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Performance Comparison of LEACH & PASCCC Clustering Protocols

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Abstract: Wireless sensor networking is currently a fast growing technology which provides the enormous range of applications for both civilian as well as for military use. There are many parameters regarding wireless sensor networks (WSN) like energy utilization, Data routing, Network Lifetime, Battery Drainage etc. To analyse and to enhance these parameters, approaches like Node Clustering, Network congestion and mitigation techniques, etc. are utilized. In this paper these parameters are analysed and implemented for Leach (low energy adaptive clustering hierarchical) Protocol and PASCCC (Priority Based application specific congestion control clustering) Protocol and a comparison is done for both the protocols for different parameters.

Keywords: Wireless sensor network (WSN), Sensor node, Clustering, Congestion, Data aggregation

I. INTRODUCTION

Modern progress in semiconductor technology and networking techniques have encouraged the use of sensor networks for monitoring and information gathering [1]. Wireless sensor network consist of battery operated tiny nodes which are deployed over a wide geographical region to lookout the happened events and gather the collected data to a centralized location. Based on node moment, wireless sensor networks are classified into static and mobile node networks [2]. When the static nodes die or glitches, network holes are formed which results in communication breach amid sensor nodes [2]. Mobile nodes have the advantage over stationary nodes in term of network coverage. Routing algorithms can be classified into three types- a) Data Centric b) Cluster based hierarchical routing c) Location based algorithms [4].

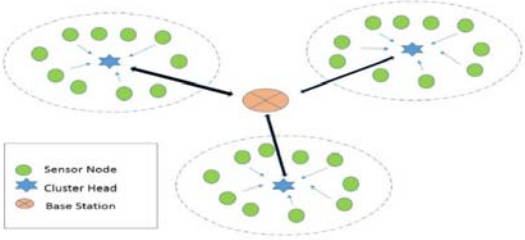


Figure 1. Cluster Based Hierarchical routing

To enhance the life time of the network, the battery power of the nodes must be utilized effectively. According to statics, cluster based routing method utilizes only 1/8th of energy as compared to other routing protocols for the same conditions [3]. Cluster Base hierarchical routing is as shown in the Fig. 1, organize the network into number of clusters. Each cluster is having one Cluster head that sends the collected data from its associated nodes to the distant Base station. Leach is considered as basic stepping stone for Clustering based protocols. Leach had some limitation, such as it was based on the static node architecture, node homogeneity and congestion prone due to unbalanced clustering etc. These shortcomings are overcome by PASCCC protocol. PASCCC has all the characteristics such as node mobility, Heterogeneity, Balanced clustering mechanism etc. Experimentally PASCCC is proved more efficient as compared with the LEACH and its other variant protocols.

II. LITERATURE SURVEY

There are so many protocols available till date, which are having different attributes and improvements over others to enhance the stability period and reduce the network congestion in the network. Basic foundation for clustering based protocol is LEACH protocol. Heinzelman et al. [7] proposed a protocol "LEACH" (low energy adaptive clustering hierarchical). In LEACH, the total network is divided into number of clusters and a Cluster Head (CH) is nominated for each cluster. In every round a different CH is chosen to distribute the energy among all the nodes. An advancement over the LEACH is a chain-based protocol called as PEGASIS (Power-Efficient Gathering in Sensor Information Systems) [8]. Based upon energy allocation to each node, Smaragdakis et al. [9] proposed SEP (Stable Election Protocol) .In SEP, some of the nodes are equipped with extra energy making the network heterogeneous. LEACH and SEP protocol often selects low energy nodes as CH. To avoid this problem Kim and Chung [10] suggested LEACH-Mobile protocol. But again, here is the limitation of time slot allocation to each node. First protocol which considered threshold for data is TEEN (Threshold-Sensitive Energy Efficient Protocol), which was proposed by Manjeshwar and Agrawal [11].TEEN was application specific protocol, where nodes send data to the respective CH only when a certain threshold is achieved.

To avoid congestion in the network, Wan et al. [12] proposed CODA (Congestion Detection and Avoidance).CODA compares the past and present network conditions to find the congestion. The next advancement was "Fusion Method" presented by Hull et al. [13], where nodes gets the channel after happening of any event. This method puts a problem of

selecting threshold level. ESRT proposed by Sankarasubramaniam et al. [14] is somewhat different from all the other protocols, which uses a single bit for indication of congestion. This bit is sent along the packet in the packet header. Mian Ahmad Jan [2] proposed PASCCC (Priority based application specific congestion clustering) protocol which considered mobility, nodes heterogeneity, threshold & congestion detection & mitigation techniques.

III. LEACH PROTOCOL

Leach is the basic foundation for clustering protocols [7]. It is the first kind of protocol which consider network area as number of clusters and cluster head as representative of that cluster. Clustering operation is divided into two phases- a) Set up Phase b) Steady state Phase. Set up phase includes the clusters creation and CH's selection whereas steady state phase includes data transmission between nodes and CH's and between CH's and Base station. Once all the nodes are arranged into clusters, each cluster head allocates the time slot for the associated nodes. The CH performs data aggregation to compress the data and send that data to the Base station. In LEACH, CH's are rotated randomized to distribute the energy evenly among all the nodes.

CH are chosen based up on threshold denoted by T(n) [7] represented by Equation 1. In each round, every node takes a number between 0 &1. If that selected number is less than this threshold value, then that node is selected as CH for that round.

$$T(n) = \begin{pmatrix} p/(1-p[r \bmod \left(\frac{1}{p}\right)]) & n \in G \\ o & otherwise \end{pmatrix} \quad (1)$$

Here T (n) = Threshold level for CH selection
p = percentage of the proposed CH's in each round
r = current round
n = number of nodes that belong to group of nodes G, which have not been selected as CH in previous (1/p) rounds

IV. PASCCC PROTOCOL

The basic clustering operation of PASCCC is based upon the Leach protocol [7]. In addition to clustering, PASCCC protocol also incorporate some additional characteristics such as node heterogeneity, node mobility, congestion detection and mitigation techniques etc.

In PASCCC following conventions are used [2] -

1. Nodes are arranged in a random fashion in the network and are having different energy levels. There are normal and advanced nodes present in the network. Advanced nodes are equipped with extra energy to make the network heterogeneous.
2. Nodes can regulate their energy to make the communication with distant CH.
3. Base station location is not permanent. It can be inside or outside the network area.
4. To cover the vacant area created by dead nodes, alive nodes can move the area with random waypoint mobility model [17].
5. PASCCC is application specific protocol equipped with two sensors at each node, which acts as a reactive protocol for temperature packets and Proactive protocol for Humidity packets.

Leach does not include energy dependent threshold for heterogeneous nodes while selection of CH, thereby resulting in selection of lower energy nodes as CH in respective rounds [7]. PASCCC provides the remedy for this by considering the energy consumption of node which is selected as CH. Threshold for CH selection in PASCCC is represented by Equation 2 [20].

$$T(n) = \begin{pmatrix} (p * Econ)/(1-p[r \bmod \left(\frac{1}{p}\right)]) & n \in G \\ o & otherwise \end{pmatrix} \quad (2)$$

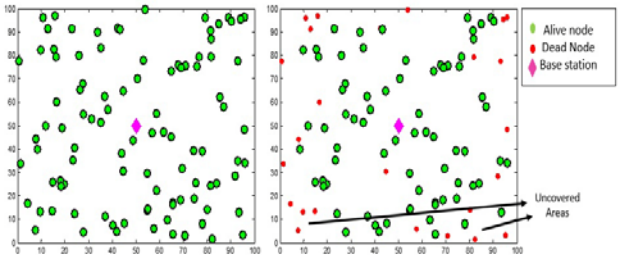
Here, Econ = Energy consumed by node to be selected as CH.

The major differences between LEACH and PASCCC protocols [2]-[3] are as listed in the table I.

Table I. Comparison between LEACH and PASCCC Protocol

Parameter	*LEACH*	*PASCCC*
Residual Energy(For CH selection)	No	Yes
CH Distribution	Non-uniform	Uniform
Node Energy	Homogeneous	Heterogeneous
Node Mobility	No	*Yes(Random waypoint Model)[17]
Load Balancing	Moderate	Good
Base station Location	Fixed	Not-Fixed
Application Specific	No	Yes
Energy Efficient	No	Yes

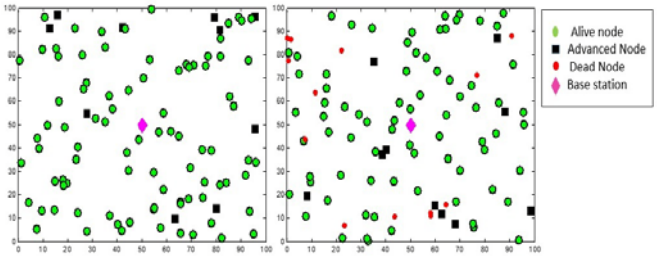
Node deployment in LEACH protocol is as shown in fig. 2(a). In leach all the nodes are stationary. These nodes are deployed randomly to cover and monitor the entire network area. After successive rounds, some stationary nodes die or glitches which creates the uncovered or vacant areas as shown in fig. 2(b). This results in communication breach among sensor nodes.



(a) (b)

Figure 2. LEACH static node Topology (a) Node deployment in first round. (b) Uncovered regions in successive rounds.

PASCCC solves this problem by mobile nodes which covers these vacant areas. In first round, nodes are deployed as same as that for LEACH as shown in fig. 3(a). In successive rounds as the "uncovered areas" are created, then the network topology is re-arranged so that entire area is covered as shown in fig. 3(b) [2].



(a) (b)

Figure 3. PASCCC node Topology (a) PASCCC node deployment (b) Node mobility after successive rounds

V. ENERGY DISSIPATION MODEL OF SENSOR NODES

The basic radio model [8], which is used for energy calculation in clustering protocols is represented here in fig. 4.

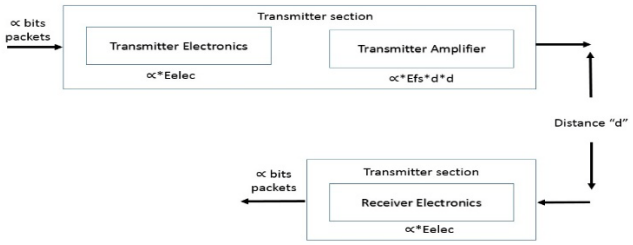


Figure 4. Radio Energy Dissipation Model [8]

In wireless sensor networks energy is utilized in the following processes [20]–

a) Data sensing by nodes

b) Processing and transmission of sensed data

Data Sensing - Energy utilization for data sensing is same for CH's and non-CH's nodes and is represented by the Equation 3 [1]

$$E_{sense} = \beta \times r \quad (3)$$

Here E_{sense} = Energy consumed during data sensing

β = energy consumed for sensing single bit

r =Total payload of Packet

Processing and transmission – Energy utilization for processing and transmission of data is different for non CH nodes & CH nodes and are as represented by Equation 4 & Equation 5 respectively [7]. CH nodes energy utilization is higher due to the Data aggregation and Long distance communication with Base station [2].

$$E_{T(\propto,d)} = \begin{bmatrix} n*\propto*E_{elec} + n*\propto*E_{da} + \propto*E_{fs}*d^2 & for \;\; d < d_0 \\ n*\propto*E_{elec} + n*\propto*E_{da} + \propto*E_{Two-ray}*d^4 & for \;\; d \geq d_0 \end{bmatrix} \quad (4)$$

$$E_{T(\propto,d)} = \begin{bmatrix} \propto*E_{elec} + \propto*E_{fs}*d^2 & for \;\; d < d_0 \\ \propto*E_{elec} + \propto*E_{Two-ray}*d^4 & for \;\; d \geq d_0 \end{bmatrix} \quad (5)$$

Here $E_{T(\propto,d)}$ = Energy consumption for processing and Transmission of data

n = Total number of nodes associated with each Cluster head

∝ = Packet –size

E_{elec} = Energy consumed by amplifier for processing data

E_{da} = Energy consumed for data aggregation

d = distance between node and associated CH

Cross-over distance d_0 is represented by Equation 6 [2].

$$d_0 = \sqrt{\frac{E_{fs}}{E_{Two-ray}}} \quad (6)$$

If distance $d<d_0$ then free space model (E_{fs}) is used Otherwise Two ray model ($E_{Two-ray}$) is used.

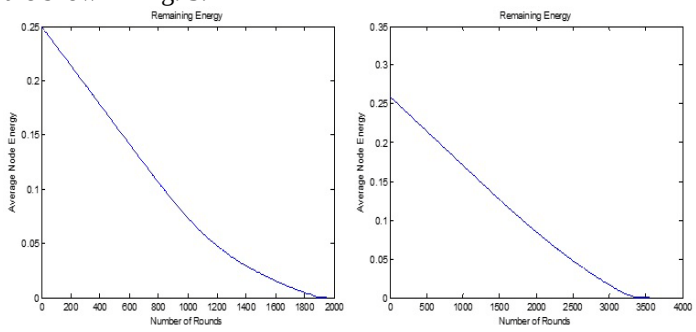
VI. RESULTS AND DISCUSSION

In this section, a comparison of PASCCC with LEACH protocol is presented. MATLAB simulation tool is used for simulation and values of parameters are as shown in table II.

Table II. Parameter Table

Parameter	*Description*	*Value*
n	Number of nodes	100
Length *Breadth	Network Size	100*100
p	CH Probability	0.1
E_o	Node Energy	LEACH: 0.25j PASCCC: 0.25j (Normal node) 0.35j (Advance Node)
E_{elec}	Radio Electronics Energy	50 nj/bit
d_o	Cross-Over Distance	87m
E_{fs} E_{Two_ray}	Radio Amplifier Energy	10pj/bit/m2 0.0013pj/bit/m4
∝	Packet Size	2000 bytes

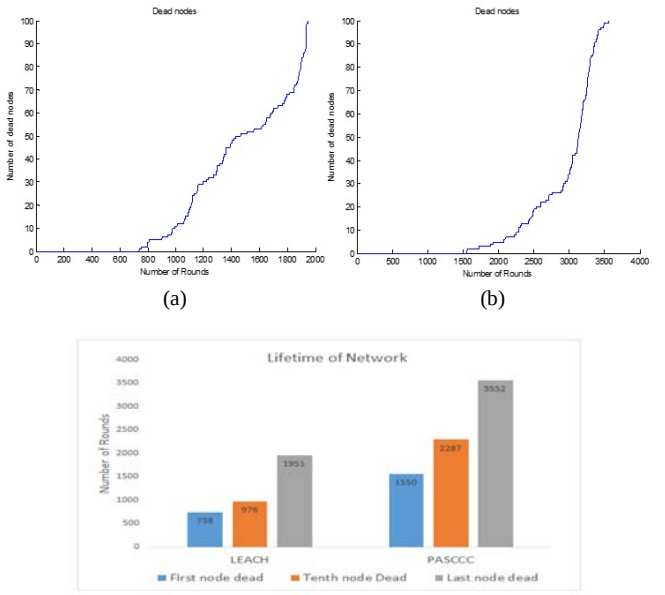
Residual Energy: Leach acts as Proactive protocol [7] as every time nodes have some data to be sent to CH whereas PASCCC acts as reactive protocol for temperature packets and Proactive protocol for Humidity packets [2]. Nodes enters into sleep mode in PASCCC until a specific threshold is achieved thereby reducing the duty cycle of nodes. PASCC performed better for node energy utilization as compared with LEACH protocol. Simulation results and comparison for residual energy are shown in fig. 5.



(a) (b)

Figure 5. Energy Consumption through the network lifetime. (a)Leach with intital energy 0.25j. (b) PASCCC with intital energy 0.35j.

Lifetime of the network: Lifetime of the network is defined as the time elapsed between first node dead and the time when all of the nodes becomes dead [2]. In other words it can also be defined as the time between stability period and instability region. Experiments showed that due to PASCCC application specific characteristics, network life time is better as compared to LEACH protocol as shown in fig. 6.

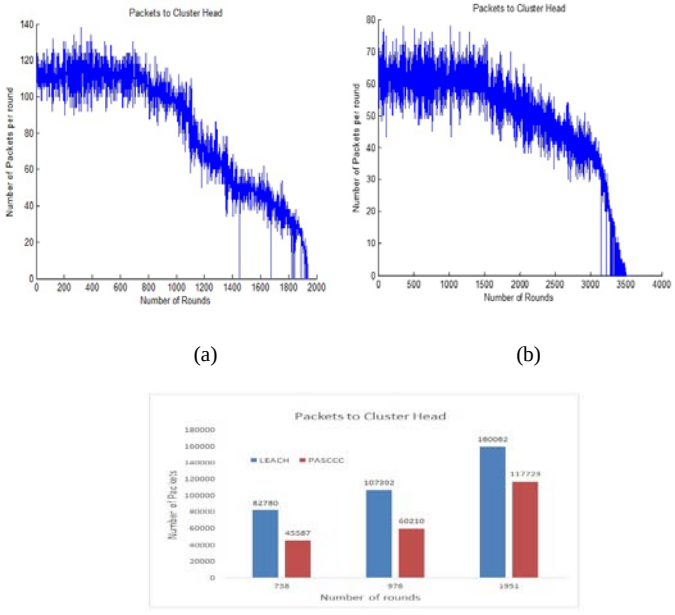


(a) (b)

(c)

Figure 6. Lifetime of the network (a) leach protocol. (b) PASCCC protocol. (c) comparision of leach and PASCCC protocols.

Packets to CH: Number of packets transmitted to CH in PASCCC are lesser in amount as compared with Leach protocol which leads to lower energy utilization. Comparison results for packets transmitted to CH are as shown in fig. 7.

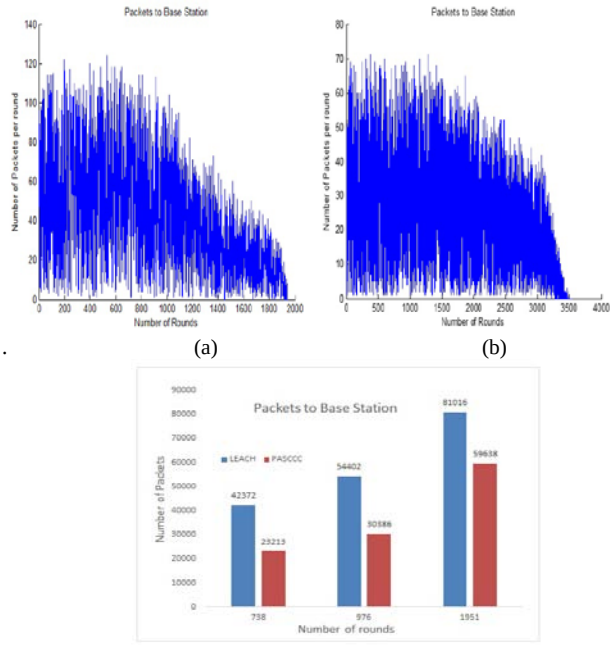


(a) (b)

(c)

Figure 7. Average number of packets to CH. (a) Leach. (b) PASCCC. (c) comparision of leach and PASCCC protocols

Packets to BS: In order to avoid information overload, CH aggregate the data and send this aggregated data to BS. Data aggregation converts the bulk of data to a small meaningful sets [7]. Comparison results for packets transmitted to BS are as shown in fig. 8.



. (a) (b)

(c)

Figure 8. Average number of packets to BS. (a) Leach. (b) PASCCC. (c) comparision of leach and PASCCC protocols

VII. CONCLUSION

In this paper, we described LEACH and PASCCC protocol and showed the experimental results for comparing these protocol based on different parameters. Both protocol works on same basic clustering hierarchal routing but leach has some short comings which are improved by PASCCC protocol. PASCCC have many inherent characteristics such as node heterogeneity, node mobility to cover vacant spaces, application specific architecture, lower duty cycle etc. These all parameters makes the PASCCC protocol more energy efficient protocol as compared to leach .Furthermore PASCCC can be made more efficient for larger networks by applying different queuing mechanism and algorithms as applied to mesh networks to reduce congestion, delay and to increase throughput.

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