International Journal of Smart Sensor and Adhoc Network

Volume 2 | Issue 4 Article 16

July 2012

REVIEW ON HIERARCHICAL ROUTING IN WIRELESS SENSOR NETWORKS

ER NEETIKA
Dept. of ECE, BBSBEC, Fatehgarh Sahib, Punjab, India, erneetika1@gmail.com

SIMARPREET KAUR
Dept. of ECE, BBSBEC, Fatehgarh Sahib, Punjab, India, simarpreet.kaur@bbsbec.ac.in

REVIEW ON HIERARCHICAL ROUTING IN WIRELESS SENSOR NETWORKS

NEETIKA[1] & SIMARPREET KAUR[2]

[1,2]Dept. of ECE, BBSBEC, Fatehgarh Sahib, Punjab, India
Email: erneetika1@gmail.com,simarpreet.kaur@bbsbec.ac.in

Abstract:-The Wireless Sensor Network(WSN) has become an interesting field of research of the 21st century. It is a type of the wireless ad-hoc network. This has brought about developing low cost, low-power and multi-function sensor nodes. The network life for wireless sensor network plays an important role in survivability. Energy efficiency is one of the critical concerns for wireless sensor networks. Sensor nodes are strictly constrained in terms of storage, board energy and processing capacity. For these reasons, many new protocols have been proposed for the purpose of data routing in sensor networks. These protocols can be classified into three main categories: data-centric, location-based and hierarchical. This paper mainly deals with some of the major Energy-efficient hierarchical routing protocols for wireless sensor networks. First we will discuss the energy-efficient Hierarchical routing protocols in brief along with their important features, objectives, drawbacks and area of application. Finally, we provide a comparison of these various protocols.

Keyword**—** *Hierarchical clustering, Base Station, Cluster Head, Sensor nodes, Wireless Sensor Networks.*

I. INTRODUCION

In the field of wireless networking there is another form of networking which is called as wireless sensor network. WSN can be viewed as a network consisting of hundreds or thousands of wireless sensor nodes which collect the information from their surrounding environment and send their sensed data to Base Station or sink node[1]. It is also play an important part in civilian technologies like monitoring of traffic control and many others.

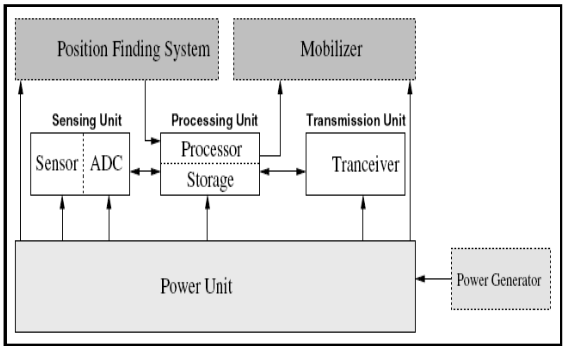

Fig 1. The components of a sensor node

Fig 1. shows the structural view of a sensor network. A typical sensor node consists of the four components: sensor unit, central processing unit (CPU), power unit, and communication unit. They are assigned with different tasks. The sensor unit consists of sensor and ADC (Analog to Digital Converter). 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. Power unit supplies power to sensor unit, processing unit and communication unit. Each node may also consist of the two optional components namely Location finding system and Mobilizer. If the user requires the knowledge of location with high accuracy then the node should pusses Location finding system and Mobilizer may be needed to move sensor nodes when it is required to carry out the assigned tasks. But Sensor network nodes are limited with respect to energy supply, restricted computational capacity and communication bandwidth.

The ideal wireless sensor is networked and scalable, fault tolerance, consume very little power, smart and software programmable, efficient, capable of fast data acquisition, reliable and accurate over long term, cost little to purchase and required no real maintenance.

The basic goals of a WSN are to:

- Determine the value of physical variables at a given location
- Detect the occurrence of events of interest, and estimate parameters of the detected event or events
- Classify a detected object and
- Track an object

Thus, the important requirements of a WSN are:

- Use of a large number of sensors
- Attachment of stationary sensors
- Low energy consumption
- Self organization capability
- Collaborative signal processing and
- Querying ability

II. ROUTING PROTOCOLS USED IN WSN

Routing Protocols in WSNs can be divided into depending on protocol operation WSN can be classified into:

- Multipath-based routing
- Query-based routing
- Negotiation-based routing
- QOS-based routing
- Coherent-based routing

In addition to this, Routing protocols can be classified into three categories depending on how the source finds a route to the destination:

- Proactive
- Reactive
- Hybrid

In proactive protocols, all routes are computed before they are really needed. In reactive protocols, routes are computed on demand.

Hybrid protocols use a combination of these two above protocols.
Routing Protocols can also be divided depending on the network structure:

- Flat-based routing
- Hierarchical-based routing and
- Location-based routing

In flat-based routing, all nodes are typically assigned equal roles or functionality.
In hierarchical-based routing, nodes will play different roles in the network.
In location-based routing, sensor nodes positions are exploited to route data in the network.

III. ENERGY EFFICIENT HIERARCHICAL ROUTING

Among the issues in WSN the consumption of energy is one of the most important issues. Hierarchical routing protocols are found to be more energy efficient than other protocols. By the use of a clustering technique they minimize the consumption of energy greatly in collecting and disseminating data. Hierarchical routing protocols minimize energy consumption by dividing nodes into clusters. In each cluster, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency, reduces the size of the routing table by localizing the route setup within the cluster, conserves communication bandwidth. A variety of protocols have been proposed for prolonging the lifetime of WSN. Some of the hierarchical protocols are LEACH, PEGASIS, TEEN, APTEEN. Fig 2. shows architectural view of Hierarchical Routing.

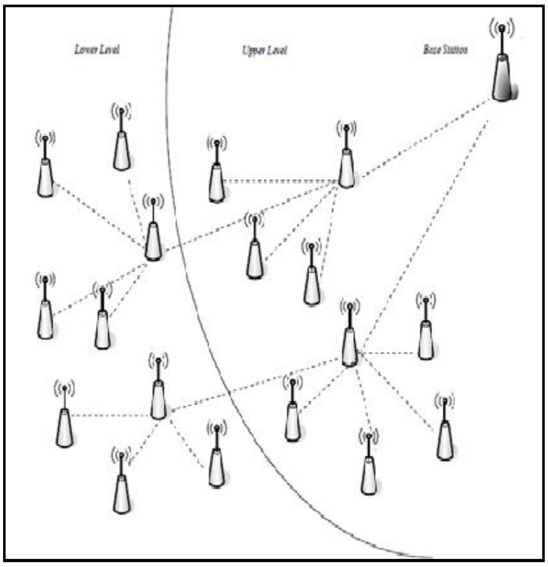

Fig 2. Hierarchical Routing

A. *Low-energy adaptive clustering hierarchy (LEACH)*

Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular distributed cluster-based routing protocols in wireless sensor networks [2]. LEACH, which was presented by Heinzelman in 2000[[3],[4]].It is a routing algorithm designed to collect and deliver data to the data sink, typically a base station.

Objectives of LEACH Protocol:

- Extension of the network lifetime.
- Reduced energy consumption by each network sensor node[5].
- Use of data aggregation to reduce the number of communication messages.

To achieve these objectives, LEACH adopts a hierarchical approach to organize the network into a set of clusters. Each cluster is managed by a selected cluster head. The cluster head assumes the responsibility to carry out multiple tasks.

The first task consists of periodic collection of data from the members of the cluster. Upon gathering the data, the cluster head aggregates it in an effort to remove redundancy among correlated values .

The second main task of a cluster head is to transmit the aggregated data directly to the base station. The transmission of the aggregated data is achieved over a single hop. The network model used by LEACH is depicted in Fig3.

The third main task of the cluster head is to create a TDMA-based schedule whereby each node of the cluster is assigned a time slot that it can use for transmission. The cluster head advertises the schedule to its cluster members through broadcasting.

To reduce the likelihood of collisions among sensors within and outside the cluster, LEACH nodes use a code-division multiple access–based scheme for communication.

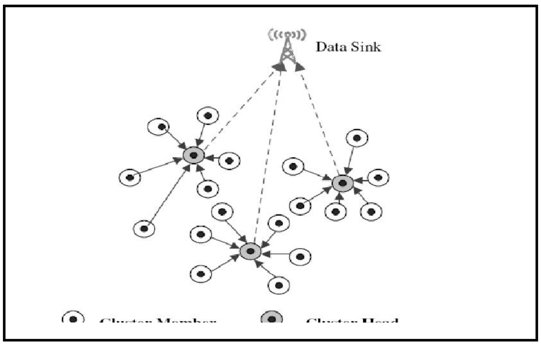

Fig 3. Clustering in LEACH Protocol

The basic operations of LEACH are organized in two distinct phases. These phases are illustrated in Fig4.The first phase, the setup phase, consists of two steps, cluster-head selection and cluster formation. The second phase, the steady-state phase, focuses on data collection, aggregation, and delivery to the base station.

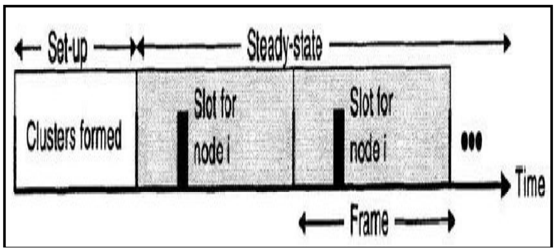

Fig 4. LEACH phase

The duration of the setup is assumed to be relatively shorter than the steady-state phase to minimize the protocol overhead. At the beginning of the setup phase, a round of cluster-head selection starts. The cluster-head selection process ensures that this role rotates among sensor nodes, thereby distributing energy consumption evenly across all network nodes. To determine if it is its turn to become a cluster head, a node, n, generates a random number v, between 0 and 1 and compares it to the cluster-head selection threshold, T(n). The node becomes a cluster head if its generated value, v, is less than T(n). The cluster-head selection threshold is designed to ensure with high probability that a predetermined fraction of nodes, P, is elected cluster heads at each round. Further the threshold ensures that nodes which served in the last 1=P rounds are not selected in the current round. To meet these requirements, the threshold T(n) of a competing node n can be expressed as follows:

$$T(n) = \begin{cases} 0 & \text{if } n \notin G \\ \dfrac{P}{1 - P(r \bmod (1/P))} & \forall n \in G \end{cases}$$

The variable G represents the set of nodes that have not been selected to become cluster heads in the last 1/P rounds and r denotes the current round. The predefined parameter, P, represents the cluster-head probability. It is clear that if a node has served as a cluster head in the last 1/P rounds, it will not be elected in this round At the completion of the cluster-head selection process, every node that was selected to become a cluster head advertises its new role to the rest of the network. Upon receiving the cluster-head advertisements, each remaining node selects a cluster to join. The selection criteria may be based on the received signal strength, among other factors. The nodes then inform their selected cluster head of their desire to become a member of the cluster. Upon cluster formation, each cluster head creates and distributes the TDMA schedule, which specifies the time slots allocated for each member of the cluster. Each cluster head also selects a CDMA code, which is then distributed to all members of its cluster. The code is selected carefully so as to reduce inter-cluster interference.

Drawbacks of LEACH protocol:

- Dynamic clustering causes extra overhead(Head changes, Advertisements etc.) which may decrease the gain in energy consumption.
- The protocol assumes that all nodes will have same amount of initial energy capacity in each election round, assuming that being a CH consumes approximately the same amount of energy for each node

Applications of LEACH protocol are Fault detection and diagnosis.

B. Power-Efficient Gathering in Sensor Information Systems(PEGASIS)

PEGASIS [6] is chain-based protocol. PEGASIS outperforms LEACH protocol . The basic idea of the protocol as shown in fig.(4) is that nodes need only communicate with their closest neighbors, and they take turns in communicating with the BS, only one node transmits to BS. Thus, the data is gathered and moves from node to node, aggregated and eventually sent to the base station.

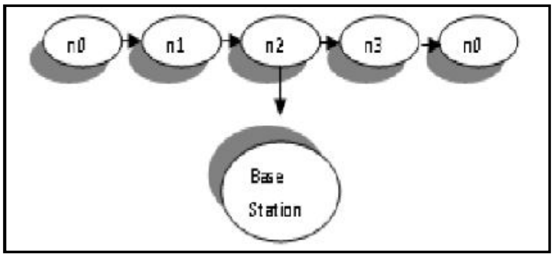

Fig 5 Chain based PEGASIS

The chain construction is performed in a greedy way. To locate the closest neighbor node in PEGASIS, each node uses the signal strength to measure the distance to all neighboring nodes and then adjusts the signal strength so that only one node can be heard.

Assumptions of PEGASIS protocol:

- PEGASIS assumes that all sensor nodes have the same level of energy and are likely to die at the same time.
- (All nodes have global knowledge of network.

Unlike LEACH, PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the BS (sink) instead of using multiple nodes. A sensor transmits to its local neighbors in the data fusion phase instead of sending directly to its CH as in the case of LEACH.

Objectives of PEGASIS protocol:

- To increase the lifetime of each node by using collaborative techniques and to allow only local coordination between nodes are close together so that the bandwidth consumed in communication is reduced.
- PEGASIS reduces the overhead caused by dynamic cluster formation in LEACH i.e. decreasing the number of transmissions and reception by using data aggregation.

Drawbacks of PEGASIS protocol:

- PEGASIS introduces excessive delay for distant node on the chain
- The single leader can become a bottleneck

C. Hierarchical PEGASIS(H-PEGASIS)

An extension to PEGASIS, called Hierarchical-PEGASIS was introduced in [7] with the objective of decreasing the delay incurred for packets during transmission to the BS. H-PEGASIS proposes a solution to the data gathering problem by considering energy × delay metric. In order to reduce the delay in PEGASIS, simultaneous transmissions of data messages are pursued.

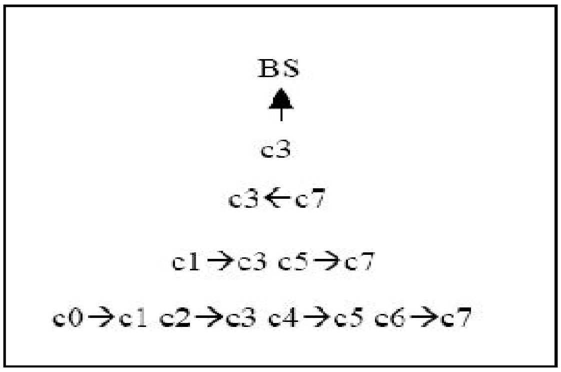

Fig 6.Hierarchical PEGASIS

To avoid collisions and possible signal interference among the sensors, two approaches have been investigated .The first approach incorporates signal coding, e.g. CDMA. In the second approach only spatially separated nodes are allowed to transmit at the same time. The chain-based protocol with CDMA capable nodes, constructs a chain of nodes, that forms a tree like hierarchy, and each selected node in a particular level transmits data to the node in the upper level of the hierarchy.

Features of H-PEGASIS protocol:

- This method ensures data transmitting in parallel and reduces the delay significantly
- Such hierarchical extension has been shown to perform better than the regular PEGASIS scheme by a factor of about 60

Applications of H-PEGASIS routing protocol are surveillance such as motion detection etc.

D. Threshold-Sensitive Energy Efficient Sensor Network Protocol (TEEN)

TEEN [8],[9 is a hierarchical clustering protocol and data-centric protocols. (TEEN) is designed to be responsive to sudden changes in temperature. The sensor network architecture is mainly based on a hierarchical grouping in which closer nodes will form clusters and this process goes on the second level until base station (sink) is reached.

The cluster head broadcasts two thresholds namely hard and soft thresholds to the nodes after the clusters are formed. Hard threshold is the minimum threshold used to trigger a sensor node to switch on its transmitter and transmit the cluster head. Thus, the hard threshold will perform transmission only when the sensed attribute is in the required range and reduces the number of transmissions. On the other hand, in soft threshold mode, any small change in the value of the sensed attribute is transmitted. The nodes sense their environment continuously and store the sensed value for transmission. The time line for TEEN is as shown in fig.(7).

Thereafter the node transmits the sensed value if one of the following conditions satisfied:

- Sensed value > hard threshold (HT).
- Sensed value ~ hard threshold >= soft threshold (ST)

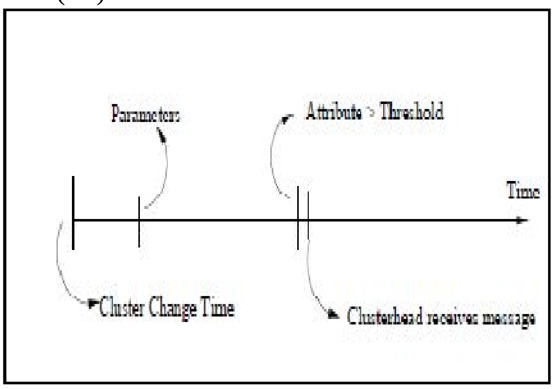

Fig 7.Time Line for TEEN

The hard and soft threshold values can be adjusted to control the number of packet transmissions. Since the user may not get any data at all if the thresholds are not reached.

TEEN is best suited for time critical applications where the users can control a trade-off between energy efficiency, data accuracy, and response time dynamically.

Features of TEEN *protocol:*

- Suitability for time critical sensing applications and data reaches the user almost instantaneously
- Since message transmission consumes more energy than data sensing, so the energy consumption in this scheme is less than the proactive networks
- At every cluster change time, the attributes are broadcast afresh and so, the user can change them as required

Drawbacks of TEEN protocol:

- A node may wait for their time slot for data transmission. time slot may be wasted if a node has no data for transmission
- Cluster heads always wait for data from nodes by keeping its transmitter on

Applications of *TEEN* protocol are Intrusion detection, explosion detection etc.

E. Adaptive Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN)

The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN)[10][11]is an extension to TEEN and it uses same architecture as TEEN. It aims at both reacting to time critical events and capturing periodic data collections. The architecture of APTEEN is same as in TEEN, which uses the concept hierarchical clustering for energy efficient communication between source sensors and the sink. When the base station forms the clusters, the cluster heads will broadcast the attributes and the transmission will be scheduled to all nodes. Cluster heads will also perform data aggregation in order to save energy. APTEEN supports three different query types: historical, to analyze past data; and persistent to monitor an event for a period of time and one-time, to take a snapshot view of the network. The time line for APTEEN is as shown in fig. (8).

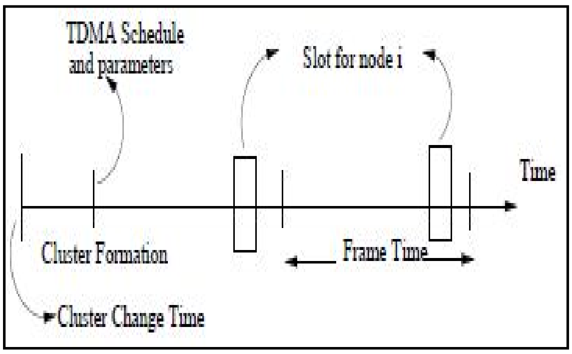

Fig 8.Time line for APTEEN

Features of APTEEN protocol:

- APTEEN combines both proactive and reactive [12]policies.
- APTEEN guarantees lower energy dissipation and a larger number of sensor alive

Drawbacks of APTEEN protocol:

- Overhead and complexity of forming clusters in multiple levels
- Implementing threshold based functions
- Dealing with attribute-based naming of queries.

Applications of *APTEEN protocol* are habitat monitoring for example animal monitoring in the forest etc.

IV. COMPARISON OF ROUTING ROTOCOLS

Table1. Gives comparison of various above mentioned power efficient routing protocols for wireless sensor networks. In LEACH the first node death will occur 8 times later than the conventional methods and hence the network lifetime will increase considerably. PEGASIS increases network lifetime two-fold[13]compared to the LEACH protocol. The performance of APTEEN lies between TEEN and LEACH with respect to energy consumption and lifetime of the network.

TABLE 1.
COMPARISON OF DIFFERENT HIERARCHICAL ROUTING PROTOCOL

Routing protocol	**LEACH**	**PEGASIS/ H-PEGASIS**	**TEEN**	**APTEEN**
Network type	Proactive	Reactive	Reactive	Reactive
Mobility	Fixed BS	Fixed BS	Fixed BS	Fixed BS
Power required	High for BS	Max	High for BS	High for BS
Overhead	High	Low	High	High
Data aggregated	At cluster head	No	At cluster head	At cluster head
Cluster formed	Distributed	N/A	Distributed	Distributed
CH selection	Random	N/A	Attribute based	Attribute based

Cluster stability	Moderate	N/A	High	High

V. CONCLUSION AND FUTURE WORK

The energy efficiency is one of the main design challenges of protocols for WSNs due to the limited energy resources of sensors. The surveyed and summarized recent research works focus mainly on the energy efficient hierarchical cluster-based routing protocols for WSNs. They have the common objective of trying to extend the lifetime of the sensor network, while not compromising data delivery. All above mentioned protocols have some advantages and some limitations .This paper has covered only few sample of routing protocols ,since this is a vast area under research. So we can select an effective protocol, depending up on the network, applications and other conditions.

Further research would be needed to address issues related to Quality of Service (QOS) though the performance of the protocols discussed here is promising in terms of energy efficiency. The protocol like LEACH, TEEN, APTEEN and PEGASIS are showed to be energy efficient than its previous models but the main drawbacks in these protocols are that nodes are assumed to be stationary and static. Future works will focus mainly on achieving better energy efficiency in routing mechanism for mobile wireless sensor nodes.

ACKNOWLEDGMENTS

We are grateful to Mr. Pardeep Goyal who remained a constant source of strength and inspiration throughout our research work. We are also thankful to the Almighty for blessing us to complete this work successfully.

REFERENCES

[1] Sarjoun S. Doumit, Dharma P. Agrawal: *Self-Organizing and Energy-Efficient Network of Sensors*,IEEE, pp. 1-6 (2002).

[2] Wei D., Kaplan S., and Chan H., "*Energy Efficient Clustering Algorithms for Wireless Sensor Networks*," in Proceedings of IEEE Communications Society (ICC'2008), Beijing, pp. 236-240, 2008.

[3] W.R.Heinzelman, *Energy-efficient communication protocol for Wireless microsensor networks*, In: Proc. of 33rd Annual Hawaii Inter Cord on System Sciences, Hawaii, USA: IEEE Computer Society, 2000.

[4] Heinzelman W. B., Chandrakasan A. P., and H.Balakrishnan *"An Application-specific Protocol Architecture for Wireless Micro sensor Networks*", IEEE Trans. on Wireless Communications, 2002, pp.660-670.

[5] Neetika , Simarpreet Kaur, *Optimizing Energy and Improving Lifetime of Cluster Based Heterogeneous Protocol in Wireless Sensor Network.* International Research Journal of Computer Science Engineering and Applications Vol 1 Issue 3 December 2012,ISSN 2319-8672

[6] S. Lindsey and C.S. Raghavendra, PEGASIS: *Power efficient Gathering in Sensor Information System*., Proceedings IEEE Aerospace Conference, vol. 3, Big Sky, MT, Mar. 2002, pp. 1125-1130.

[7] S. Lindsey, C. S. Raghavendra and K. Sivalingam, *"Data Gathering in Sensor Networks using the Energy*Delay Metric*", in the Proceedings of the IPDPS Workshop on Issues in Wireless Networks and Mobile Computing, San Francisco, CA, April 2001.

[8] A. Manjeshwar and D. P. Agrawal, .TEEN: *A Protocol for Enhanced Efficiency in Wireless Sensor Networks*., in the Proceedings of the 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, San Francisco, CA, April 2001.

[9] W. Lou, *.An Efficient N-to-1 Multipath Routing Protocol in Wireless Sensor Networks*., Proceedings of IEEE MASS'05, Washington DC, Nov. 2005, pp. 1-8.

[10] J. Al-Karaki, and A. Kamal, *Routing Techniques in Wireless Sensor Networks: A Survey*, IEEE Communications Magazine, vol. 11, no. 6, Dec. 2004,pp. 6-28.

[11] A. Manjeshwar and D. P. Agrawal, APTEEN: *A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks*, 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Net- works and Mobile Computing, 2002,195-202.

[12] Sanjay W aware, Dr. Nisha Sarwade , Pallavi Gangurde, *A Review of Power Efficient Hierarchical Routing Protocols in Wireless Sensor Networks*, International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 2, Issue 2,Mar-Apr 2012, pp.1096-1102,p-1096

[13] Vivek Katiyar, Narottam Chand and Surender Soni, *A survey on clustering algorithms for Heterogeneous wireless sensor network*, Advanced Networking and Applications,vol:02,issue:04 pages:745-754,08 NOV,2010.

◈◈◈