Efficient, Least Cost, Energy-Aware (ELCEA) Quality of Service Protocol in Wireless Sensor Networks

Nida Maheen[1], **Sanath Kumar M T**[2]

[1]M.Tech 4th Semester, Dept. of DECS, VTU-RO, P.G.Centre, Mysore-570029, Karnataka
[3]Asst. Prof., Dept. of DECS, VTU-RO, P.G.Centre, Mysore-570029, Karnataka

Abstract: ***Recent advances in wireless sensor networks have led to many new routing protocols specifically designed for sensor networks. Almost all of these routing protocols considered energy efficiency as the ultimate objective in order to maximize the whole network lifetime. However, the introduction of video and imaging sensors has 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 paper, we propose Efficient, Least Cost, Energy-Aware (ELCEA) QoS routing protocol for sensor networks which can also run efficiently with best-effort traffic. The protocol finds a least cost, delay-constrained path for realtime data in terms of link cost that captures nodes' energy reserve, transmission energy, error rate and other communication parameters. Moreover, the throughput for non-real-time data is maximized by adjusting the service rate for both real-time and non-real-time data at the sensor nodes. Simulation results have demonstrated the effectiveness of our approach for different metrics***.

Keywords: Wireless Sensor Network, DIJKSTRA'S Algorithm, Energy Aware of Sensor Node, Quality of Service, Finding the path which is energy efficient with required QOS.

1. Introduction

Wireless Sensor Networks (WSNs) are rapidly emerging as an important new area in wireless and mobile computing research. Wireless sensors facilitate many application in a wide range of areas, such as traffic data collection in transportation, earthquake monitoring for emergency response, combat zone surveillance and disease diagnosis in medical environments. Sensor nodes typically have limited computational resources and battery power in autonomous environments without energy supply. A wireless sensor network generally consists of a large number of sensor nodes that communicate with their neighbors and send data to a base station or gateway through multi-hop transmission.
In recent years there has been a growing interest in Wireless Sensor Networks (WSNs). Recent advancements in the field of sensing, computing and communications have attracted research efforts and huge investments from various quarters in the field of WSNs. Also sensing networks will reveal previously unobserved phenomena. Communication among the sensors, in case of Wireless Sensor Network is done using wireless transceivers.

Wireless Sensor Networks (WSNs) is widely considered as one of the most important technologies for the twenty-first century. In the past decades, it has received tremendous attention from both academia and industry all over the world. WSNs typically consist of a large number of low-cost, low-power, and multifunctional wireless sensor nodes, with sensing, wireless communications and computation capabilities. These sensor nodes communicate over short distance via a wireless medium and collaborate to accomplish a common task, for example, environment monitoring, military surveillance, and industrial process control. The basic philosophy behind WSNs is that, while the capability of each individual sensor node is limited, the aggregate power of the entire network is sufficient for the required mission [1, 4, 5].

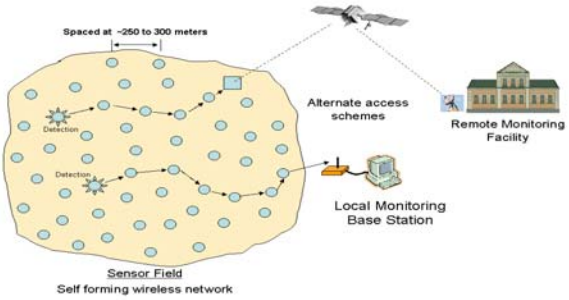


Figure 1: WSNs Architecture

Sensor nodes are battery-powered and are expected to operate without attendance for a relatively long period of time. In most cases it is very difficult and even impossible to change or recharge batteries for the sensor nodes. WSNs are characterized with denser levels of sensor node deployment, higher unreliability of sensor nodes, and sever power, computation, and memory constraints. Thus, the unique characteristics and constraints present many new challenges for the development and application of WSNs [4, 5].

Since sensor nodes are battery powered, they have limited energy capacity. Energy poses a big challenge for network designers in hostile environments, for example, a battlefield, where it is impossible to access the sensors and recharge their batteries. Furthermore, when the energy of a sensor reaches a certain threshold, the sensor will become faulty and will not be able to function properly, which will have a major impact on the network performance. Thus, routing protocols designed for sensors should be as energy efficient as possible to extend their lifetime, and hence prolong the network lifetime while guaranteeing good performance overall.

1.1 Internal Components of Sensor Node

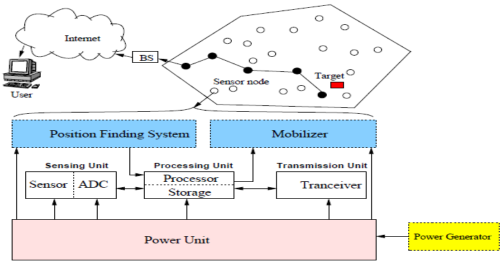


Figure 2: Internal Components of Sensor Node

The main components of a sensor node are a microcontroller, transceiver, external memory, power source and one or more sensors [2].

Controller: The controller performs tasks, processes data and controls the functionality of other components in the sensor node. While the most common controller is a microcontroller, other alternatives that can be used as a controller are: a general purpose desktop microprocessor, digital signal processors, FPGAs and ASICs. A Digital Signal Processors may be chosen for broadband wireless communication applications, but in Wireless Sensor Networks the wireless communication is often modest: i.e., simpler, easier to process modulation and the signal processing tasks of actual sensing of data is less complicated. Therefore the advantages of DSPs are not usually of much importance to wireless sensor nodes. FPGAs can be reprogrammed and reconfigured according to requirements, but this takes more time and energy than desired

Transceiver: Sensor nodes often make use of ISM band which gives free radio, spectrum allocation and global availability. The possible choices of wireless transmission media are Radio frequency (RF), Optical communication (Laser) and Infrared. Lasers require less energy, but need line-of-sight for communication and are sensitive to atmospheric conditions. Infrared, like lasers, needs no antenna but it is limited in its broadcasting capacity. Radio frequency based communication is the most relevant that fits most of the WSN applications. WSNs tend to use license-free communication frequencies: 173, 433, 868, and 915 MHz; and 2.4 GHz. The functionality of both transmitter and receiver are combined into a single device known as transceivers. Transceivers often lack unique identifiers. The operational states are transmitted, receive, idle, and sleep. Current generation transceivers have built-in state machines that perform some operations automatically. Most transceivers operating in idle mode have a power consumption almost equal to the power consumed in receive mode. Thus, it is better to completely shut down the transceiver rather than leave it in the idle mode when it is not transmitting or receiving. A significant amount of power is consumed when switching from sleep mode to transmit mode in order to transmit a packet.

External Memory: From an energy perspective, the most relevant kinds of memory are the on-chip memory of a microcontroller and Flash memory or off-chip RAM is rarely, if ever, used. Flash memories are used due to their cost and storage capacity.

Power Source: The sensor node consumes power for sensing, communicating and data processing. More energy is required for data communication than any other process.. Power is stored either in batteries or capacitors. Batteries, both rechargeable and non-rechargeable, are the main source of power supply for sensor nodes.. Current sensors are able to renew their energy from solar sources, temperature differences, or vibration. Two power saving policies used are Dynamic Power Management (DPM) and Dynamic Voltage Scaling (DVS). DPM conserves power by shutting down parts of the sensor node which are not currently used or active. A DVS scheme varies the power levels within the sensor node depending on the non-deterministic workload.

Sensors: Sensors are hardware devices that produce a measurable response to a change in a physical condition like temperature or pressure. Sensors measure physical data of the parameter to be monitored. The continual analog signal produced by the sensors is digitized by an analog-to-digital converter and sent to controllers for further processing. A sensor node should be small in size, consume extremely low energy, operate in high volumetric densities, be autonomous and operate unattended, and be adaptive to the environment.

1.2 Protocol Stack of Sensor Node

The protocol stack used by the sink and all sensor nodes is given in Fig. 1.6. . This protocol stack combines power and routing awareness, integrates data with networking protocols, communicates power efficiently through the wireless medium, and promotes cooperative efforts of sensor nodes. The protocol stack consists of the application layer, transport layer, network layer, data link layer, physical layer, power management plane, mobility management plane, and task management plane [16].

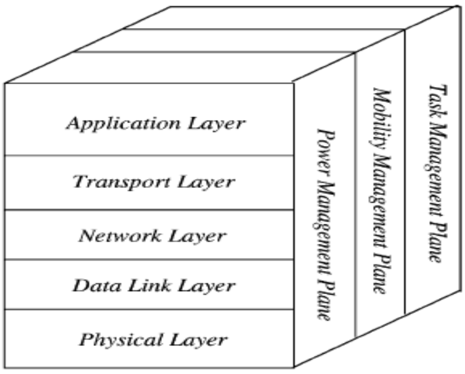


Figure 3: Protocol Stack of a Sensor Node.

Depending on the sensing tasks, different types of application software can be built and used on the application layer. The transport layer helps to maintain the flow of data if the sensor networks application requires it. The network layer takes care of routing the data supplied by the transport layer. Since the environment is noisy and sensor nodes can be mobile, the MAC protocol must be power aware and able to minimize collision with neighbours' broadcast. The physical layer addresses the needs of a simple but robust modulation, transmission and receiving techniques. In addition, the power, mobility, and task management planes monitor the power, movement, and task distribution among the sensor nodes. These planes help the sensor nodes coordinate the sensing task and lower the overall power consumption.

The power management plane manages how a sensor node uses its power. For example, the sensor node may turn off its receiver after receiving a message from one of its neighbours. This is to avoid getting duplicated messages. Also, when the power level of the sensor node is low, the sensor node broadcasts to its neighbours that it is low in power and cannot participate in routing messages. The remaining power is reserved for sensing. The mobility management plane detects and registers the movement of sensor nodes, so a route back to the user is always maintained, and the sensor nodes can keep track of who are their neighbour sensor nodes. By knowing who the neighbour sensor nodes are, the sensor nodes can balance their power and task usage. The task management plane balances and schedules the sensing tasks given to a specific region. Not all sensor nodes in that region are required to perform the sensing task at the same time.

2 Energy Efficient and QOS Routing Protocols in WSN

In this paper we are discussing only the energy-efficient and QoS routing protocols only and details of those routing protocols is given below.

2.1 LEACH Protocols

Low-Energy Adaptive Clustering Hierarchy (LEACH) is clustering based protocol uses randomized rotation of local cluster base stations. The nodes in LEACH are divided into clusters and each cluster consists of Cluster Members and a Cluster Head [CH]. The CHs are not selected in the static manner that leads to quick die of sensor nodes in the network LEACH uses Time Division Multiple Access (TDMA) protocol in order to regulate the channel access within a cluster. The peer to peer communication between the CH and a member is done just during the time slot that assigned to that member, and the other members will be in their sleep state. Hence, it decreases the energy dissipation [8, 9, 11].

2.2 Directed Diffusion

Directed diffusion is data-centric routing protocol for collecting and publishing the information in WSNs. It has been developed to address the requirement of data flowing from the sink toward the sensors, i.e., when the sink requests particular information from these sensors. Its main objective is extending the network life time by realizing essential energy saving. In order to fulfill this objective, it has to keep the interactions among the nodes within a limited environment by message exchanging. This unique feature with the ability of the nodes to response to the queries of the sink, results in considerable energy savings [4, 9].

2.3 Gossiping Protocol

Gossiping is data-relay protocol, like Flooding protocol, does not need routing tables and topology maintenance. It was produced as an enhancement for Flooding and to overcome the drawbacks of Flooding, i.e., implosion. In Flooding, a node broadcasts the data to the all of its neighbors even if the received node has just received the same data from another node. The broadcasting will continue until the data will be received by the destination. However, in Gossiping, a node randomly chooses one of its neighbors to forward the packet to, once the selected neighbor node receives the packet it chooses, in turn, another random neighbor and forwards the packet to including the node which sent the packet itself. This process will continue till the destination or number of hop has been exceeded. As a result, just the selected nodes/neighbors will forward the packet to the sink [4, 9].

2.4 TEEN (Threshold sensitive Energy Efficient sensor Network)

TEEN is a cluster based hierarchical routing protocol based on LEACH. This protocol is used for time-critical applications. It has two assumptions one is the BS and the sensor nodes have same initial energy and another one is the BS can transmit data to all nodes in the network directly. In this protocol, nodes sense the medium continuously, but the data transmission is done less frequently. The network consists of simple nodes, first-level cluster heads and second-level cluster heads. TEEN uses LEACH’s strategy to form cluster. First level CHs are formed away from the BS and second level cluster heads are formed near to the BS.
TEEN has the following drawbacks, one is a node may wait for their time slot for data transmission. Again time slot may be wasted if a node has no data for transmission. Another one is cluster heads always wait for data from nodes by keeping its transmitter on [4, 8, 11].

2.5 APTEEN (Adaptive Threshold TEEN)

APTEEN is an improved version of TEEN and it has all the features of TEEN. It is developed for hybrid networks and captures both periodic data collection and reacting to time critical events. APTEEN supports queries like Historical-analyze past data values, a snapshot of the current network view, persistent monitor an event for a period of time. In each round, after deciding the cluster head, the cluster head broadcaststhe following parameters like attributes(interested physical parameters), thresholds(hard threshold value and soft threshold value), time schedule(time slot using TDMA) and count time(maximum time period between two successive reports sent by a node). It allows the user to set threshold values and also a count time interval. If a node does not send data for a time period equal to the count time, it is forced to sense and retransmit the data thus maintaining energy consumption [4, 8, 11].

2.6 Sequential Assignment Routing (SAR)

SAR is one of the first routing protocols for WSNs that introduces the notion of QoS in the routing decisions. It is a table-driven multi-path approach striving to achieve energy efficiency and fault tolerance. Routing decision in SAR is dependent on three factors: energy resources, QoS on each path, and the priority level of each packet. The SAR protocol creates trees rooted at one-hop neighbors of the sink by taking QoS metric, energy resource on each path and priority level of each packet into consideration. By using created trees, multiple paths from sink to sensors are formed. One of these paths is selected according to the energy resources and QoS on the path. Failure recovery is done by enforcing routing table consistency between upstream and downstream nodes on each path. Any local failure causes an automatic path restoration procedure locally. the protocol suffers from the overhead of maintaining the tables and states at each sensor node especially when the number of nodes is huge [4, 11].

2.7 SPEED

This is another QoS routing protocol for sensor networks that provides soft real time end-to-end guarantees. The protocol requires each node to maintain information about its neighbors and uses geographic forwarding to find the paths. The routing module in SPEED is called Stateless Geographic Non-Deterministic forwarding (SNFG) and works with four other modules at the network layer. The beacon exchange mechanism collects information about the nodes and their location.

Delay estimation at each node is basically made by calculating the elapsed time when an ACK is received from a neighbor as a response to a transmitted data packet. By looking at the delay values, SNGF selects the node, which meets the speed requirement. If it fails, the relay ratio of the node is checked, which is calculated by looking at the miss ratios of the neighbors of a node (the nodes which could not provide the desired speed) and is fed to the SNGF module. SPEED does not consider any further energy metric in its routing protocol [4, 11].

2.8 Efficient, Least Cost, Energy-Aware (ELCEA) QoS Protocol

In this QoS aware protocol for sensor networks. 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' energy reserve, transmission energy, error rate and other communication parameters. The protocol finds a list of least cost paths by using an extended version of Dijkstra's algorithm and picks a path from that list which meets the end-to-end delay requirement [4].

3 Algorithm for ELCEA-QOS Protocol

The ELCEA- QoS Routing algorithm includes the following steps, they are:

Step 1: If the Node senses some parameter and ready to send the data (Sender Node) to Base Station or Sink from sensor network, first it looks for neighbor nodes and which is the shortest path to send data to Base Station or Sink.

Step 2: The sender will uses the Dijkstra's Algorithm to find the shortest path in the network from Sender Node to Base Station (BS). The dijkstra's algorithm will lists the shortest paths from Sender Node to BS.

Step 3: After getting the list of shortest paths the Sender node is need to found which path in the list is Energy-Efficient and provide required QoS. To find that the node needs some calculation, that calculation is Link Path Cost and End to End delay. Here Link Path Cost is used to find the Energy-Efficient path and End to End delay is used to find QoS of the obtained path. The following equations are used to find Link Path Cost and End to End Delay from Sender node to BS.

$$cost_{ij} = \sum_{k=0}^{6} CF_k = c_0 \times (dist_{ij})^l + c_1 \times f(energy_j) + c_2 / T_j + c_3 + c_4 + c_5 + c_6 \times f(e_{ij}) \qquad \text{--- (1)}$$

Where,

$dist_{ij}$ is the distance between the nodes i and j,

f($energy_j$) is the function for finding current residual energy of node j,

T is the expected time under the current consumption rate until the node j energy level reaches the minimum acceptable threshold,

f(e_{ij}) is the function for finding the error rate on the link between i and j**.**

The factors CF_k are defined similar as in, however the cost function is further extended for error rate cost. The end-to-end delay is modelled as a constraint on the whole path and includes the propagation delay. Hence, it's not part of the cost function. Cost factors are defined as follows,

CF_0 (Communication Cost) = $c_0*(dist_{ij})^l$ where c_0 is a weighting constant and the parameter l depends on the environment, and typically equals to 2. This factor reflects the cost of the wireless transmission power, which is directly proportional to the distance raised to some power l. The closer a node to the destination, the less its cost factor CF_0 and more attractive it is for routing.

CF_1 (Energy Stock) = $c_1*f(energy_j)$. This factor reflects the remaining battery lifetime, which favours nodes with more energy. The more energy the node contains, the better it is for routing.

CF_2 (Energy Consumption Rate) = c_2 / T_j, where c_2 is a weighting constant and j T is the Expected time under the current consumption rate until the node j energy level hits the minimum acceptable threshold. The factor CF_2 makes heavily used nodes less attractive, even if they have a lot of energy.

CF_3 (Relay Enabling Cost) = c_3, where c_3 is a constant reflecting the overhead required to switch an inactive node to become a relay. This factor favours relay-enabled nodes to be used for routing rather than the inactive nodes.

CF_4 (Sensing-State Cost) = c_4, where c_4 is a constant added when the node j is in a sensing state. This factor does not favour selecting sensing-enabled nodes to serve as relays. It's Preferred not to overload these nodes in order to keep functioning as long as possible.

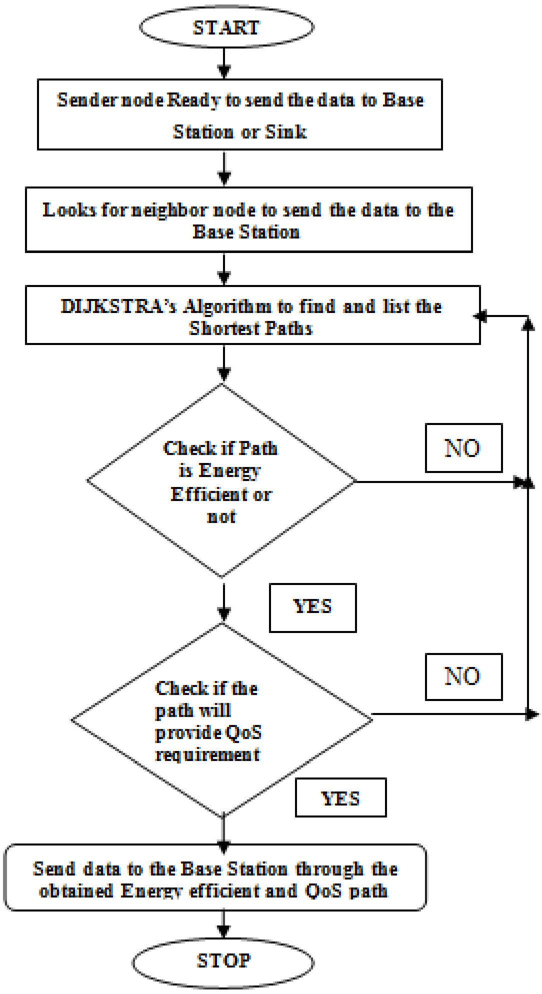
CF_5 (Maximum Connections Per Relay) = c_5. Once this threshold is reached, we add an extra cost c_5 to avoid setting additional paths through that relay. This factor extends the life of overloaded relay nodes by making them less favourable.

CF_6 (Error Rate) = $c_6*f(e_{ij})$ where f is a function of distance between nodes i and j and Buffer size on node j (i.e. $dist_{ij}$ / buffer _ $size_j$). The links with high error rate will increase the cost function, thus will be avoided.

Step 4: If the node does not find the Energy-Efficient and required QoS path then it will start from step 3 until it will find the Energy-Efficient and required QoS path.

Step 5: After finding the Energy-Efficient and required QoS path the node will send the data to the Base Station or Communicate with Base Station through that path.

3.1 Flow Chart



4 Simulation Results

The below showing figure is the Simulation Window for the task that is been performed in MATLAB tool. In this window we need to run the wsnfig.m file in order to get the tabulation window as shown below.

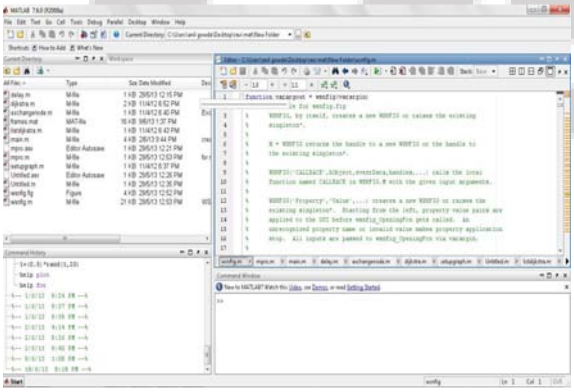


Figure 4: MATLAB Simulation Window

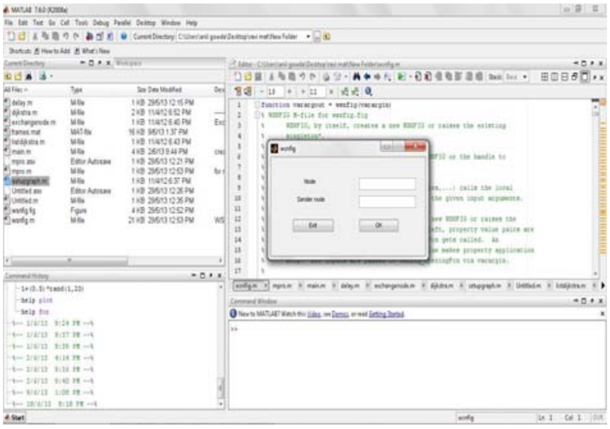


Figure 5: GUI Tabulation Window

The above figure is the GUI Tabulation window, this window we will get after run the wsnfig.m file in simulation window. In this window we need to give numeric value for number of nodes we required in the network and also we need to enter which node is sender node, after entering the numeric values we need to click Ok button then we will get figure window for simulated output. If we click on the Exit button the MATLAB tool clear the Command window, Closes the all opened window in the MATLAB.

4.1 For 75 number of Nodes

Simulation Output Figure Window

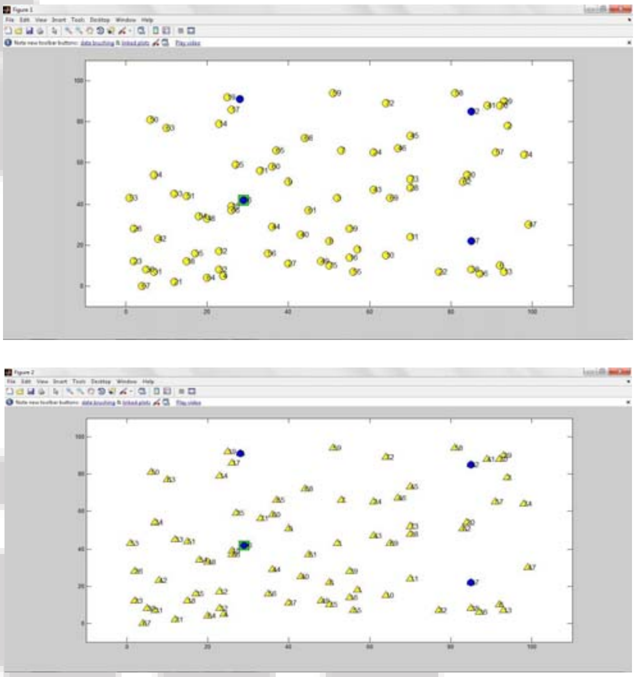


Figure 6: Simulation Output Figure Window for 75 number of Nodes.

After entering the Node as 75 and Sender node as 5 in GUI tabulation window and after clicking Ok we will get both windows. The first figure window will appears immediately and this shows the shortest path with energy efficient and required QoS. Here we can see all the nodes are in circle shape but only connected nodes will be in the Blue color remaining are in Yellow color. The second figure window we will get after some time to show that the nodes are connected. Here, only the connected nodes will be in Blue color and Circle in shape but remaining nodes is in Yellow color and Triangle in shape. After simulation it's picking the path as 5>52>37>76. In Command window it shows as 76 37 52 5. And here 76 node is base station.

4.2 For 100 number of Nodes

Simulation Output Figure Window

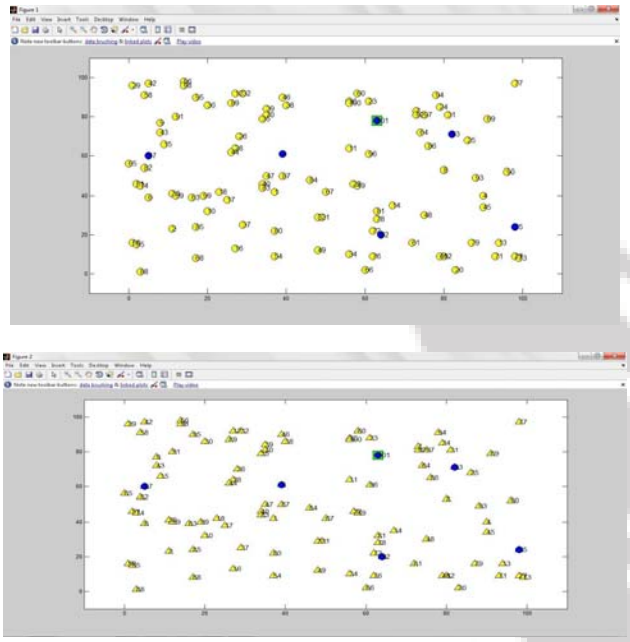


Figure 7: Simulation Output Figure Window for 100 number of Nodes.

After entering the Node as 100 and Sender node as 5 in GUI tabulation window and after clicking Ok we will get both windows. The first figure window will appears immediately and this shows the shortest path with energy efficient and required QoS. Here we can see all the nodes are in circle shape but only connected nodes will be in the Blue color remaining are in Yellow color. The second figure window we will get after some time to show that the nodes are connected. Here, only the connected nodes will be in Blue color and Circle in shape but remaining nodes are in Yellow color and Triangle in shape. After simulation it's picking the path as 5>53>75>52>57>101. In Command window it shows as 101 57 52 75 53 5. And here 101 node is base station.

5 Conclusion

One of the main challenges in the design of routing protocols for WSNs is energy efficiency due to the scarce energy resources of sensors. The ultimate objective behind the routing protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime. The energy consumption of the sensors is dominated by data transmission and reception. Therefore, routing protocols designed for WSNs should be as energy efficient as possible to prolong the lifetime of individual sensors, and hence the network lifetime.

In recent years, the routing protocols in WSNs has become one of the most important research area, and there have been existed a large number of research achievements. This project given the challenges and issues at present in WSNs and also classify the routing protocols into seven categories on the basis of network structure. The majority of the work reported in this project focuses on the design and performance of Efficient, Least Cost, Energy-Aware QoS protocol, which will be the energy efficient and also it has to maintain QoS requirements like bandwidth, end-to-end delay, jitter and energy. How-ever, the Efficient, Least Cost, Energy-aware QoS routing protocols is rarely using in WSNs field. If we use this protocol in WSNs it increase the life time of the network and creates good communication path to sensors.

5.1 Future Work

In recent years, the Wireless Sensor Networks are using Energy-Efficient routing algorithms for maintain the network as long as possible, but not giving more importance on Quality of Service requirements. If we give importance on both (Energy Efficient and QoS Requirement) requirements we can maintain a good communication path in network and we can maintain the network as long as possible.

References

[1] http://en.wikipedia.org/wiki/Wireless_sensor_network
[2] http://en.wikipedia.org/wiki/Sensor_node
[3] Marjan Radi, Behnam Dezfouli, Kamalrulnizam Abu Bakar and Malrey Lee, "Multipath Routing in Wireless Sensor Networks: Survey and Research Challenges", Sensors 2012, January, 2012, pp. 650-685.
[4] Shio Kumar Singh, M P Singh, and D K Singh, "Routing Protocols in Wireless Sensor Networks-A Survey", International Journal of Computer Science & Engineering Survey (IJCSES) Vol.1, No.2, November, 2010, pp. 63-83.
[5] S.K. Singh, M.P. Singh, and D.K. Singh, "A survey of Energy-Efficient Hierarchical Cluster-based Routing in Wireless Sensor Networks", International Journal of Advanced Networking and Application (IJANA), vol. 02, issue 02, Sept.–Oct. 2010, pp. 570–580.
[6] S.K. Singh, M.P. Singh, and D.K. Singh, "Energy-efficient Homogeneous Clustering Algorithm for Wireless Sensor Network", International Journal of Wireless & Mobile Networks (IJWMN), vol. 2, no. 3, Aug. 2010, pp. 49-61.
[7] Jun Zheng and Abbas Jamalipour, "Wireless Sensor Networks: A Networking Perspective", a book published by A John & Sons, Inc, and IEEEE, 2009.
[8] Subhajit Pal, Debnath Bhattacharyya, Geetam S. Tomar, Tai-hoon Kim "Wireless Sensor Networks and its Routing Protocols: A Comparative Study", International Conference on Computational Intelligence and Communication Networks, 2010, pp. 314-319.
[9] Alaauldin Ibrahim, Malik Kemal Sis, Sen Cakir, "Integrated Comparison of Energy Efficient Routing Protocols in Wireless Sensor Network: A survey", IEEE symposium on Business, Engineering and Industrial applications [ISBEIA], Langkawi, Malaysia, 2010, pp. 237-242.
[10] Cosmin Cirstea, "Energy Efficient Routing Protocols for Wireless Sensor Networks: A Survey", IEEE 17th

International Symposium for Design and Technology in Electronic Packaging (SIITME), oct-2011, pp. 277-282.

[11] Deepak Goyal, Malay Ranjan Tripathy, “Routing Protocols in Wireless Sensor Networks: A Survey”, Second International Conference on Advanced Computing & Communication Technologies, 2012, pp. 474-480.

[12] Nikolaos A. Pantazis, Stefanos A. Nikolidakis and Dimitrios D. Vergados, “Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey”, IEEE Communications Surveys & Tutorials, 2012, pp. 1-41.

[13] M. Aslam, N. Javaid, A. Rahim, U. Nazir, A. Bibi, Z. A. Khan, “Survey of Extended LEACH-Based Clustering Routing Protocols for Wireless Sensor Networks”, IEEE 14th International Conference on High Performance Computing and Communications, 2012, pp. 1232-1238

[14] Rachid Ennaji, Mohammed Boulmalf, “Routing in Wireless Sensor Networks”, IEEE, 2009.

[15] Dr.R.Asokan, “A Review of Quality of Service (QoS) Routing Protocols for Mobile Ad hoc Networks”, IEEE ICWCSC, 2010.

[16] I.F. Akyildiz, W. Su*, Y. Sankarasubramaniam, E. Cayirci, “Wireless sensor networks: a survey”, Broadband and Wireless Networking Laboratory, School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA, Received 12 December 2001; accepted 20 December 2001, Published by Elsevier Science B.V. Computer Networks 38 (2002), 2002, pp. 393-422.

Author Profile

Nida Maheen received the B.E degree in Electronics and communication Engineering from Bahubali College of Engineering in 2012 and pursuing M. Tech in Digital Electronics and Communication Systems from Department of P.G. Studies, VTU Regional Office, Mysore in 2014.

Sanath Kumar M T received the B.E degree in Electronics and Communication from Ghousia College of Engineering in 2010 and the M. Tech degree in VLSI from PES College of Engineering in 2012. At present working as a lecturer in Digital Electronics and Communication Systems. Department of P.G. Studies, VTU Regional Office, Mysore

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