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Survey on Energy Consumption Models In Wireless Sensor Network

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***Abstract*—The wireless sensor network is one of the most interesting research areas, having great impact on technological development. This paper focuses on survey of various energy efficient approaches. During the recent years many energy efficient approaches are proposed in the area of Wireless Sensor Network. For further researches, understanding of these approaches is essential.**

Keywords*— *Wireless Sensor Networks, clustering, Cluster Head, Routing, Nodes, Sink.

I. INTRODUCTION

Many future applications will increasingly depend on wireless sensor networks. A sensor network consists of numerous sensor/actuator devices. Wireless Sensor Networks is an emerging technology. In the near future, the wireless sensor networks are expected to consist of several numbers of inexpensive nodes, each of them having sensing capability with limited computational and communication power, which enable us to deploy a large-scale sensor network. A critical aspect of in wireless sensor network is network lifetime. The nodes in Wireless sensor networks are with limited energy capabilities. Wireless sensor network are usable as long as they can sense and communicate data to other nodes. Sensing and communication are the major processes which consume energy. So power management and sensor scheduling can effectively increase the networks lifetime. The use of wireless sensor networks is increasing day by day and at the same time it faces the problem of energy constraints in terms of limited battery lifetime.

Wireless Sensor Network has several technical challenges in data processing and wireless communication to deal with dynamically changing Energy, Processing power and Bandwidth. Another important issue in Wireless Sensor Network is to maximize Sensor Network lifetime. In order to achieve this, it is necessary to minimize the energy utilization of a node. Energy consumption in wireless sensor node is attributed to transmitting/receiving, processing, and forwarding the data to neighboring nodes.

Generally, the factors that affect the wireless communications can be categorized into three types:

1. Radio frequency interference that could occur almost anytime and anywhere
2. Network change that is either predictable as a result of planned adjustment or unpredictable due to the node failure.
3. Environmental effects that affect the wireless channel condition [1].

This paper considers such issues and describes the methods to improve network lifetime through reducing energy consumption.

II. ARCHITECTURAL DESCRIPTION OF WSN

This section covers the details regarding the architectural description of WSN.

A. *Overview of WSN*

A sensor node is actually a tiny device which is capable of sensing and communicating with other nodes. Sensor node has a microcontroller which processes data and controls the functionality of other components, the processing module mainly constitute them. Wireless communication module mainly having transceiver which generally uses radio waves for communication.

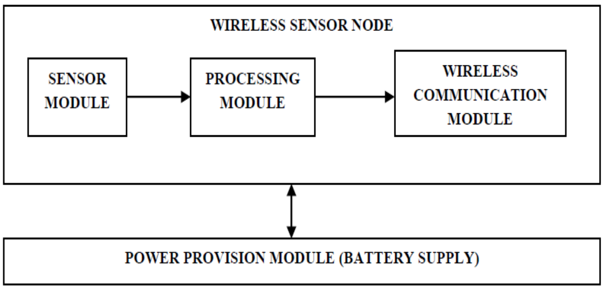

Fig.1.The architecture of a sensor node

There will be an external memory which assists in processing of data. Wireless components are equipped with an external power supply. . Power is stored either in batteries or capacitors. Batteries can be both rechargeable and non-rechargeable.

Generally, transceivers operating in idle mode have a power consumption almost equal to the power consumed in receive mode. When transceiver is not transmitting or receiving, then it is better to completely shut down the transceiver rather than leave it in the idle mode. There will be a significant amount of power consumption, when switching from sleep mode to transmit mode in order to transmit a packet.

B. Clustering Approach

Hierarchical routing methods such as clustering will be shown to improve the network life time. Clustering is a method of grouping of sensor nodes. The clustering techniques typically consider several parameters, such as the distance between the nodes, and assume that nodes are more reliable.

The cluster nodes or members are capable of sensing the data from the environment where they are deployed processes the data and transmit it to the base-station. In clustering, nodes with higher power levels that are cluster heads perform the fusion of data gathered from the other sensor nodes and transmit the aggregated data to the base-station while the nodes with low power levels only perform the sensing of the environment. They transmit the sensed data to the higher level node, known as the cluster-heads (CHs) which are at a lesser distance to the base station (BS). The cluster formation phase and the assignment of special tasks to the cluster heads (CHs) reduce the power dissipation within a particular cluster. By aggregating the sensed data by cluster heads, the amount of data to be transmitted to the base-station (BS) is reduced and the lifetime of the sensor network is increased.

The major challenges of clustering are;

1. Real time operation
2. Cost of clustering
3. Data aggregation
4. Selection of CHs
5. Synchronization and maintenance

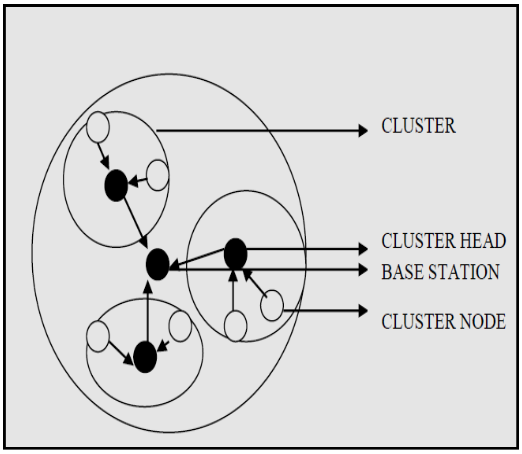

Fig.2. Clustering In WSN

III. RELATED WORKS

The energy efficiency of the sensors directly affects the lifetime of the network. There is several numbers of surveys in the literature on energy efficient models in WSNs and an attempt is made to present below and discuss the existing differences between them.

Paper [1] proposes an idea of transmit-only nodes because of receiver module takes more energy than the transmitter. Paper [2] proposes the detailed idea of clustering and selection of CHs .This paper has a comparison with LEACH protocol, which is one of the basic protocol used in clustering. In [3], which is a thesis considers the radio energy model and describes a real time scenario of motes. Paper [4] proposes the idea of local monitoring using combined approaches such as on-demand sleep-wake scheduling and guard scheduling methods.

Paper [5] proposes the idea of hot spot which is one of the efficient models. In [6] authors present the survey of energy efficient routing models. Paper [7] proposes a protocol called Y-MAC addresses a multi-channel energy efficient approach for wireless sensor networks. In [8] the authors propose a prediction technique for data collection. It determines which data will be send to the other node rather than sending all the sensed data, thus by it reduces the energy consumption. Paper [9] deals with communication synchronization in an efficient manner through relay nodes.

In [10] authors address the approach of zone division in an energy efficient manner which results in a hierarchical routing structure. Papers [11] and [12] propose the data aggregation method for reducing the energy consumption. In [12] authors describes about joint scheduling of tasks. Paper [13] proposes a probabilistic approach for energy consumption reduction. In [14] authors propose a classic energy consumption model known as Radio-energy model. Paper [17] is a useful survey paper regarding the clustering protocols.

IV. ENERGY EFFICIENT MODELS

A. Energy Consumption Models For Sensor Nodes

More up to date approach regarding the energy consumption of the WSN nodes is presented in [6]. Energy consumption of the wireless sensor nodes based on Fig.1 depends on its components and is summarized as;

1) Sensor Module: The energy consumption of this module will be,

$$E_{sensor}=E_{on\text{-}off}+E_{off\text{-}on}+E_{sensor\text{-}run} \quad (1)$$

$E_{on\text{-}off}$ is the one time energy consumption of closing sensor operation, $E_{off\text{-}on}$ is the one time energy consumption of opening sensor operation and $E_{sensor\text{-}run}$ is the energy consumption of sensing operation that is equal to the the working voltage multiplied by the current of sensors and the time interval of sensing operation.

2) Processing Module: The main activities of this module are the sensor controlling, protocol communication and processing of data. The energy consumption of the Processor $E_{cpu,}$ is the sum of the state energy consumption $E_{cpu\text{-}state}$ and the state-transition energy consumption $E_{cpu\text{-}change,}$ where i=1,2,..m is the processor operation state and m is the number of the processor state, j=1,2,..n, is the is the type of state transition and n is the number of the state-transition changes the default, adjust the template as follows;

$$E_{cpu\text{-}state}+E_{cpu\text{-}change} \quad (2)$$

3) Wireless Communication Module: The total power consumption for transmitting P_T and for receiving it will be denoted as P_R, is denoted as;

$$P_T = P_{TB}+P_{TRF}+P_A(d) \quad (3)$$

Where P_A (d) is the power consumption of the power amplifier which is a function of the transmission range d.

B. Transmit-only Nodes

Authors in [2] propose the concept of transmit-only nodes. The receiver module of a transceiver is more costly and consumes more energy than the transmitter. Transmit-only sensor nodes will be deployed for low-priority monitoring tasks, along with a certain number of standard sensor nodes for high-priority tasks. Even though a facility may be covered by multiple dedicated data sinks, there are cases when a single sink will have to handle a large number of high-priority and low-priority nodes at the same time giving rise to the need to consider efficient and reliable management for this type of systems. It is one of the better energy efficient models because we can reduce the energy consumption drastically for monitoring low priority tasks [2].

C. *Power Efficient Clustering Protocol*

In these method researchers considers the heterogeneity of sensor nodes. Here energy efficiency is achieved by limiting the number of connections that a CH should have. The energy consumed in transmitting one message of size k bits over a transmission distance d, will be,

$$E_{Tx}(k, d) = k(E_{elec} + \Delta_{AMP}\, d) = Eelec\, k + k\, \Delta_{AMP} d \qquad (4)$$

Where,

k=length of message

d=transmission distance between transmitter & receiver

Eelec= electronic energy

ΔAMP =transmitter amplifier

Δ = Path Loss (2<= Δ <=4)

Also, the energy consumed in the message reception is given by;

$$Erx = Eelec\ k \qquad (5)$$

If a node is declared as a cluster head, then following process is followed to associate the node to cluster head:

1. The node declared as CH will send the JOIN message to other nodes which are in its neighboring zone.
2. The node receives the JOIN request and examines it on the basis of signal strength. According to general radio energy model for wireless sensor networks the signal strength depends on the distance means if signal comes from the more distance has the less strength and vice-versa.
3. A node will selected as the cluster head, which has minimum distance measure from node.
4. Node sends a message for joining the cluster as cluster member.

Here, they reduce the number of communication between the sensor nodes for cluster head selection so that the energy consumption for cluster head selection can be further reduce. This increases the residual energy of the cluster head and the network survivability can be enhanced.

D. *Mica2 Specific Model*

In [3] author presented the total energy consumption for Mica2 as the summation of energy transmitting, listening, receiving, sampling data and sleeping. One can calculate energy in transmitting and receiving one bit, as:

$$Energy = Current * Voltage * Time \qquad (6)$$

Where current is in Amperes, Voltage is in Volts and Time is in seconds. The paper also proposes the model based on duty cycle .In which 50% duty cycle is provided for the deployed nodes. So from total of 3600sec the radio will be off for 1800sec.Remaining seconds will be for transmission and reception 88.75% of the seconds used by radio in ON mode without transmission, 11.25% is for transmission. Then the energy consumption will be,

$$E_{CONSUM} = E_{radio\text{-}off} + E_{radio\text{-}on} + E_{transmission} \qquad (7)$$

Where $E_{radio\text{-}off}$ is the energy consumption during radio off, $E_{radio\text{-}on}$ is the energy consumption during radio on but is in listening mode and $E_{transmission}$ is the energy consumption during radio on but is in transmitting mode [3].

E. *Energy Aware Local Monitoring*

Many security schemes are developed for WSN, one of the major one is ELMO. It is a new technique that promises to allow operation of WSN in a manner that is energy efficient and secure. ELMO consists of a set of mechanisms that significantly reduce the node-wake-time required for monitoring. The paper proposed a mechanism that uses passive wake-up antennas, known as radio-triggered power management mechanisms. In this mechanism a special hardware component, a radio-triggered circuit is connected to one of the interrupt inputs of the processor. Here the circuit itself does not draw any current and thus it is passive. The node can enter sleep mode without periodic wake-up. The wake-up mode is a usual working mode with all the functional units ready to work, then the average wake-up mode current is 20 mA. In sleep mode, a node shuts down all its components except the memory, interrupt handler, and the timer. The sleep mode current is 100A. When a network node changes from sleep mode to wake-up mode, there is a surge current of 30 mA for a maximum of 5 ms. when a power management message is sent by another node within a certain distance, then radio-triggered circuit collects enough energy to trigger the interrupt to wake up the node [4].

F. *Energy-Efficient Multi-Channel MAC Protocol*

In the paper [7], they proposed an energy efficient multichannel MAC protocol, Y-MAC, for WSNs. Their goal is to achieve both high performance and energy efficiency under diverse traffic conditions. Y-MAC is a TDMA-based multi-channel MAC protocol. In general, TDMA-based MAC protocols allocate a time slot to each node in the network. A light-weight channel hopping mechanism. Y-MAC avoids redundant channel assignment by not allocating fixed channels to the nodes. Initially, messages are exchanged on the base channel. When a traffic burst occurs, a receiver and potential senders hop to one of the other available channels, according to the hopping sequence. Since these messages are carried over additional channels, each node is guaranteed to receive at least one message on the base channel [7]. This reduces energy consumption drastically.

G. *Energy Efficient Zone Division*

A hierarchical routing method generally shows higher performance rates. Hierarchical routing comprises the formation of clusters which nodes are assigned to the specialized task of sensing which have low energy. This algorithm makes the best use of node with low number of cluster head know as super node. We divided the full region in four equal zones. The center area of the region is used to select for super node. Zones are considered separately. Zones are either divided or not depending upon the density of nodes in that zone and capability of the super node. This mechanism follows multilayer communication pattern. The number of layers depends on the network current load and statistics. This algorithm is used to generate a hierarchy of cluster heads to obtain better network management and energy efficiency [10].

H. Energy Conservation by Cluster Based Data Aggregation

In this paper they propose an Energy efficient Cluster Based Data Aggregation (ECBDA) scheme for sensor networks. Cluster members send the sensed data only to its corresponding cluster head. So, communication overhead is reduced. The data generated by the neighboring sensors are redundant and highly correlated in nature. So the cluster heads perform data aggregation to reduce the redundant packet transmission. By this approach, clusters are formed in a non-periodic fashion to avoid unnecessary transmission of setup message. Here, re-clustering is performed only when CH needs to balance the load among the nodes. Data aggregation is one of the major concepts that reduce the energy consumption of wireless sensor network. The simulation results show that this approach effectively reduces the energy consumption and the network lifetime is also increased [11].

I. Joint Scheduling of Tasks and Messages for Energy Minimization

This paper proposed the problem of joint scheduling of tasks and messages for energy minimization. Computation and communication subsystems dissipate bulk of energy in a sensor node. Recent researchers study the problem of system-wide energy management by distribution of unused time slots (slack) amongst the computation and communication subsystems using energy saving techniques like Dynamic Voltage Scaling (DVS) and Dynamic Modulation Scaling (DMS). The DVS technique saves computation energy by simultaneously reducing CPU supply voltage and frequency. The DMS technique saves communication energy by reducing the radio modulation level. In DVS, energy is always a monotonically decreasing function of delay but this is not true in the case of DMS.

The energy consumed by the radio of a wireless device is made up of two components: the transmission energy and the circuit consumption energy. The transmission energy is a function of several variables like the transmitter-receiver distance, transmission time, channel gain and atmospheric noise. The circuit consumption energy on the other hand is a linear function of the time the transmitter and receiver circuit need to be on.

The total energy expended by the communication subsystem can be mainly divided into two components: the signal transmission energy, E_{tx} and the circuit consumption energy, $E_{ckt.}$ The circuit consumption energy at the transmitter and receiver can further be categorized as the sum of energy consumption of various circuit blocks like power amplifiers, frequency synthesizers, Analog to Digital Converter, Digital to Analog converter, mixers and low noise amplifiers etc. Specifically, it can be divided into the energy consumed by the power amplifiers, Eamp; energy spent in the mode transitions (active to sleep and sleep to active), Etr and the energy consumption by the rest of the blocks can be combined as transmitter and receiver circuit consumption energy Ec. While E_{amp} and E_c are functions of the transmission time, Etr is the constant energy consumption in the transient mode. This is mainly dominated by the frequency synthesizers and is independent of the packet size or the transmission time [12]. Energy consumption by the power amplifier is given by,

$$\text{Eamp} = \alpha \text{ Etx} \tag{8}$$

Where α is dependent on the modulation scheme and the associated constellation size. Thus the energy expended in transmitting a packet of L bits can be given as:

$$E_L = \text{Etx} + \text{Eamp} + \text{Ec} + \text{Etr} \tag{9}$$

J. Classic Energy Consumption Model

In paper [14] proposes the most basic energy model as shown in following figure.

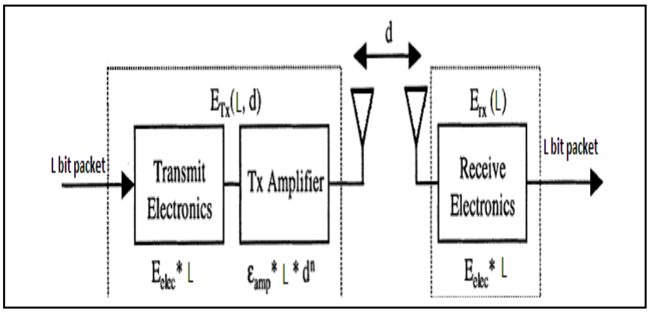

Fig. 3. Radio energy dissipation model

According to the above radio energy dissipation model, to transmit an l– bit message to distance d, the energy dissipated by the radio transmitter is;

$$\text{ETx}(l, d) = \begin{cases} lE_{elec} + l\epsilon_{fs} d^2, d<d0 \\ lE_{elec} + l\epsilon_{mp} d^4, d \geq d_0 \end{cases} \tag{10}$$

Where E_{elec}, the energy is dissipated per bit to run the transmitter or the receiver circuit, ϵ_{fs} and ϵ_{mp}depend on the transmitter amplifier model we use, and d is the distance between the sender and the receiver [14]. The reference distance d_0 is

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \tag{11}$$

To receive this message, the radio receiver expends:

$$E_{Rx}\,(l) = lE_{elec} \tag{12}$$

K. Hotspot Technique

The paper [5] addressed the hot spot problems, an unequal clustering mechanism is applied and the nodes are classified based on their distance to the base station. This results in clusters of different sizes based on transmission ranges.

Let us consider a sensor network consisting of N sensor nodes uniformly deployed over a vast field to continuously monitor the environment. They denote the i^{th} sensor by S_i and the corresponding sensor node set S = {S1, S2… SN}, where $|S_j|$=N. Some assumptions about the sensor nodes and the underlying network model

1. There is a base station (*i.e.*, data sink) located in the center of the sensing field.
2. Sensors and the base station are all stationary after deployment.
3. All nodes are homogeneous and have the same capabilities. Each node is assigned a unique identifier (ID).
4. Nodes needn't to be equipped with GPS-capable unit to get precise location information.

5. Nodes can use power control to vary the amount of transmission power which depends on the distance to the receiver.
6. Links are symmetric.

They use a simplified model for the radio hardware energy dissipation. Both the free space (d^2 power loss) and the multi-path fading (d^4 power loss) channel models are used in the model, depending on the distance between the transmitter and receiver. The energy spent for transmission of an l-bit packet over distance d, uses the same equation provided in (10). And to receive this message, the radio expends energy; this method uses the equation (11).

The network is divided into two regions: the front region and the rear region. The nodes in the front region, also known as the hot spot region, are the ones that can directly communicate with the base station. The rest of the nodes are classified as the rear region nodes, and can only communicate with the base station via one of the nodes in the front region. Initially all the nodes assume that they are not in the hot spot region by setting their 'Boolean' variable in hotspot-region to false.

However, before running the distributed clustering algorithm, a node must determine its location in either the front region or in the rear region. To achieve this, all the nodes trigger a one-shot timer and send a hot-spot setup message to the base station. Upon receiving the setup message, a base station then sends a beacon message that contains its own transmission power level PC. All the nodes that received a beacon message then set their inter-cluster transmission power level to PC and send an acknowledgement (Ack) message to the base station. The base station then sends a re-acknowledgement (Re-Ack) message to the node. The handshake operation is needed to ensure that the link is symmetric at that transmission power level.

Varying the transmission ranges of those nodes in the front and rear regions, the number of clusters can be controlled. The larger the transmission range, the larger the cluster size will be. Therefore, model adjusts the transmission range to form a small cluster in the front region, thereby alleviating the energy problem in the hot spot region [5].

L. Data Collection by Prediction Technique

In sensor networks, accurate data extraction is difficult it is often too costly to obtain every sensor readings, as well as not necessary in the sense that the readings themselves only represent samples of the true state of the world. One technique so-called prediction emerges to exploit the temporal correlation of sensor data. One important class of such algorithms is predictors, which use past input values from the sensors to perform prediction operations. The existence of such prediction capability implies that the sensors do not need to transmit the data values if they differ from a predicted value by less than a certain pre-specified threshold, or an error bound.

Predictor training and prediction operations are carried out by the base station only, but not the sensor nodes, despite their increasing computing capacity. A cluster head maintains a set of history data of each sensor node within a cluster. They use localized prediction techniques is highly energy efficient due to the reduced length of routing path for transmitting sensor data.

One model for selective sending is Є-loss approximation. Given an error bound $Є > 0$, a sensor node sends its value x_t to the cluster head if $|x_t - x_t^{|}| > Є$, where $x_t^{|}$ is a predicted representative data value to approximate the true data. The intuition of this choice is that if a value is close to the predicted value there is not much benefit by reporting such data. If the value is much different from the predicted value, it is important to consider it for computing the data distribution. It avoids the need for rampant node-to-node propagation of aggregate data, but rather it uses faster and more efficient cluster-to-cluster propagation.

Clustering and prediction techniques, which exploit temporal and spatial correlation among the sensor data, provide opportunity for reducing the energy consumption of continuous sensor data collection. Integrated approach of clustering and prediction techniques makes it essential to design a new data collection scheme, so as to achieve the network energy efficiency and stability [8].

M. Energy Efficient Communication Synchronization

The switching between the intra and inter cluster communication consumes large amount of energy. In clustering approach this leads to the decrease of energy of the cluster heads thus, the network life time will very low. There exists a direct relationship between synchronization and energy consumption so, while analyzing various energy models should also take care of the synchronization. When synchronization achieved in better way then, that network will be an energy efficient one. Here, they propose a NCS (New Clustering Structure) which involves a new node called as relay node.

The new clustering structure is illustrated in Figure, in which a cluster contains a cluster head node, a relay node and multiple cluster members. The relay nodes are always staying in o-state and they are only participating in inter-cluster communications. During data gathering process, while cluster members still send sensing packets to the corresponding cluster head node, the cluster head no longer sends the aggregated packet to the next-hop cluster head but sends to the relay node of its own cluster instead. By receiving the packets, the relay node further combines them with its own sensing packets and forwards the packets to the next-hop relay node until the packets reach the sink node. With this communication pattern, communication synchronization is simplified.

CHs can continue intra-cluster data collection immediately after sending out the aggregated packet, reducing the data collection delays. In the meanwhile, inter-cluster communication can be performed without any restrictions, incurring no waiting delays for synchronization. The wireless channel thus can be utilized better and lower packet delay can be achieved [9].

V. Challenging Factors

Wireless Sensor Network suffer from many restrictions, such as limited energy, Intruder attacks, Cost of maintenance etc. One of the most important design goals of WSNs is to go through data communication while trying, at the same time, to contribute to the longevity of the network and to preclude connectivity abasement through the use of aggressive energy management techniques.

Main factors affecting the energy consumption are;

1. Node deployment methods
2. Heterogeneity of node

3. Scalability
4. Coverage
5. Quality of service
6. Data reporting model
7. Data aggregation methods

VI. Conclusion

In WSN several researches are going based on the reduction of energy consumption. Hierarchical protocols such as clustering are efficient energy management method. Node clustering is a topology-management approach to reduce the communication overhead and exploit data aggregation in sensor networks. Clustering is highly efficient because the nodes are deployed over a large area which is also unsecure. So, monitoring is one of the critical tasks over a large area. The flat protocols may be a solution for a small network with fixed nodes. In a large network they become infeasible because of link and processing overhead.

The hierarchical protocols try to solve this problem and to produce scalable and efficient solutions. They divide the network into clusters and to efficiently maintain the energy consumption of sensors and perform data aggregation and fusion in order to reduce the number of transmitted messages to the sink.

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References

[1] Jia Zhao, Chunming Qiao, Raghuram S. Sudhaakar, Seokhoon Yoon, Improve Efficiency and Reliability in Single-Hop WSNs with Transmit-Only Nodes, *IEEE Transactions On Parallel And Distributed Systems, Vol. 24*, No. 3, pp. 520-534, 2013.

[2] S.Taruna, Kusum Jain, G.N. Purohit, Power Efficient Clustering Protocol (PECP) - Heterogeneous Wireless Sensor Network ,*IJWMN Vol. 3*, No.3, pp. 51-67, 2011.

[3] María Gabriela Calle Torres, "*Energy Consumption In Wireless Sensor Networks Using Gsp",*mtech Thesis,Dept. Electronics Engineering, University of Pittsburgh, Universidad Pontificia Bolivariana, Medellín, Colombia ,1995.

[4] Issa M. Khalil, ELMO: Energy Aware Local Monitoring in Sensor Network, *IEEE Transactions on dependable and secure computing, Vol. 8*, No. 4, pp. 523-536, 2011.

[5] A.K. Daniel, Pooja Rathi, Aakansha Agarwal, and Amaresh Maurya, Energy Efficient Clustering Protocol for Sensor Networks Using Token Based Hotspot Technique, *International Journal of Research and Reviews in Computer Science (IJRRCS) Vol. 3,* No. 2, pp. 1532-1537, 2012.

[6] Nikolaos A. Pantazis, Stefanos A. Nikolidakis and Dimitrios D. Vergados, Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey, *IEEE Communications Surveys & Tutorials, Vol. 15,* No. 2, pp. 1532-1537, 2013 .

[7] Y. Kim, H. Shin, and H. Cha, *Y-MAC: An Energy-Efficient Multi-Channel MAC Protocol for Dense Wireless Sensor Networks*, Proceedings of seventh International Conference Information Processing in Sensor Networks (IPSN), (Page:54 Year Of Publication: 2008 IPSN 978-0-7695-3157-1).

[8] Hongbo Jiang, Chonggang Wang, Prediction or Not? An Energy-Efficient Framework for Clustering-Based Data Collection in Wireless Sensor Networks , *IEEE Transactions On Parallel And Distributed Systems, Vol. 22,* No. 6, pp. 1064-1071 , 2011.

[9] Xi Deng Yuanyuan Yang, Communication Synchronization in Cluster-Based Sensor Networks for Cyber-Physical Systems, IEEE *Transactions On Emerging Topics In Computing, Volume 1,* No. 1, pp. 98-110, 2013.

[10] Ashim Kumar Ghosh, Anupam Kumar Bairagi, Dr. M. Abul Kashem, Md. Rezwan-ul-Islam, A J M Asraf Uddin, Energy Efficient Zone Division Multihop Hierarchical Clustering Algorithm for Load Balancing in Wireless Sensor Network, *(IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 2,* No. 12, pp.92-97,2011.

[11] S. Siva Ranjani , S. Radha Krishnan , C. Thangaraj , K. Vimala Devi ,Achieving Energy Conservation By Cluster Based Data Aggregation In Wireless Sensor Networks, *Springer journal Wireless Personal Communications , Vol. 73,* No.3, pp 731-751,2013.

[12] Benazir Fateh, Manimaran Govindarasu, Joint Scheduling of Tasks and Messages for Energy Minimization in Interference-aware Real-time Sensor Networks, *IEEE Transactions On Mobile Computing, Vol. 99,* No.13,pp. 1-13,2013.

[13] Rashmi Ranjan Rout, Soumya K. Ghosh, Enhancement of Lifetime using Duty Cycle and Network Coding in Wireless Sensor Networks, *IEEE Transactions On Wireless Communications, Vol. 12,* No. 2, pp. 656-667, 2013.

[14] Mohammad Javad Hajikhani, Bahman Abolhassani,An Energy Efficient Algorithm for Cluster-Head Selection in WSNs, Proceedings of fifth International Symposium on Telecommunications, (Page:397 Year Of Publication: 2010 IST 978-1-4244-8185-9).

[15] Hemappa B, Manjaiah D.H, Energy Efficient Event Driven Data Reporting System for Wireless Sensor Network, *International Journal on Computer Science and Engineering (IJCSE), Vol. 4* ,No. 05 ,2012.

[16] Jinchul Choi ,Chaewoo Lee, Energy consumption and lifetime analysis in clustered multi-hop wireless sensor networks using the probabilistic cluster-head selection method, *EURASIP Journal on Wireless Communications and Networking- Springer open access journal, Vol.11,* No.156, pp. 1-13,2011.

[17] Sanjeev Kumar Gupta, Neeraj Jain, Poonam Sinha, Clustering Protocols in Wireless Sensor Networks: A Survey, *International Journal of Applied Information Systems (IJAIS), Vol. 5,* No.2, 2013.

[18] Sourabh Jain, Praveen Kaushik, Jyoti Singhai, Energy Efficient Maximum Lifetime

[19] Routing For Wireless Sensor Network, International Journal Of Advanced Smart Sensor Network Systems (IJASSN), Vol 2, No.1, 2012.