

Sensors receive commands from and send readings to its gateway node, which processes these readings. Gateways can track events or targets using readings from sensors in any clusters as deemed by the command node. However, sensors that belong to a particular cluster are only accessible via the gateway of that cluster. Therefore, a gateway should be able to route sensor data to other gateways. Gateway nodes interface the command node with the sensor network via long-haul communication links. The gateway node sends to the command node reports generated through fusion of sensor readings, e.g., tracks of detected targets. The command node presents these reports to the user and performs system-level fusion of the collected reports for an overall situation awareness.

In this study, the efficient energy aware QoS routing protocol has been implemented and the performance were analyzed based on the following performance metrics.

- Average lifetime of a node.
- Average delay per packet.
- Network Throughput.

The parameters considered in this study are end-to-end delay, real time data generation/capture rates and packet drop probability and buffer size.

Related work: Many protocols have been proposed for QoS routing (Elmallah *et al*., 2005) in wireless ad hoc networks to satisfy the mobility status (Lee *et al*., 1995; Wang and Crowcraft, 1996). However, none of these protocols consider energy awareness along with the QoS parameters. Some of the proposed protocols consider the imprecise state information, while determining the routes (Querin and Orda, 1997; Zhang *et al*., 1993). In this technique the sensor nodes are maintained by the gateway node.

Core extraction distributed ad hoc routing protocol (Sivakumar *et al*., 1999) is a QoS aware protocol, which uses the idea of core nodes of the network, while determining the paths (Sivakumar *et al*., 1999). The QoS path can be searched through the network code. But in the data flow in sensor network architecture, there is no need to find the core of the network. Also, if any node in the core is broken, it will cost too much resource to reconstruct the core. Lin and Gerla (1997) Zhu and Corson (2002) have proposed a QoS routing protocol specifically designed for TDMA-based ad-hoc networks. This protocol can build a QoS route from a source to destination with reserved bandwidth. The bandwidth calculation is done hop-by-hop using distributed algorithms.

Energy-Aware QoS Routing Protocol is 1 of the important protocol for sensor networks proposed by Akkaya and Younis (Akkaya and Younis, 2003). In this, real-time traffic is generated by imaging sensors and this was able to find the least cost value and energy efficient path to obtain end-to-end delay during the connection.

ENERGY-AWARE QoS ROUTING

In Energy aware QoS routing protocol the real-time traffic is generated by imaging sensors. This protocol extends the routing approach and finds a least cost and energy efficient path that meets certain end-to-end delay during the connection. The link cost used is a function that captures the nodes for energy reserve, transmission energy, error rate and other communication parameters.

In order to support both best effort and realtime traffic at the same time, a class-based queuing model (Andresen *et al*., 1995) is employed. This queuing model allows service sharing for real-time and non-real-time traffic. The bandwidth ratio r, is defined as an initial value set by the gateway and represents the amount of bandwidth to be dedicated both to the real-time and non-real-time traffic on a particular outgoing link in case of a congestion. As a consequence, the throughput for normal data does not diminish. This can be done by properly adjusting such r values.

In this method, to find the end-to-end delay, the least-cost path value is calculated first. This approach is based on the cost function (Andresen *et al*., 1995) for each link and uses a K least cost path algorithm (Ernesto *et al*., 1998) to find a set of candidate routes. Such, routes are checked against the end-to-end constraints and the 1 that provides maximum throughput is picked.

To find a QoS path for sending real-time data to the gateway, end-to-end delay should be calculated. To calculate end-to-end delay first calculate Queuing delay and Propagation delay for a particular path p.

The real-time data rate by p_i nodes will be $p\lambda_{RT}$ and total real-time data rate by q_i nodes will be

$$\sum_{j=1}^{qi} r_j\mu \tag{1}$$

The total real-time data load on a sensor node is:

$$\lambda_{RT}^{(i)} = \mathrm{pi}\lambda\mathrm{RT} + \sum_{j=1}^{q_i} r_j\mu \tag{2}$$

Hence, the total queuing delay on a node is:

$$TQ_{RT}^{(i)} = \lambda_{RT}^{(i)} / r_i\mu \tag{3}$$

Where,

λ_{RT} = Real-time data generation rate for imaging sensors.

$r_i\mu$ = Service rate for real-time data on sensor node i

$(1-r_i)\,\mu$ = Service rate for non-real-time data on sensor node i.

p_i = The number of sensing-only neighbors of node i on path P.

q_i = The number of relaying-only neighbors of node i on path P.

$\lambda^{(i)}_{RT}$ = Total real-time data rate on sensor node i.

$TQ^{(i)}_{RT}$ = Total queuing delay on a node *i* for real-time traffic.

T_E = End-to-end queuing delay for a particular path P.

T_P = End-to-end propagation delay for a particular path P.

$T_{end-end}$ = Total end-to-end delay for a particular path P.

$T_{required}$ = End-to-end delay requirement for all paths.

The end-to-end delay for a particular path is:

$$T_P = \sum_{i,j\in path} c x dist_{ij} \tag{4}$$

where, c is a constant, which is obtained by dividing a weighting constant by the speed of wireless transmission. Hence, total end-to-end delay will be:

$$T_{end-to-end} = \left(\frac{\lambda_{RT}}{\mu}\right)\left[\frac{p_i + \sum_{j=1}^{q_i} r_j}{r_i}\right] + \sum_{i,j\in path}\left(c x dist_{ij}\right) \tag{5}$$

To calculate the end-to-end delay for a particular path, the optimal r-values for each link is also necessary. If all r-values be same for every link then the above formula can be simplified as:

$$T_{end-to-end} = \left(\frac{\lambda_{RT}}{r\mu}\right)\sum_{i,j\in path} p_i + \sum_{i,j\in path}\left(q_i + c x dist_{ij}\right) \tag{6}$$

Then the problem is stated as an optimization problem as follows:

$$\mathrm{Max}\left(\sum_{i,j\in path}((1-r)\mu)\right) \tag{7}$$

subject to, $T_{end-to-end} \le T_{required}$ and $0 \le r < 1$

The list of least cost paths by using the extended version of Dijkstra's algorithm and picks a path from that list which meets the end-to-end delay requirement. The algorithm to find the least cost path is shown in Fig. 2.

```
  Calculate $Cost_{ij}$, $\forall i, j \in V$
Find the least cost path for each node by using
Dijkstra's shortest path algorithm
for each imaging sensor node i do
begin
            compute r from
    $T_{end-to-end}(p_i) = T_{required}$
            if (r is range[0,1]) then
                Add r to a list corresponding to node i
            else
                Find K least cost paths ($p^k_i$) to the
    gateway by extended Dijkstra.
                for each $k \in K$ do
                      Recompute r from
    $T_{end-to-end}(p^k_i) = T_{required}$
                      if (r is in range (0,1)) then
                                break;
                if no appropriate r is found
                      Reject the connection
    end
   Find max r from the list
```

Fig. 2: Least cost path algorithm

SIMULATION EXPERIMENT

This section describes the performance metrics, simulation environment and experimental results. The following metrics are considered to capture the performance of the QoS routing approach.

Average lifetime of a node: This gives a good measure of the network lifetime. A routing algorithm, which maximizes the lifetime of network, is desirable. This metric also shows the efficiency of the algorithm in energy consumption.

Average delay per packet: It is defined as the average time a packet takes from a sensor node to the gateway. Most energy aware routing algorithms try to minimize the consumed energy. However, the applications that deal with real-time data is delay sensitive. So, this metric is important.

Network throughput: Defined as the total number of data packets received at the gateway divided by the simulation time. The throughput for both real-time and non-real-time traffic will be considered independently.

In the experiments the cluster consists of 100 randomly placed nodes in a 1000×1000 meter square area. The gateway position is determined randomly within the cluster boundaries. A free space propagation channel model (Gerla *et al*., 1999) is assumed with the capacity set to 2 Mbps. Packet lengths are 10 Kbit for data packets and 2 Kbit for routing and refresh packets. Each node is assumed to have an initial energy of 5 joules. The buffers for real-rime data and normal data have default size of 15 packets. A node is considered non-functional if its energy level reaches 0. For the term CF1 in the cost function, used the linear discharge curve of the alkaline battery (Akkaya and Younis, 2003).

For a node in the sensing state, packets are generated at a constant rate of 1 packet/sec. The real-time packet generation rate (RT l) for the nodes, which have imaging/video capability is greater than the normal rate. The default value is 3 packets/sec. A service rate (m) of 5 packets/sec is assumed. Each data packet is time-stamped, when it is generated to allow the calculation of average delay per packet. In addition, each packet has an energy field that is updated during the packet transmission to calculate the average energy per packet. A packet drop probability is taken to be 0.01. This is used to make the simulator more realistic and to simulate the deviation of the gateway energy model from the actual energy model of nodes.

It is assumed that the cluster is tasked with a target-tracking mission in the experiment. The initial set of sensing nodes is chosen to be the nodes on the convex hull of sensors in the cluster. The set of sensing nodes changes as the target moves. Since, targets are assumed to come from outside the cluster, the sensing circuitry of all boundary nodes is always turned on. The sensing circuitry of other nodes are usually turned off but can be turned on according to the target movement. Also, assume that each sensor node is capable of taking the image of target to identify it clearly and can turn on its imaging capability on demand. During simulation, a small subset of current active nodes, which are the closest nodes to the target, are selected to turn on their imaging capability. Therefore, the imaging sensor set may change with the movement of the target.

The packet-sensing rate for imaging sensors is bigger than the normal sensors, hence more packets are generated, when imaging sensors are employed. These packets are labeled as real-time packets and treated differently in sensor nodes. The r-value is initially assumed to be 0 but it's recalculated as imaging sensors get activated. The default end-to-end delay requirement (Chen and Nahrstedt, 1999) for a QoS path is assumed to be 10 sec, which is a reasonable amount of time to get image data periodically in a real-time target tracking application. Targets are assumed to start at a random position outside the convex hull. Targets are characterized by having a constant speed chosen uniformly from the range 4-6 m s^{-1} and a constant direction chosen uniformly depending on the initial target position in order for the target to cross the convex hull region. It is assumed that only 1 target is active at a time. This target remains active until it leaves the deployment region area. In this case, a new target is generated.

PERFORMANCE RESULTS

In this study, the following performance results were obtained from the simulation study. Different parameters considered in the simulation study are end-to-end delay, buffer size, packet drop probability and real-time data generation/capture.

Effect of end-to-end delay and real-time date generation rate on network r-values: The network r-value goes down, while the end-to-end delay requirement gets looser. Since, the delay is not too strict, most of the nodes will be able to find a QoS path. The results are depicted in Fig. 3. More band width will be required for congested network with more realtime data packets, while increasing the realtime data generation rate. This will cause the r-value to increase so that each node can serve more real-time packets shown in Fig. 4.

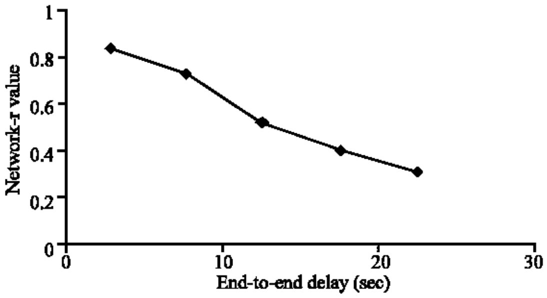

Fig. 3: Network r-value with different end-to-end delay values

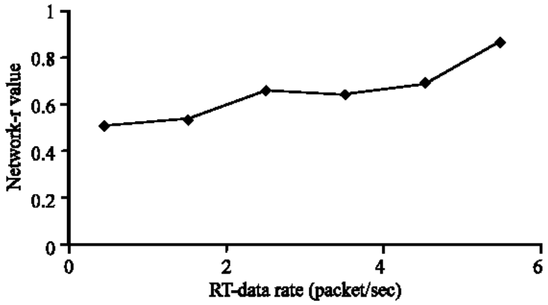

Fig. 4: Network r-value with different real-time data rates

Effect of real-time data rate on performance: In this, the performance has been analyzed for real-time and non-real-time data throughput. The results are shown in Fig. 5-7. While, the number of real-time packets increase, it gets more difficult to satisfy increasing number of QoS paths. Hence, this can cause some rejection or packet drops for realtime data causing throughput for real-time data to decrease. However, the throughput for nonreal-time data does not change much since, there is already a constant dedicated bandwidth for such data, ensured by the r-value. The r-value was restricted to strictly less than 1, causing the throughput for non-real-time data (1-r) μ to be always greater than 0. The algorithm does not sacrifice the throughput for non-real-time data for the sake of real-time data.

Figure 6 shows the effect of real-time data rate on average delay per packet. The delay increases with the rate since packets (especially real-time packets) incur more queuing delay and share the same amount of bandwidth. The lifetime of a node is also considered in order to see the effect of real-time data rate on energy metric. Figure 7 shows that the average energy for a sensor node increases with the real-time data rate. The reason for this increase is that the throughput decreases, causing the number of packets arriving to the gateway to decrease. Therefore, fewer packets will be relayed by the sensor nodes, which will save energy from transmission and reception energy costs.

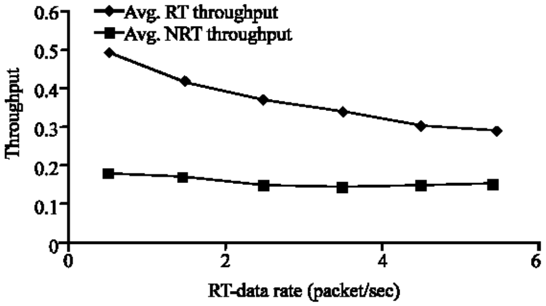

Fig. 5: Effect of rt-data rate on throughput

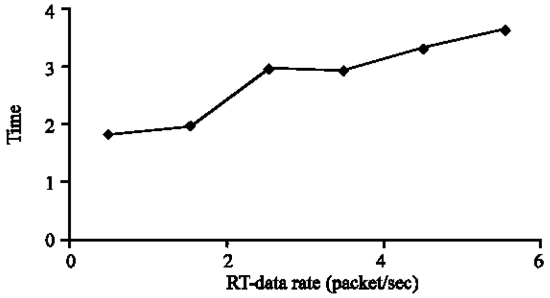

Fig. 6: Effect of rt-data rate on average delay for a packet

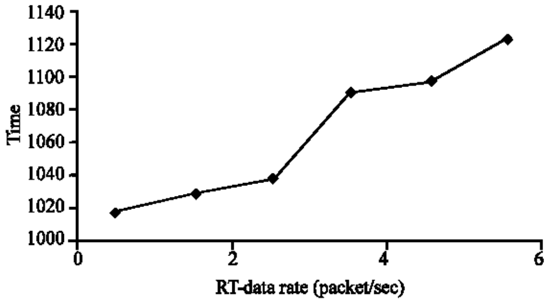

Fig. 7: Effect of rt-data rate on average lifetime of a node

Effect of packet drop probability on performance: In this the probability of packets drop was varied from 0.01-0.05. The results are shown in Fig. 8-10. The average delay per packet decreases with the increasing probability. When, the number of hops the packet traverse increases, the probability that it will be dropped increases. The packets that arrive to the gateway are most probable to take a small number of hops and thus incurring less delay. So, the throughput decreases due to lost packets. Also, the average node lifetime increases since not all packets reach their destination and thus the node energy is conserved.

Effect of buffer size on performance: In queuing model buffers were used in each node and there is a limit on the size of those buffers. The buffer size was varied to see if there is any effort on the performance of the algorithm. The results are shown in Fig. 11 and 12. The average

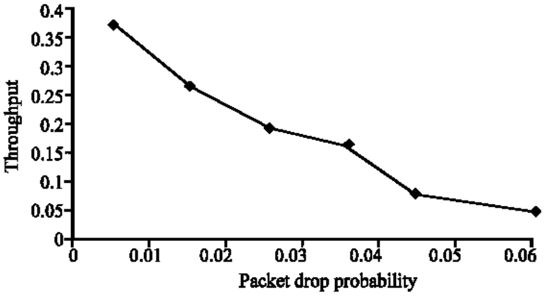

Fig. 8: Effect of packet drop prob. on throughput

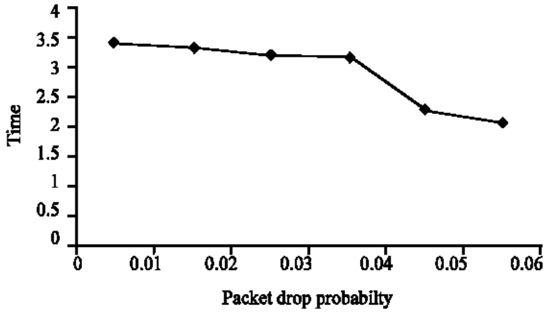

Fig. 9: Effect of packet drop prob. on average delay per packet

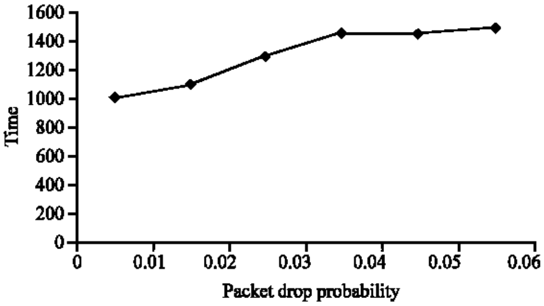

Fig. 10: Effect of packet drop prob. on average lifetime of a node

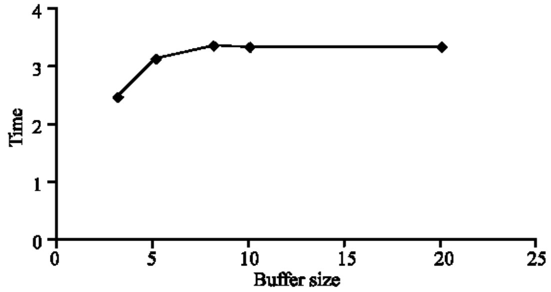

Fig. 11: Effect of buffer size on average delay per packet

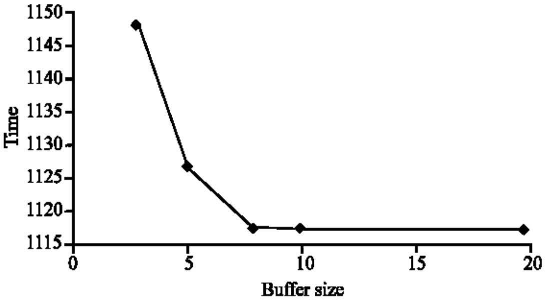

Fig. 12: Effect of buffer size on average lifetime of a node

delay per packet increases with the buffer size since, the throughput increases. Packets are not dropped, when there is enough space in the buffers. This will increase the number of packets arriving to the gateway. The packets from far nodes will be also be able to reach the gateway. More packets from far nodes mean more delay, which eventually increases the average delay per packet. The increasing number of packets arriving to the gateway will also increase the energy consumption by increasing the number of transmission and reception costs, therefore decreasing the average lifetime of a node.

CONCLUSION

In this study, it has been analyzed the performance of energy-aware QoS routing protocol for sensor networks with respect to different performance metrics has been analysed. From the simulation environment the following performance results were obtained in this study. When, network r-value goes down then the end-to-end delay requirement gets looser. Since, the delay is not too strict, most of the nodes will be able to find a QoS path. When, the number of real-time packets increase, it gets more difficult to satisfy increasing number of QoS paths. Hence, this can cause some rejection or packet drops for real-time data causing throughput for real-time data to decrease. However, the throughput for non-real-time data does not change much, since there is already a constant dedicated bandwidth for such data, ensured by the r-value. The average delay per packet decreases with the increasing probability. The average delay per packet increases with the buffer size, since, the throughput increases. Packets are not dropped when there is enough space in the buffers.

REFERENCES

Andresen, J.B., T.S. Rappaport and S. Yoshida, 1995. Propagation measurements and models for wireless communications channels. IEEE. Commun. Mag., 33 (1): 42-49.

Akkaya, K. and M. Younis, 2003. Proc. 23rd Int. Conf. Distributed Comput. Sys. Workshops, pp: 710-715.

Buczak and V. Jamalabad, 1998. Self-organization of a heterogeneous sensor network by genetic algorithms. Intell. Eng. Systems Through Artificial Neural Networks, 8: 259-264.

Chen, S. and K. Nahrstedt, 1999. Distributed quality-of-service routing in Ad-Hoc networks. IEEE. J. Selected areas in Commun., 17 (8): 1488-1505.

Ernesto, Q.V.M., M.M. Marta and L.E.S. Jose, 1998. The K shortest paths problem. Research Report, CISUC.

Elmallah, E.S., H.S. Hassanein and H.M. AboElFotoh, 2005. Supporting QoS routing in mobile ad hoc networks using probabilistic locality and load balancing. Prec. Global Telecommun. Conf. IEEE., 5: 2901-2906.

Floyd, S. and V. Jacobson, 1995. Link sharing and resource management models for packet networks. IEEE/ACM Trans. Networking, 3 (4): 365-386.

Gerla, M., G. Pei and S.J. Lee, Wireless, 1999. Mobile Ad-Hoc Network Routing. In the Proceedings of IEEE/ACM FOCUS, New Brunswick, NJ., pp: 1112-1124.

Lin, C.R., 2000. On demand QoS routing in multihop mobile networks. IEICE Trans. Commun., 3: 1735-1744.

Lin, C.R. and M. Gerla, 1997. Adaptive clustering for mobile wireless networks. IEEE J. Selected Areas of Commun., 15 (7): 1265-1275.

Lee, W.C., M.G. Hluchyi and P.A. Humblet, 1995. Routing subject to quality of service constraints integrated communication networks. IEEE Network.

Querin and A. Orda, 1997. QoS-based routing in networks with inaccurate information: Theory and algorithms. In Proc. IEEE INFOCOM, Japan, pp: 75-83.

Sohrabi, K., J. Gao, V. Ailawadhi and G.J. Potie, 2000. Protocols for self-organization of a wireless sensor network. IEEE Personal Commun., pp: 16-27.

Sivakumar, R., P. Sinha and V. Bharghavan, 1999. CEDAR: A core-extraction distributed Ad Hoc routing algorithm. IEEE J. Selected Areas Commun., 17 (8): 1454-1465.

Singh, S., M. Woo and C.S. Raghavendra, 1998. Power-aware routing in mobile Ad-Hoc networks. In the Proceedings of ACM MOBICOM, Dallas, Texas, pp: 181-190.

Wang, Z. and J. Crowcraft, 1996. QoS-based routing for supporting resource reservation. IEEE J. Selected Area of Communications.

Zhu, C. and M.S. Corson, 2002. QoS routing for mobile Ad Hoc networks. In the Proceedings of IEEE INFOCOM, 2: 958-967.

Zhang *et al.*, 1993. RSVP: A New Resource ReServation Protocol. IEEE Network.