Parul* et al.
(IJITR) INTERNATIONAL JOURNAL OF INNOVATIVE TECHNOLOGY AND RESEARCH
Volume No.4, Issue No.3, April – May 2016, 3011 – 3017.

HCPOR-Hierarchical Centralized and Power Optimized Routing Protocol

PARUL
P.G Student,
M.TECH , Electronics and Communication
Department of Electronic & Communication Engineering,
SKITM Engineering College,
Bahadurgarh, Haryana, India

RAVIKANT KAUSHIK
Asst. Professor
Department of Electronic & Communication Engineering,
SKITM Engineering College,
Bahadurgarh, Haryana, India

Abstract - **WSN is a multi-hop ad hoc network of hundreds or thousands of sensor devices. The sensor nodes collect useful information such as sound, temperature, and light. Moreover, they play a role as the router by communicating through wireless channels under battery-constraints.WSN liable monitoring both civil and military applications. WSN routing protocol refers to selecting paths in the network along which data is transmitted. Routing directs forwarding, the passing of packets from their source node toward their ultimate destination node through intermediary sensor nodes. All protocols must be designed in such a way as to minimize energy consumption and preserve. The designed protocol HCPOR is simulated in OMNET++.OMNeT++ is a public-source, component-based, modular and open-architecture simulation environment with strong GUI support and an embeddable simulation kernel. It provides component architecture for models. Components (modules) are programmed in C++, and then assembled into larger components and models using a high-level language (NED).It runs well on LINUX, most other Unix-like systems, Win32 platforms (NT4.0, Window 2000, XP). HCPOR is compared with already developed routing Protocol Low Energy Adaptive Clustering.**

Hierarchy-Centralized (LEACH-C) by the help of MATLAB. A comparison between two is done on the basis of energy dissipation with time and the system lifetime of network. System lifetime is basically for how long the system works.

Keywords- **WSN, HCPOR, LEACH, ADC, SHPER**

I. INTRODUCTION

WSN, a user should be able to task some sensors to monitor specific events, and know when interested events happen in the interested field. Thus, the sensor network builds a bridge between the real world and computation world. Each node typically consists of the five components: sensor unit, analog digital convertor (ADC), central processing unit (CPU), power unit, and communication unit. The sensor unit is responsible for collecting information as the ADC requests, and returning the analog data it sensed. ADC is a translator that tells the CPU what the sensor unit has sensed, and also informs the sensor unit what to do. Communication unit is tasked to receive command or query from, and transmit the data from CPU to the outside world. CPU is the most complex unit. It interprets the command or query to ADC, monitors and controls power if necessary, processes received data, computes the next hop to the sink, etc.

Many Routing protocols are existent in the wireless sensor network. Depending on how the sender of a message gains a route to the receiver, routing protocols can be classified into three categories, namely, proactive [27], [40], reactive [28], [14], and hybrid protocols [13], [15]. In proactive protocols, all routes are computed before they are really needed, while in reactive protocols, routes are computed on demand. Hybrid protocols use a combination of these two ideas. Since sensor nodes are resource poor, and the number of nodes in the network could be very large, sensor nodes cannot afford the storage space for “huge” routing tables. Therefore reactive and hybrid routing protocols are attractive in sensor networks.

According to nodes’ participating style, routing protocols can be classified into three categories, namely, direct communication[29], flat [40], [30]–[41], and clustering protocols [27] [28],[41] In direct communication protocols, a sensor node sends data directly to the sink. Under this protocol, if the diameter of the network is large, the power of sensor nodes will be drained very quickly. Furthermore, as the number of sensor nodes increases, collision becomes a significant factor which defeats the purpose of data transmission. Under flat protocols, all nodes in the network are treated equally. When a node needs to send data, it may find a route consisting of several hops to the sink. Normally, the probability of participating in the data transmission process is higher for the nodes around the sink than those nodes far away from the sink. So, the nodes around the sink could run out of their power soon. In the clustered routing architecture, nodes are grouped into clusters, and a dedicated cluster head node collects, processes, and forwards the data from all the sensor nodes within its cluster. One of the most critical issues in wireless sensor networks is represented by the limited availability of energy on network nodes[4], thus, making good use of energy is necessary to increase network lifetime.

In hierarchical routing architecture, sensor nodes self configures them for the formation of cluster heads. In this thesis, I will design a routing protocol with named Hierarchical Centralized and Power optimized Routing Protocol-HCPOR. This protocol is base station assisted i.e. this protocol utilizes a high-energy base station to set up clusters and routing paths, perform randomized rotation of cluster heads, and carry out other energy-intensive tasks. So, in terms of power it will be highly power efficient. It is centralized since in this protocol, rather than self-configuration, base station is used (that is centralized located in the sensor field). Lastly, the new protocol HCPOR will be compared with BCDCP and LEACH-C.

II. WIRELESS SENSOR NODE

A sensor node is a node in a WSN that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. The typical architecture of the sensor node is shown in Figure 1. The main components of a sensor node as seen from the figure are microcontroller, transceiver, external memory, power source and one or more sensors.

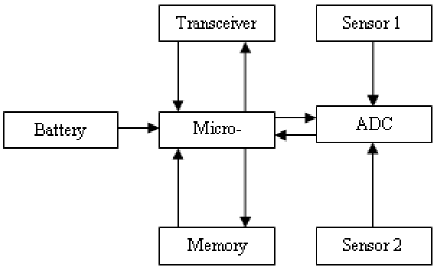

Figure 1 : A typical architecture of the sensor node

Sensor nodes can be deployed in a WSN in two ways:

1. Manual: Location of each sensor node is planned with required level of precision e.g. fire alarm sensors in a building, habitat monitoring, sensors planted underground for precision agriculture.
2. Random: Locations of sensor nodes are random e.g. airdropped in a disaster hit area or war fields.

III. WIRELESS SENSOR NETWORK

WSN consist of many small compact devices, equipped with sensors (e.g. acoustic, seismic or image sensors), that form a wireless network. Each sensor node in the network collects information from its surroundings, and sends it to a base station, either from sensor node to sensor node i.e. multi hop, or directly to a base station i.e. single hop.

A WSN may consist of hundreds or up to thousands of sensor nodes and can be spread out as a mass or placed out one by one. The sensor nodes collaborate with each other over a wireless media to establish a sensing network, i.e. a WSN. Because of the potentially large scale of the WSN, each individual sensor node must be small and of low cost. The availability of low cost sensor nodes has resulted in the development of many other potential application areas, e.g. to monitor large or hostile fields, forests, houses, lakes, oceans, and processes in industries. The sensor network can provide access to information by collecting, processing, analyzing and distributing data from the environment.

In many application areas the WSN must be able to operate for long periods of time, and the energy consumption of both individual sensor nodes and the sensor network as a whole is of primary importance. Thus energy consumption is an important issue for WSN.

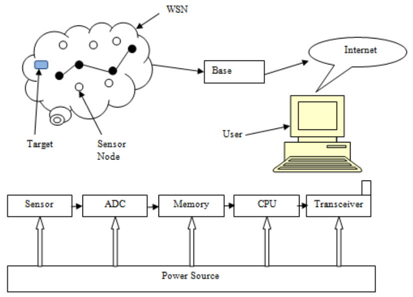

Figure 2: Wireless Sensor Network

IV. ROUTING CHALLENGES IN WSNS

WSNs have several restrictions, such as limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes. One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. The design of routing protocols in WSNs is influenced by many challenging factors. These factors must be overcome before efficient communication can be achieved in WSNs.

In the following, we summarize some of the routing challenges and design issues that affect the routing process in WSNs.

(a) **Node deployment:** Node deployment in WSNs is application-dependent and can be either manual (deterministic) or randomized. In manual deployment, the sensors are manually placed and data is routed through predetermined paths. However, in random node deployment, the sensor nodes are scattered randomly, creating an ad hoc routing infrastructure. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation. Inter-sensor communication is normal within short transmission ranges due to energy and bandwidth limitations. Therefore, it is most likely that a route will consist of multiple wireless hops.

(b) **Energy Consumption:** Sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment. As such, energy-conserving forms of communication and computation are essential. Sensor node lifetime shows a strong dependence on battery lifetime. In a multihop WSN, each node plays a dual role as data sender and data router. The malfunctioning of some sensor nodes due to power failure can cause significant topological changes, and might require rerouting of packets and reorganization of the network.

V. CONCEPT AND THEORY OF PROBLEM

According to nodes' participating style, routing protocols can be classified into three categories, namely, direct communication, flat and clustering protocols. In direct communication protocols, a sensor node sends data directly to the sink. Under this protocol, if the diameter of the network is large, the power of sensor nodes will be drained very quickly. Furthermore, as the number of sensor nodes increases, collision becomes a significant factor which defeats the purpose of data transmission. Under flat protocols, all nodes in the network are treated equally. When a node needs to send data, it may find a route consisting of several hops to the sink. Normally, the probability of participating in the data transmission process is higher for the nodes around the sink than those nodes far away from the sink. So, the nodes around the sink could run out of their power soon. In the clustered routing architecture, nodes are grouped into clusters, and a dedicated cluster head node collects, processes, and forwards the data from all the sensor nodes within its cluster. One of the most critical issues in wireless sensor networks is represented by the limited availability of energy on network nodes thus, making good use of energy is necessary to increase network lifetime.

1) *Energy Aware Routing Protocol:*

This protocol defines three phases:

Setup phase*:* localized flooding occurs to find the routes and create the routing tables. While doing this, the total energy cost is calculated in each node. For instance, if the request is sent from the node N_i to node N_j, N_j calculates the cost of the path as follows:

$$C_{Ni,Nj} = Cost(N_i) + Metric(N_j, N_i) \qquad (1)$$

Here, the energy metric used captures transmission and reception costs along with the residual energy of the nodes. Paths that have a very high cost are discarded. The node selection is done according to closeness to the destination. The node assigns a probability to each of its neighbors in routing forwarding table (FT) corresponding to the formed paths. The probability is inversely proportional to the cost, that is

$$P_{Ni,Nj} = {\frac{1}{C_{Ni,Nj}}} \Big/ {\sum K \varepsilon FT_j \frac{1}{C_{Ni,Nj}}} \qquad (2)$$

Nj then calculates the average cost for reaching the destination using the neighbors in the forwarding table (FTj) using the formula:

$$Cost(N_j) = \sum_{i \varepsilon FT_j} P_{N_i N_j}, C_{N_j N_i} \qquad (3)$$

Data communication phase*:* Each node forwards the packet by randomly choosing a node from its forwarding table using the probabilities.

Route maintenance phase*:* Localized flooding is performed infrequently to keep all paths alive.

The problem with this protocol is two-fold. Firstly, the protocol assumes that the nodes are aware of their location and there is an addressing scheme being used to address the individual nodes. This complicates the initial set up phase for the network using these protocols. Secondly, only a path is used for sending information to the sink. By using this method the protocol would struggle to recuperate from a path failure.

2) Low Energy Adaptive Clustering Hierarchy (LEACH)

Low Energy Adaptive Clustering Hierarchy is one of the first hierarchical routing protocols for sensor network. The conventional clustering technique used in wireless sensor networks does not improve network lifetime since this scheme assumes the cluster heads to be fixed, and thus requires them to be high-energy nodes. Low-Energy Adaptive Clustering Hierarchy (LEACH) that provides a hierarchical protocol that makes the use of local coordination among the nodes to enable scalability and robustness for sensor networks. So, LEACH is an energy conserving communication protocol where all the nodes in the network are uniform and energy constrained. An end user can access the remotely monitored operation, where large numbers of nodes are involved. The nodes organize themselves into local clusters, with one node acting as the randomly selected local cluster head. If the allocated cluster heads are always fixed, then they would die quickly, ending the useful lifetime of all nodes belonging to those clusters. LEACH includes random alternation of the high-energy cluster head nodes to enable the sensors to uniformly sustain the power. Sensors nominate themselves to be local cluster heads at any given time with some probability. These cluster head nodes relay their status to the other sensors in the network. Each sensor node resolves which cluster to follow by choosing the cluster head that requires the minimum communication energy. This allows the transceiver of each unassigned node to be turned off at all times except during it's transmit time, thus minimizing the energy dissipated in each sensor. LEACH divides the operation of the entire network into many rounds. Further, each round has set-up phase or initializing phase and steady state (data transmission) phase. During the set-up phase some sensor nodes project themselves as potential cluster heads and announce their cluster head position to the rest of the nodes in the network, and then other nodes organize themselves into local clusters by choosing the most appropriate cluster head (normally the closest cluster head). During the steady-state phase the cluster heads receive sensed data from cluster members, and then transfer the aggregated data to the BS. In LEACH, The decision of each node to become cluster head is taken based on the suggested percentage of cluster head nodes p. A sensor node chooses a random number, r, between 0 and 1. If this random number is less than a threshold value, T (n), the node becomes a cluster-head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, denoted by G. T (n) is given by:

$$T(n) = \begin{Bmatrix} \dfrac{p}{1 - p*(r \bmod \frac{1}{p})} & if\ n \in G, \\ 0 & \text{otherwise} \end{Bmatrix} \tag{4}$$

Optimal number of cluster heads is estimated to be 5 % of the total number of nodes.

One of the advantages of LEACH is that it is completely distributed. It does not require global knowledge of the network. LEACH increase the lifetime of the network. On the other hand it uses single –hop routing within cluster and not applicable to network in large regions. Dynamic clustering brings extra overhead like advertisements etc.

2) Scaling Hierarchical Power Efficient Routing (SHPER)

A hierarchical scheme used in SHPER protocol in a similar way as in other protocols discussed earlier. However, contrary to other non-centralized routing protocols, the election of the cluster heads is not randomized rather it is based on the residual energy of the nodes. Cluster head selection is done by the base station itself. Base station asks each node to send their residual energy initially. And based on the energy of each node and the predefined percentage of cluster heads, base station selects the cluster head.

The operation of SHPER protocol may be divided in two phases: Initialization phase, and Steady state phase.

(a) **Initialization Phase:** Initially, all the nodes switch on their receivers in order to receive TDMA schedule from the base station. The base station broadcasts TDMA schedule, the size of TDMA schedule depends on the number of the nodes in the network, to all the nodes for collecting the global information about the network topology. Table 1 demonstrates the TDMA schedule. According to this schedule each node advertises itself. Each time that a node advertises itself, the other nodes which hear this advertisement realize their relative distance from this node, according to the received signal strength of the advertisement

Cluster Head ID	Time Slot1	Time Slot2	Time Slot3
00	01	10	11
01	00	10	11
10	00	01	11
11	00	01	10

Table 3: The schedule creation scheme used in SHPER for a cluster with four nodes

After the completion of node advertisement procedure, the base station selects the nodes as cluster head. The total number of cluster heads is predefined. The base station randomly elects some of the nodes as high level cluster head from which it has received an advertisement reply message and some of the nodes as low level cluster head from which it have not received message. The id's of the new elected cluster heads and the values of the thresholds are broadcasted by the base station. These thresholds used in this protocol are similar to the thresholds as described in TEEN and APTEEN. The non-cluster head nodes decide as to which cluster they want to fit in. This assessment is based on the largest signal strength of the advertisement message heard previously. The signal to noise ratio is compared from various cluster heads surrounding the node. The non cluster-head nodes notify the respective cluster-head about the decision to join the cluster. In order to be able to indirectly route its messages to the base station, each lower level cluster head selects the upper level cluster node that it is going to belong to, in order to be able to indirectly route its messages to the base station. This selection is based on the discovery of the path r=(c_1,c_2,…,c_n), between the source cluster head c_1 and the base station c_n that spans n-2 intermediate cluster head nodes c_2,…,c_{n-1}, for which the Routing Index RI(r) shown in equation (2), is the maximum :

$$RI(r) = \sum_{i=2}^{n-1} E_r - \sum (C_i, C_{I+1})$$

After each node has decided to which it has to belong, it informs its cluster head that I will be a member of yours cluster. Each cluster head receives all the messages from the nodes that want to be included in its cluster and according to their number, generates a TDMA schedule of corresponding size as described in Table 1.Each cluster head sends transmission schedule (TDMA) to the nodes that are under its cluster that when to transmit data in order to avoid collision. Each node, during its allocated transmission time, sends to the cluster head quantitative data concerning the sensed events and using the hard and soft threshold values. Along with the data concerning the sensed attributes the node transmits the current value of its residual energy. The radio of each non cluster head node can be turned off until the node's allocated transmission time comes, thus minimizing energy dissipation in these nodes. In this way, each cluster head receives the data from its cluster nodes. Each cluster head aggregates the data it has received along with its own data and makes composite message. This composite message contains the id of the node which has highest residual energy among the cluster nodes, along with the most excessive (e.g. maximum) value of the sensed variable and the id of the corresponding node that has sensed it. Then, during its own time slot, each cluster head transmit its composite message to the base station either directly or indirectly via intermediate upper level cluster heads following the path suggested by the index calculation given in formula 2. The base station collects all the messages that are transmitted to it

Steady State phase: In this phase, by using the data of the received messages, the base station determines the new cluster heads. More precisely, the node which has the highest residual energy, in each cluster, is chosen as a new cluster head and the process continues again as given in the initialization phase. But in each time, the new hard and soft thresholds are defined.

VI. PROPOSED ALGORITHM (Hierarchical Centralized and Power Optimized Routing Protocol-HCPOR)

The foundation of HCPOR lies in the realization that the base station is a high-energy node with a large amount of energy supply. Thus, HCPOR utilizes the base station to control the coordinated sensing task performed by the sensor nodes. In HCPOR the following assumption are to be considered.

- A fixed base station is located far away from the sensor nodes.
- The sensor nodes are energy constrained with a uniform initial energy allocation.
- The nodes are equipped with power control capabilities to vary their transmitted power.
- Each node senses the environment at a fixed rate and always has data to send to the base station.
- All sensor nodes are immobile.

The radio channel is supposed to be symmetrical. Thus, the energy required to transmit a message from a source node to a destination node is the same as the energy required to transmit the same message from the destination node back to the source node for a given SNR (Signal to Noise Ratio). Moreover, it is assumed that the communication environment is contention and error free. Hence, there is no need for retransmission.

Each node has the ability of monitoring its residual energy. The initial energy of nodes is selected to be the same for all nodes and set to 2J. The data packet size of each one of the messages transmitted within the network is set to 100 bits. It is further assumed that E_{elec} = 50nJ/bit and εamp= 100pJ/bit/m2.

The two key elements considered in the design of HCPOR are the sensor nodes and base station. The sensor nodes are geographically grouped into clusters and capable of operating in two basic modes:

- The cluster head mode
- The sensing mode

In the sensing mode, the nodes perform sensing tasks and transmit the sensed data to the cluster head. In cluster head mode, a node gathers data from the other nodes within its cluster, performs data fusion, and routes the data to the base station through other cluster head nodes. The base station in turn performs the key tasks of cluster formation, randomized cluster head selection, and CH-to-CH routing path construction.

HCPOR is a wireless sensor routing protocol with the base station being an essential component with complex computational abilities, thus making the sensor nodes very simple and cost effective. HCPOR operates in two major phases: setup and data communication phase.

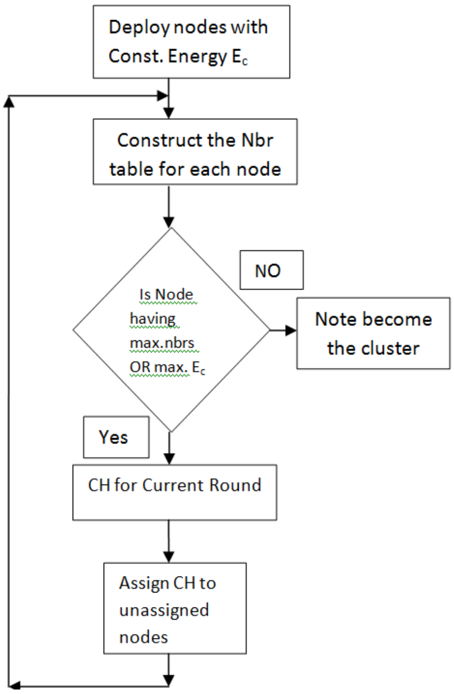

Figure 4: Cluster Head Formation Flow chart

VII. SIMULATION RESULTS

Probably the most important factor is the programming language; almost all network simulation tools are C/C++-based. Performance is a particularly interesting issue with OMNeT++ since the GUI debugging/tracing support involves some extra overhead in the simulation library. However, in a reported case, an OMNeT++ simulation was only 1.3 slower than its counterpart implemented in plain C (i.e. one containing very little administration overhead), which is a very good showing. A similar result was reported in a performance comparison with a PARSEC simulation.

To access the performance of HCPOR, we simulated HCPOR using OMNET++ and MATLAB to compare its performance with other centralized based clustering routing protocol BCDCP and LEACH-C. Performance is measured by quantities matrices of average energy dissipation, system lifetime and number of nodes that are alive. Throughout the simulations we consider network node configuration with 100 nodes where, each node is assigned an initial energy of 2J.

Figure 5 shows the average energy dissipation of the protocols under study over the number of rounds of operation. This plot clearly shows that HCPOR has a much more desirable energy expenditure curve than that of BCDCP and LEACH-C.

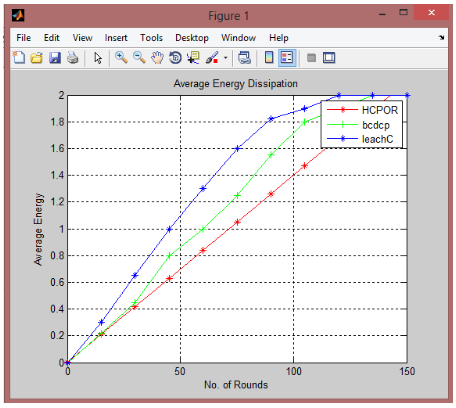

Figure 5: A Comparison of HCPOR's Avg. energy dissipation with other centralized routing protocol LEACH-C and BCDCP.

System Lifetime

The improvement gained through HCPOR is further exemplified by the system lifetime graph in Figure 6. This plot shows the number of nodes that remain alive over the number of rounds of activity for the 100 m × 100 m network scenario. With HCPOR, around 80% of the nodes remain alive for 60 rounds, while the corresponding numbers for BCDCP is70% and for LEACH-C is 55% respectively. And With this, around 44% of the nodes alive for 105 rounds in HCPOR, while the corresponding numbers for BCDCP is 42% and in case of LEACH-C40% node alive. Approximately, All the nodes are dead for LEACH-C and BCDCP after 105 rounds.

Furthermore, If system lifetime is defined as the number of rounds for which 75 percent of the nodes remain alive; HCPOR exceeds the system lifetime of BCDCP and outperforms that of BCDCP by 30 percent.

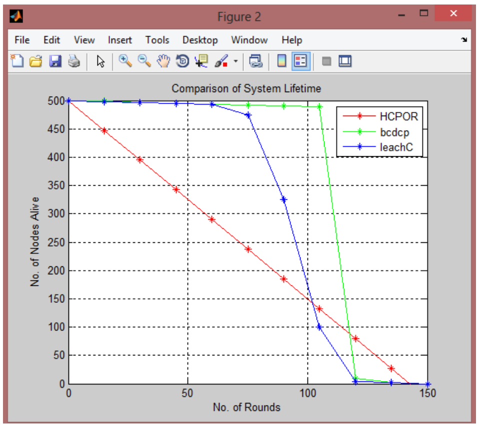

Figure 6: Comparison of HCPOR's System lifetime with other centralized clustering based routing protocol LEACH-C and BCDCP.

VIII. CONCLUSION

A wireless sensor network is a multi-hop ad hoc network of hundreds or thousands of sensor devices. The sensor nodes collect useful information such as sound, temperature, and light. Moreover, they play a role as the router by communicating through wireless channels under battery-constraints. Wireless sensor networks enable there liable monitoring of a variety of environments for both civil and military applications. In wireless sensor networks, the routing protocol refers to selecting paths in the network along which data is transmitted. Routing directs forwarding, the passing of packets from their source node toward their ultimate destination node through intermediary sensor nodes. In this thesis, we look at routing protocols, which can have a significant impact on the overall reliability and energy dissipation of these networks.

WSNs differ from traditional wireless communication networks in several of their characteristics. One of them is power awareness, due to the fact that the batteries of sensor nodes have a restricted lifetime and are difficult to be replaced. Therefore, all protocols must be designed in such a way as to minimize energy consumption and preserve the longevity of the network. That is why, routing protocols in WSNs aim mainly to accomplish power conservation while in traditional networks they focus primarily on the Quality of Service (QoS).

IX. ACKNOWLEDGMENT

The author is grateful to Mr. Ravikant Kaushik sir and co Guide Mr. Gourav Khurana (Asst. Prof. DITM) for enlightening discussions and for help in developing the knowledge for this paper.

X. REFERENCES

[1]. Arslan Munir, Student Member, IEEE, And Ann Gordon-Ross, Member, IEEE, An MDP-Based Dynamic Optimization Methodology For Wireless Sensor Networks ,IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED NETWORKS. VOL 23, NO.24, APRIL 2012.

[2]. Debmalya Bhattacharya And R. Krishna moorthy, Power Optimization In Wireless Sensor Networks, IJCSI, Vol. 8, Issue 5, No. 2, September 2011 .

[3]. Surendra Bilouhan, Prof. Roopam Gupta, Optimization Of Power Consumption In Wireless Sensor Network, International Journal Of Scientific & Engineering Research Volume 2, Issue 5,May 2011.

[4]. By Poojasethi, Navneet verma "Energy Efficient Centralized Hierarchical Routing Protocol For Wireless Sensor Network" In National Workshop-Cum-Conference On Recent Trends In Mathematics And Computing (RTMC) 2011 Proceedings Published In International Journal Of Computer Applications® (IJCA) 15.

[5]. Dionisiskandris, Panagiotistsioumas, Anthony Tzes, Nikolaospantazis, And Limitrios D. Vergados, "Hierarchical Energy Efficient Routing In Wireless Sensor Networks," 16th Mediterranean Conference On Control And Automation Congress Centre, Ajaccio, France June 25- 27, 2008.

[6]. N. A. Pantazis, And D. D. Vergados, "A Survey On Power Control Issues In Wireless Sensor Networks," IEEE Communications Surveys, 4th Quarter, Vol. 9, No. 4, Pp. 86-107, 2007.

[7]. H. Pham, D. Pediaditakis, and A. Boulis.From Simulation To Real Deployments In WSN And Back.In T2pwsn 2007, 2007.

[8]. NS-2 Networking Simulator, Http://Www.Isi.Edu/Nsnam/Ns/, Accessed In January 2007.

[9]. Nikolaos A. Pantazis, Dimitrios J. Vergados, Dimitrios D. Vergados, "Increasing Intelligent Wireless Sensor Networks Survivability By Applying Energy-Efficient Schemes," In Proceedings Of The 3rd IFIP Conference On Artificial Intelligence Innovations & Applications (AIAI 2006), Athens, Greece , June 2006 .

[10]. Siva D. Muruganathan, Daniel C. F. Ma, Rolly I. Bhasin, And Abraham O. Fapojuwo "A Centralized Energy-Efficient Routing Protocol For Wireless Sensor Networks" 0163-6804/05© 2005 Ieee Ieee Radio Communications • March 2005

[11]. K. Akkaya And M. Younis, "A Survey Of Routing Protocols In Wireless Sensor Networks," Elsevier Ad Hoc Network Journal, Vol. 3, No. 3 Pp. 325-349, 2005.

[12]. C.Leuschner, "The Design Of A Simple Energy Efficient Routing Protocol To Improve Wireless Sensor Network Lifetime," Master's Thesis, Electrical, Electronic And Computer Engineering, University Of Retoria, April 2005.[Online].