

# Energy Efficient Clustered Chain Based Power Aware Routing Protocol For Wireless Sensor Networks

Parendra Kumar Singh



Department of Computer Science and Engineering  
National Institute of Technology Rourkela  
Rourkela – 769 008, India

# Energy Efficient Clustered Chain Based Power Aware Routing Protocol For Wireless Sensor Networks

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*by*

***Parendra Kumar Singh***

*(Roll 211cs1053)*

*under the supervision of*

***Prof. Bibhudatta Sahoo***



Department of Computer Science and Engineering

National Institute of Technology Rourkela

Rourkela – 769 008, India



Computer Science and Engineering  
**National Institute of Technology Rourkela**

Rourkela-769 008, India. [www.nitrkl.ac.in](http://www.nitrkl.ac.in)

**Prof. Bibhudatta Sahoo**

Professor

## Certificate

This is to certify that the work in the thesis entitled "*Energy Efficient Clustered Chain Based Power Aware Routing Protocol For Wireless Sensor Networks*" by *Parendra Kumar Singh*, bearing roll number 211cs1053, is a record of an original research work carried out by him under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of *Master Of Technology* in *Computer Science and Engineering*. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

***Prof. Bibhudatta Sahoo***

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# Abstract

WSNs has emerged as an important computing platform in the recent few years. Wireless Sensor Networks consists of a large number of sensor nodes, which are operated by a small battery. Sensor nodes can be deployed in the harsh environment. Once they are deployed, it becomes impossible to replace or recharge its battery. So the battery power of sensor node should be used efficiently. Many routing protocols have been proposed so far to maximize the network lifetime and decrease the consumption energy. One of the first Clustered based routing is LEACH. It organises the network into number of clusters and each cluster has a CH (cluster head). All the sensor nodes in a cluster send its data to their CH and the CH aggregates their data and then send it to the BS (Base Station). This protocol suffers from the overhead of clustering in each round. PEGASIS is a chain based protocol. It constructs the Chain among the sensor nodes in the network, so that each node sends and receives data from a single neighbor. But this suffers from transmission delay. To overcome this problems we propose EECCPAR (Energy Efficient Clustered Chain Based Power Aware Routing) for WSNs. In this protocol clusters are formed of the sensor networks. Then chain is formed in each cluster so that sensors can receive from its previous neighbor and send its data to its next neighbor node in the chain. Thus it reduces the distance between the sensor nodes and the CHs. In this way it saves a lot of energy of the sensors. And also a chain is constructed among the CHs. Thus it has reduced the energy for transmitting the aggregated data to the BS. In this each CHs do not send their data directly to the BS but sends to its neighbor and it transmits it to its neighbor in the chain and finally reaches the BS. Thus enhances the lifetime of the sensor network and reduced the transmission cost. Our protocol also considers the time critical data. For this a MAX threshold has been introduced. If any sensed attributes value is greater than MAX threshold, it means it is time critical data. So this data will be transferred to the BS directly without any delay. Simulation result shows that this protocol is better than LEACH and PEGASIS protocols.

**Keywords:** Wireless Sensor Networks, Clustering, Network Lifetime, Chain Based Routing, Data Aggregation.

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# List of Abbreviations

BS	Base Station
CHs	Cluster Heads
RSSI	Receiver Signal Strength Information
WSNs	Wireless Sensor Networks
WANETs	Wireless Ad-hoc Networks



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# Chapter 1

## Introduction

Recent advancement in micro-electronics technology facilitated sensor designers to develop low price, low power and small sized sensors. Thousand of sensor are deployed in order to achieve high quality network. In the recent few years WSNs has emerged as an important technology for monitoring physical environment. WSNs consist of large number of sensor nodes which are small in size, inexpensive and battery powered. These WSNs can be used in various applications such as Military surveillance, environment monitoring, border protection, health care monitoring, weather monitoring. These applications require data without delay and energy consumed by them should be small. WSNs are deployed in harsh environment. Since it is not possible to replace or charge battery of sensor nodes, So it is desirable to design communication protocols such that energy source is used effectively and the delay in the network in minimum.

Sensor nodes senses the environment, gathers the data from its surrounding (computation) and communicates it to the base station (BS). Out of the three tasks communication takes large amount of battery power of a sensor node, so the major concern is the communication task. we have to minimize the communication cost in order to save battery power.

Wireless sensor networks[1] consists of a thousands of sensor nodes which are deployed randomly environment or space. In sensor network there is a BS (base

station) which is located far away from the sensor field. Sensor nodes send the sensed data to the BS. For sending the sensed data to BS directly a lot of energy is consumed. So it is desirable to develop some protocols to minimize this communication cost. Energy conservation and maximization of network lifetime are the key challenges in the design and implementation of WSNs.

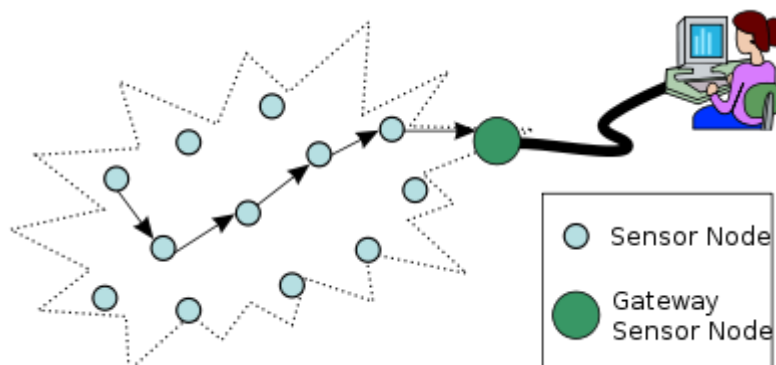


Figure 1.1: Wireless Sensor Network

### 1.0.1 Architecture Of Sensor Node

Every sensor node mainly consists of four components. They are sensing unit, transceiver, processing unit and power source. Some sensor nodes also consist of optional components like location finding system, power generator and mobilizer.

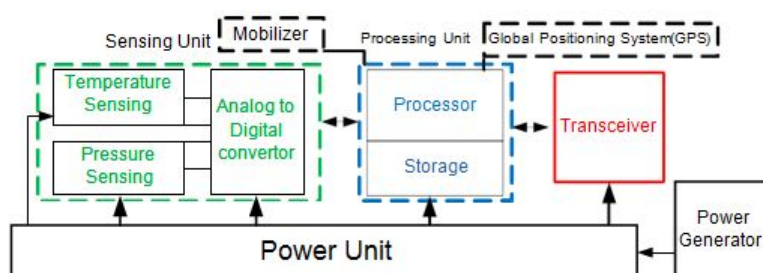


Figure 1.2: Sensor Node's Architecture

The sensing unit generally consists of sensor and ADC (Analogue and digital

converter).The ADC converts the analogue data to digital data so that node can process it before transmitting the data.Transceiver connects the node to the network.The processing unit consists of processor and memory.This unit is responsible for managing the task of sensor unit.Mobilizer is used to enable node movement.

### 1.0.2 Protocol Stack For WSNs

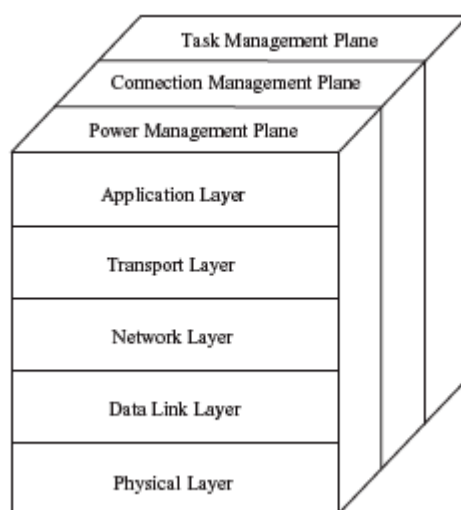


Figure 1.3: Protocol stack for WSN

Description of each layer is as follows:

- Physical Layer : This layer addresses the needs of robust modulation, receiving techniques and transmission.
- Data link layer: Minimize collision with the neighbouring broadcasts.
- Network layer: Various routing are performed here.
- Transport layer:Flow of data is being maintained here.

- Application layer: Various application software runs here depending upon sensing task.

Most important part of a sensor node is its battery power. So in order to increase the network life time it should be utilized properly. For this various methods have been proposed till now. Out of which Routing has utilized the sensors nodes energy very effectively.

## **1.1 Comparision Of WSNs And Wireless Ad-hoc Network**

- Network Size: WSNs nodes varies from few hundred node to thousands of nodes but WANETs consist of limited no. of nodes i.e few hundred of nodes. Bluetooth pico net is an example of WANET. WLAN is also example of WANET.
- Network Density: Network density in WSNs is usually high, with big quantity of nodes are close to each other but in case of WANET very few nodes are close to each other. The size of nodes of WSN is very small. It is as small as one Euro coin but nodes of WANET are mostly laptops, palmtops, cellular phones etc.
- Node Proneness To Failure: WSNs nodes are placed in inaccessible areas or isolated areas like forest or disaster areas. Nodes once deployed in this areas are very difficult to replace. The nodes may drain their energy or they may be damaged. But MANETS have rechargeable batteries in their nodes. This node are not subjected to difficult environmental conditions that could damage them.
- Frequency Of Topology Change: Topology change frequency is high in WSNs because of node failure, node addition, node moving and environmental

intreferece.The network has to adapt iteself to the changing topology.topology may change in few milli seconds in WSNs.In WANETs,nodes joins the network after request and then leave the network after sometime,which is less than a minute.

- Communication Paradigm Employed: WSNs uses the mechnism of broadcasting in order to communicate with the other nodes but WANETs uses point to point communication.
- Resource Limitations Of nodes: The Energy resourses of WSN nodes cannot be replenished,because unlike WANETs the WSNs doesn't have rechargeable batteries.once the nodes are deployed in the environment, they cannot be recharged or replaced.The memories of WSNs is of few Kilobytes but that of WANETs is of Gigabytes.The processors used in WSNs are of few MHz but that of WANETS is of GHz.
- Node Identification: Node identification by globally identifier are not always possible in WSNs,since the no. of node in WSNs is very high and there is a possibility the nodes may exit the network very frequently.In WANETs nodes have unique identifiers likt IP(Internet Protocol) address.

## 1.2 Application Of WSNs

WSNs were designed to perform high level information processing task.Sensor nodes are deployed in harsh environment.Sensor nodes senses the environmental conditions such as temperature,pressure etc and then it sends the sensed data to the BS.Application of sensor networks is very vast.Some of the applications of sensor networks are:

- Environmental condition monitoring:It includes sensing Volcanoes, oceans, Glaciers, forest.

- Industrial monitoring: It includes Machine health monitoring, Factory.
- Agriculture: Irrigation management, green houses.
- Battlefield awareness.

## 1.3 Routing in wireless sensor networks

The routing in wireless sensor networks is challenging. It suffers from a lot of challenges.

### 1.3.1 Design challenges for routing

The main challenges are:

- Scalability: If Sensor nodes are increased in the sensor networks then networks functionality should not be decreased but it should increase. It is called scalable network. Routing protocols should be designed such that it should work with large number of sensor nodes spread in large area.
- Fault Tolerance: The ability of sensor network to function prone to some sensor node failures. Sensor nodes may fail due to physical damage or out of energy. The failure of some sensor nodes should not affect the overall performance of the sensor network.
- Production Cost: The production cost of a sensor node should be such that the overall cost of deploying wireless sensor networks should be cheaper than traditional sensors. The cost of a single sensor should not be less than US 1 dollar.
- Power Constraints: Large scale WSNs have extremely low energy and power at their disposal. So routing protocol should be designed in such a way that transmission and reception of data is fully justified.



## **1.4 Thesis Organization**

Our thesis is organised as follows: Chapter 1. presents Introduction, Chapter.2 presents related work, Chapter.3 describes the Proposed work, Chapter.4 describes the Simulation and result and Chapter 5 presents conclusion and future work.

# Chapter 2

## Literature Review

In this chapter, the design consideration for wireless sensor networks routing protocols are discussed. Then some well known WSNs routing protocols are being discussed.

### 2.1 Design of wireless sensor network routing protocols

Routing is important for efficient performance of WSNs. A lot of research is being done to design efficient routing protocols for WSNs. Desired features of routing protocols is fault tolerance, scalability, energy efficiency etc.

#### 2.1.1 Overview of routing protocols

Routing protocols in WSNs can be classified as follows:

- Flat routing: In flat networks, each node plays the same role and sensor nodes collaborate together to perform sensing task. In wireless sensor networks due to large number of sensor nodes, it is not feasible to assign global

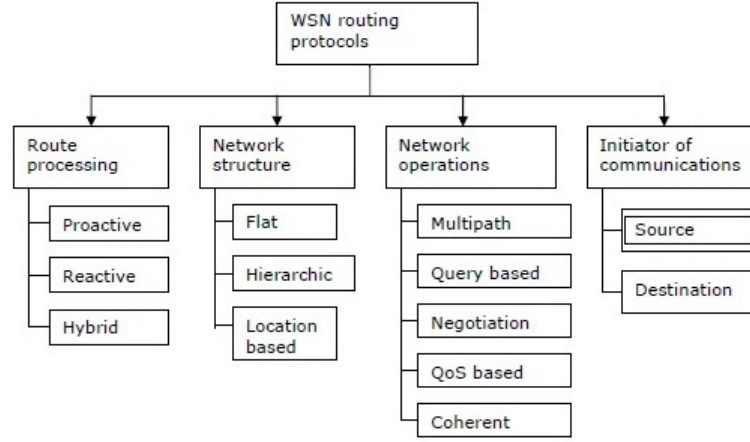


Figure 2.1: Routing protocols in WSNs

identifier to each node. In flat routing, BS send queries to certain region and waits for data from sensors located in that particular region. SPIN (Sensor Protocol For Information Via Negotiation) [13,15], Directed Diffusion [16], Rumor Routing [17] are Data-Centric routing.

- **Hierarchical Routing:** Hierarchical routing protocols are cluster base routing protocols. Hierarchical routing have good scalability and energy efficiency in communication. In this routing protocols the nodes with higher energy does data aggregation/processing and send the aggregated data to the sink (i.e. Base Station) and lower energy nodes senses the environment for data and send the sensed data to higher energy nodes. Hierarchical routing tries to improve lifetime of the network, overall energy efficiency and scalability of sensor nodes by creating clusters, cluster heads and performing data fusion within the clusters. LEACH (Low Energy Adaptive Clustering Hierarchy) [2,20], PEGASIS (Power Efficient Gathering In Sensor Information Systems) [3], SMECN (Small Minimum Energy Communication Network), HEED (Hybrid Energy-efficient Distributed Clustering approach) [8] are some examples of this routing protocol.
- **Location Based Routing:** In this routing, Sensor nodes are addressed

by means of their locations. The distance between the neighboring nodes are obtained on the basis of incoming signal strength. In some instances GPS (Global Positioning System) may be used to find the location of the nodes. GAF (Geographic Adaptive Fidelity), GEAR (Geographic And Energy aware Routing) [21], SPAN [19] are some of the location based routing protocols.

## 2.2 Key Problems Of Routing Protocols

To Design an algorithm for WSNs, following issues must be considered.

- Sensor nodes are battery-operated and most often constrained in energy due to the inability of recharging of nodes. Hence one of the important method in protocol design is the energy consumption.
- Sensor nodes should be sensitive and adaptive to the dynamic environment when they are deployed.
- A sensor network algorithm should be self organizing and distributed since WSNs is infrastructure less.
- The security of the nodes should be considered.
- Scalability is another important factor to be considered when designing a topology for WSN.

Clustering routing protocols [12] have provided much longer network lifetime in contrast to flat routing protocol and location based routing protocol. In clustering routing protocol whole network is divided into number of clusters and one node in each cluster is the cluster-head which collects data from the sensor nodes within a cluster and then aggregates the received data from sensor nodes, then transmits the aggregated data to the base station (BS).

Clustering advantages:

Main advantage of clustering routing is that it reduces the number of packet or data transmission. Clustering protocols allows non-cluster head nodes to transmit data to shorter distance in order to save their energy.

Advantages Of Data Aggregation :

Various types of data aggregation have been proposed till date. In [11] a new data aggregation was introduced which compresses the data, originally inspired by [10]. The author of [11] discussed different data aggregation schemes: in-network, grid based, hybrid based. The most commonly used data aggregation such as in LEACH and LEACH like protocols assumes perfect aggregation in which multiple packets are sent from the cluster members to their respective cluster-heads but only a single copy is forwarded to the base station.

## **2.3 Review of WSNs Hierarchical routing protocols**

This section contains review of cluster based routing protocols. They are :

### **2.3.1 Low Energy Adaptive Clustering Hierarchy(LEACH)**

LEACH (Low Energy Adaptive Clustering Hierarchy) [2] was one of the earliest Hierarchical clustering protocol in order to increase the lifespan of the network. In LEACH protocol sensor nodes organize themselves into clusters. LEACH protocol consists of rounds. In each cluster one node acts as CH (Cluster Head) and the remaining nodes as the member nodes of that cluster. Only CHs can directly communicate to BS and the non-cluster head nodes use CHs as an intermediate router to communicate with the BS. CHs collect all the data from its member nodes and aggregate them and then send the aggregated data to the base station (BS). Because of this additional responsibilities CHs dissipate energy more quickly than other nodes and if CHs remain permanently then they die more quickly.

as in case of static clustering. So, LEACH adopts the randomized rotation for CHs to save battery of individual nodes. In this way LEACH maximizes the lifetime of the network and also reduces the energy dissipation by compressing the data before sending it to the BS.

Operation of LEACH protocol is based on rounds, where each round consists of two phases. These are setup phase and steady state phase. In setup phase CHs and clusters are created. All nodes are managed into multiple clusters. Some nodes elect themselves as the CHs without consideration with the other nodes. CH nodes elect themselves on behalf suggested percentage  $P$  and their previous record as a CH. All nodes which are not cluster heads in the previous  $1/p$  rounds, generate a random number between 0 and 1 and if that value is less than the threshold  $T(n)$  then this node becomes CH. Threshold value is set as following formula:

$$T(n) = \begin{cases} \frac{P}{1 - P(r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad (2.1)$$

Where  $G$  is the set of the nodes that have not been selected as CHs in previous  $1/p$  rounds,  $P$  is the suggested percentage of CHs,  $r$  is the current round. If a node has become CH in the current round then it will become CH after next  $1/p$  rounds. Now each selected CHs broadcast their status by using CSMA/CA protocol. Non-cluster head nodes select their CHs by comparing Received Signal Strength Indication (RSSI) of multiple CHs from which advertisement came. The sensor nodes send the join-request message along with the CHs IDs to which they want to join. After the clusters are formed, CHs send TDMA schedule to their respective cluster members.

After clusters are formed and each member gets their time slot then Steady state phase begins. In this phase nodes communicate to CH during allocated time slots otherwise nodes are in sleep mode. All the sensor nodes send their data to their CHs and CHs aggregate the data and then send it to the BS. In this way the lifetime of the sensor network is increased. Usually steady state phase is longer than the setup

phase. LEACH network topology is shown below:

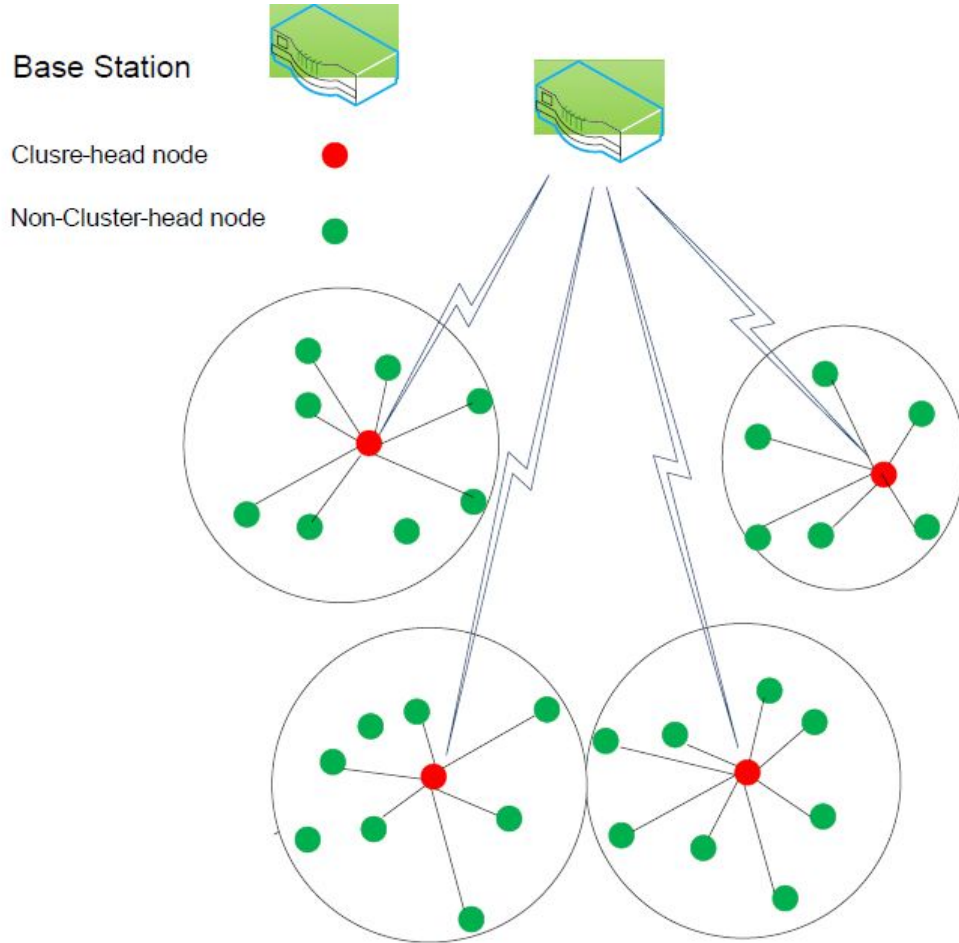


Figure 2.2: Clustering topology of LEACH

LEACH reduces energy dissipation with the help of following features:

- Reducing number of data transmission by performing data aggregation before sending it to BS.
- Reducing the number of direct transmission to base station by using CHs.
- LEACH increases the lifetime of the nodes by randomized rotation of CHs.
- LEACH allows the non cluster head nodes to sleep until their time slot comes. This saves a lot of energy.

- LEACH makes WSNs scalable and robust.

#### **Disadvantages of LEACH protocol:**

Cluster heads (CHs) are selected randomly, so the optimal number and distribution of cluster heads cannot be ensured. The node with the low remaining energy has the same probability as the node with high remaining energy to become the CH. So if a node with low energy is selected as CH, that node will die very early. This will degrade the network lifetime. LEACH cannot be used for large networks.

### **2.3.2 LEACH-Centralized (LEACH-C)**

LEACH-C[20] also consists of rounds. The setup phase and the steady state phase. This differs from traditional LEACH in setup phase and steady state phase is the same. In LEACH-C during setup phase each sensor node sends their energy status, location information and node IDs to the base station. The base station species some nodes as CHs and non-CHs by using central control algorithm. By using Central control algorithm BS compares the energy of all the nodes with specific average energy level. If energy of the nodes is less than average energy, BS categorizes that node as member node. BS selects optimal number of CHs from the node whose energy is above the average energy level. Then the BS broadcasts the node IDs of selected CHs to all network nodes. BS also tries to minimize the distance between nodes and CHs. This central algorithm produces much better clustering than distributed clustering algorithm. LEACH-C uses some necessary assumptions that each node can compute its energy, know its location and can transmit this information to BS no matter how far the BS is from the node.

Steady state phase is same as the LEACH protocol but LEACH-C enhances the number of packets received at the BS. It is because of optimal number of selected cluster head and their effective location with respect to non-CH nodes. LEACH-C is slightly better than LEACH.

#### **Drawbacks of LEACH-C protocol:**

In setup phase all the nodes have to send their information to the BS. This dissipates



extra energy of all nodes in each round. BS selects suitable CHs and broadcast its IDs to the network. Normal nodes also dissipates energy unnecessarily matching their node IDs to CHs node IDs. This is the main disadvantage of LEACH-C.

### 2.3.3 Power Efficient Gathering In Sensor Information Systems(PEGASIS)

PEGASIS[3] is a chain based routing. To overcome the burden of dynamic clustering in LEACH, PEGASIS constructs chain instead of clusters. In PEGASIS all nodes communicates with their closest neighbors and continues their communication until the aggregated data reach the BS. Thus this improves the network lifetime, since it reduces the power consumption required per round. PEGASIS protocol also consist of rounds. They are:

- Chain Formation.
- Leader Selection.
- Data Transmission.

#### CHAIN FORMATION:

For constructing the chain the PEGASIS protocol starts from furthest from the base station and uses Greedy algorithm to form chain. Each node communicates with its two neighbors to transmit data. In Fig.2.3 node C0 lies furthest from base station. So chain starts from C0. After that node C1 is selected and so on till node C5.

#### Leader Selection

At the beginning of each round leader node is selected randomly. The benefit of selecting the random node is that if the node dies at random location the network will be robust. After the leader is selected a token is passed to the end node to initiate

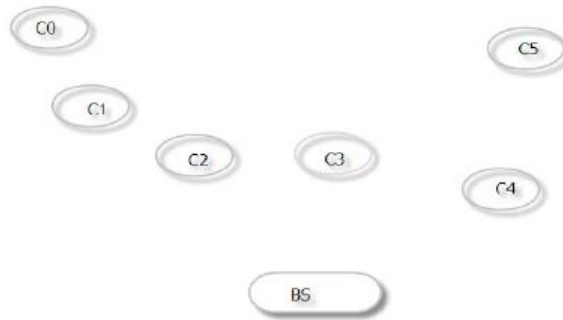


Figure 2.3: Chain formation in PEGASIS

the data gathering. Passing token also consumes energy but the size of token is so small that the cost for passing is very small.

### Data Transmission

The node who has the token starts sending its data to its neighbor. The neighbor node fuses its data with the data which it has received and then passes the data to its neighbor. This process continues till it reaches the leader node. Then the leader node transmits the fused data to the BS. The leader node is then rotated randomly in each round.

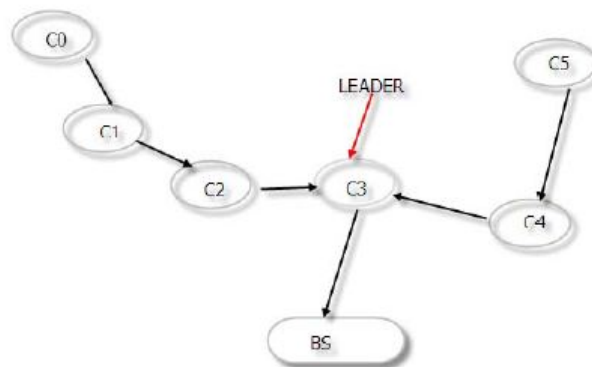


Figure 2.4: Data Transmission

### Drawback of PEGASIS Protocol:

PEGASIS doesn't consider the location of nodes and its energy while selecting the

leader nodes. PEGASIS suffers from LLs(Long links) since in constructing chain we use Greedy algorithm and in Greedy algo. the closest node selected is closest locally and it may not be the nearest or closest globally. So delay in Transmission is more. So further modification in PEGASIS can be done.

## 2.4 Chain Cluster Based Mixed Routing(CCM)

Tang et al.[7] proposed CCM algorithm for WSNs. In this protocol sensor nodes are organised as horizontal chains and vertical clusters with chain heads only. In this data transmission is carried out in two steps: chain clustering and then cluster routing. In the first stage a number of chains are formed in horizontal basis and in each chain there is a chain head. Each node in the chain transmits their data to their chain heads in parallel. After this a cluster is formed which contains only chain heads of all the chains. Then all the chain heads send their fused data to a voted cluster head in the cluster formed.

## 2.5 CBRP

Zarei et al.[4] proposed CBRP protocol for data gathering in WSNs. CBRP clusters the sensor network by using new factors. After that a spanning tree is constructed for sending aggregated data to the BS. In this tree there is a root node and all others are non-root nodes. Only root node can send data to the BS. The drawback of CBRP is the much overhead in communication of non data messages exchanged between sensor nodes.

## 2.6 Energy Efficient Clustering Protocol(EECPL)

Bajaber and Awan.[5] proposed EECPL routing protocol to enhance the lifetime of the sensor networks. EECPL elects a cluster sender and a cluster head for each

cluster. Cluster head is responsible for creating and distributing TDMA schedule for each node in the clusters and cluster sender takes the data from sensor nodes and aggregate then and then send them to the base station. EECPL clusters the network into no. of clusters and selects a cluster head and a cluster sender. In each cluster a ring is formed such that each node sends data to a single neighbor and receives from one neighbor only. When the cluster sender gets the aggregated data from the sensor nodes then it transmits it to the BS directly.

# Chapter 3

## Proposed Model

### 3.1 Introduction

In WSNs the main source of energy is the battery and the power of it is very limited. Once the sensor nodes are deployed in the harsh environment, it is impossible to replace it or recharge it. So it is better to utilize the battery power efficiently. Keeping this in mind many energy efficient protocols have been proposed till date.

Cluster based routing have helped a lot in order to enhance the lifetime of the sensor network and reduce the communication cost. All the Conventional based clustering[2,3,4,8] protocols divide the sensor network into number of clusters and each cluster has a cluster head. The sensor nodes send their sensed data to their respective CHs and the CHs perform data aggregation and then send the aggregated data to the BS. Thus CHs drain energy more quickly than other nodes in the clusters, reducing the lifetime of the networks. Some clustering protocols like LEACH[2] rotate the cluster heads in order to maintain the energy of all the nodes. But it suffers from clustering overhead. Static clustering fixes the clusters and thus the overhead of dynamic clustering is avoided. But fixed clusters do not allow new nodes to join the clusters and thus the nodes' performance is not affected by

nodes dying. To avoid this chain based routing protocols were proposed. PEGASIS is a chain based protocol but it suffers from transmission delays due to long links(LL). In order to avoid this we proposed Energy Efficient Clustered Chain Based Power Aware Routing Protocol(EECCPAR) For Wireless Sensor Networks. The main goal of this protocol is to enhance the lifetime of the network and reduce the communication cost by evenly distributing the energy load among all sensor nodes. This protocol divides the network into clusters and then constructs chain among cluster members and also among CHs. During data transmission CHs introduces three Thresholds i.e. MIN, MAX and Change Factor. Simulation results show that this protocol performs better than PEGASIS. This protocol doesn't suffers from clustering overhead, since clustering is not performed in each phase.

## 3.2 Assumptions And Radio Energy Model

Various assumption of our model is discussed. First order radio model is being used.

### 3.2.1 Assumptions

- BS is located far away from the sensing field and the sensor nodes are stationary once they are deployed.
- Sensor nodes are homogeneous .i.e all the sensor nodes have same initial energy, a battery.
- Radio channel is symmetric means the energy consumed for transmitting a message is the same for receiving it.
- All the sensor nodes have knowledge of its location and energy.

### 3.2.2 Radio Energy Model

The energy model described in [2,20] is being used by us here for communication energy dissipation. Transmission Energy required to transmit 1 bit of data over distance  $d$  is calculated as:

$$E_{Tx}(l, d) = \begin{cases} lE_{elec} + \epsilon_{fs} d^2, & d < d_0 \\ lE_{elec} + \epsilon_{amp} d^4, & d \geq d_0 \end{cases} \quad (3.1)$$

To receive same message energy required will be:

$$E_{Rx}(l) = lE_{elec} \quad (3.2)$$

Where  $E_{elec}$  is the energy dissipated to run the receiver or transmitter amplifier and  $\epsilon_{fs} d^2$  or  $\epsilon_{amp} d^4$  is the amplifier energy, depends upon acceptable bit-error rate. In equation one can see that in receiving data a lot of energy is required. Thus the no of transmission and receiving should be reduced, in order to maximize the energy usage.

## 3.3 Energy Efficient Clustered Chain Based Power Aware Routing Protocol (EECCPAR)

We propose an Energy Efficient Clustered Chain Based Power Aware Routing Protocol (EECCPAR) for WSNs in order to enhance network lifetime and reduce communication cost. The operation of our protocol is divided into rounds. Each round consists of following phases:

1. Clustering Phase.
2. Chain Formation Phase.
3. Data Transmission Phase.

Due to reduction of clustering overhead, clustering is not performed in each round

in our proposed protocol. So sensor nodes use residual energy of nodes to select CH for the next round rather than BS station selecting the CHs.

### 3.3.1 Clustering Phase

Clustering phase consists of the following stages:

- Cluster Head Selection.
- Cluster Formation.

#### Cluster Head Selection

In our model, each node maintains a neighboring table to store the information about its neighbors. Each node knows about its residual energy and location by using GPS (Global Positioning System). Then each node broadcasts its information to all the nodes in the radio range  $r$  by using CSMA MAC protocol. Each node which is one hop away in the radio range  $r$  of the broadcasting node is a neighbor of the node. Each node receives the information message in the radio range and updates its neighborhood table. Then each node calculates its distance from its neighbor nodes and also they calculate their weights by the following formula:

$$W_i = RE_i * \sum_{j=1}^{Number\ of\ nodes} \frac{1}{d^2(v_i, v_j)} \quad (3.3)$$

In the above equation  $W_i$  is the weight of node  $i$  and  $d(v_i, v_j)$  is the distance between node  $i$  and node  $j$ . Now each node broadcasts its weight in the radio range  $r$  and the node which has the highest weight among all its neighbors in the radio range  $r$  is selected as Cluster Head (CH).

#### Cluster Formation

After the cluster heads are selected, they (CHs) broadcast an advertisement message, which contains the nodes ID and header which distinguishes it from



other messages. CHs use non persistent CSMA MAC protocol to broadcast the advertisement messages. Based upon the RSSI (Received Signal Strength Information) the nodes select their CH (Cluster Head). Now the node sends the join request message to the chosen CH. The join request message contains the CH's ID to which the node wants to join and also it contains the node's ID. The node uses non persistent Carrier Sense Multiple Access (CSMA) MAC protocol to send the join request message to the CHs.

The clustering phase is not performed in each round because of its high overhead. If any node dies in the cluster then the CH informs the BS that the sensors should not perform clustering in the beginning of the next round. Otherwise sensors nodes select the new CHs based on the Residual energy of the nodes.

### 3.3.2 Chain Formation Phase

This round consists of following stages:

- 1.Chain Formation Within Clusters.
- 2.Chain Formation Among CHs.

#### Chain Formation Within Clusters

After clusters are formed and CHs are selected, the CHs create chain between the nodes within the clusters, so that each node receives data from its previous neighbor and aggregate its data with the data received from its previous neighbor and send it to its next neighbor.

The chain in the cluster is formed starting from the furthest node from the CH. Then the node which is close neighbor of the selected node is selected as next node of the chain. So on till the last node is added to the chain. When the chain construction is complete, then the CH creates TDMA schedule for each node in the cluster, which specifies the time slot for each node in the cluster. Then, CH sends the time schedule and chain information to all the sensor nodes in the cluster.

### Chain Formation Among CHs

The CHs sends their location and Residual energy to the BS. The BS creates a chain of cluster heads based on the received information. Then the BS sends it to the CHs. The BS applies Greedy algorithm to construct the chain among the CHs. It starts from the furthest node to the nearest node from the BS and nearer node to the BS has the better opportunity to become the leader of the CHs in the chain.

Thus the clusters and chain formed are as follows:

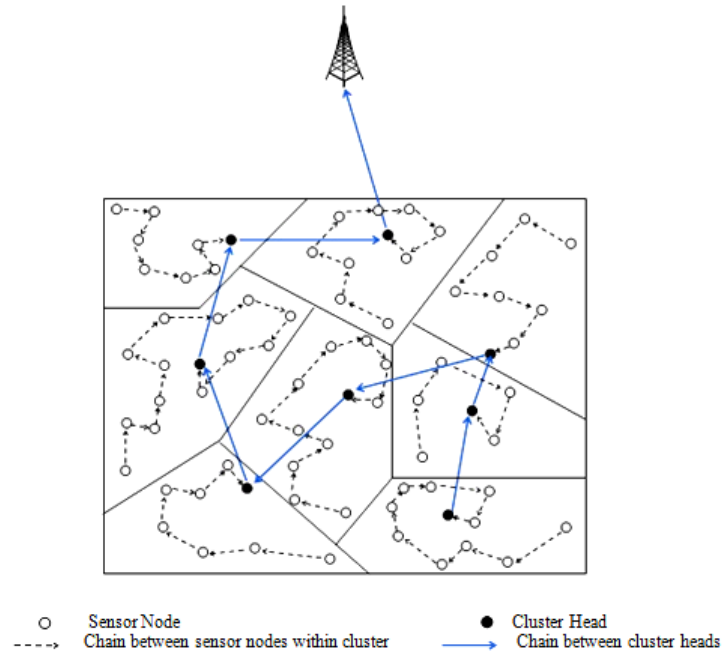


Figure 3.1: Clusters and chain formed

### 3.3.3 Data Transmission Phase

When the chain is formed within each clusters, the cluster head broadcasts the following three parameters :MIN threshold, MAX threshold and Change factor to all the nodes of its clusters. In the chain each node sends its value to its neighbor. The neighbor node aggregates the value received from its previous neighbor with its own

value and and sends the aggregated value to its next neighbor.

Every sensor node senses the environment continuously. If the sensed value of the node is less than the MIN threshold, then the sensor node doesn't aggregate its sensed value with the data received from its previous node in the chain. This node directly sends the data received from the previous node of the chain without aggregating with its own data to the next neighbor node in the chain. Thus MIN threshold saves the energy of the nodes by not allowing them to perform data aggregation. When the value of the sensed attribute is more than MIN threshold but less than MAX threshold and the change in sensed attribute value is less than the change factor, then node doesn't have to do the aggregation of sensed attribute with the previous nodes data in the chain. Thus change factor also plays important role in enhancing energy efficiency of the sensor network. Because of the above two cases if any node doesn't receive any data from its previous node in the chain, then the node doesn't have to perform data aggregation. Thus in this way a lot of energy is saved of the Sensor nodes. If the value of sensed attribute is greater than MIN threshold but less than MAX threshold and the change in the attribute value is more than the change factor, then the node will aggregate its data with the data received from its previous neighbor in the chain and then it will pass it to the next neighbor. In this way the data will reach the CH.

When the CHs receive the data from its cluster members, then the transmission of data starts in the CHs chain. In these the nodes aggregate their data with the previous neighbors data and send it to the next neighbor. At last the aggregated data reaches the leader of CHs chain and the leader of cluster heads chain send the data to the BS.

In normal cases the sensed data will have to wait for their scheduled timeslot to be transmitted. But delay in time critical data is not tolerable. Thus the concept of MAX threshold is being used for time critical data. If the value of sensed attribute is less than MAX threshold, then normal mode of transmission will be followed and if the

value is greater than MAX threshold, it means it is time critical data. So in that case the critical data is sent directly to the CH and CH sends the Data directly to the BS.

Data transmission distance within clusters is smaller than the distance between CHs. Thus the energy of CHs will drain more quickly than sensor nodes within clusters. So CHs should be rotated in order to balance the energy of the nodes. Each sensor node sends its residual energy along with the aggregated data in the chain. The next node in the chain compares its energy with the previous node of the chain and selects the higher residual energy and sends it to the next node along with the aggregated data. When this data reaches the CH, it selects the node with the highest residual energy as CH for the next round. Then the next round begins.

# Chapter 4

## Simulation And Results

### 4.1 Simulation And Results

The performance of EECCPAR protocol is being evaluated by simulation. For simulation we used MATALAB and tested our protocols performance with PEGASIS and LEACH.

For performance evaluation following parameters are taken into account:

- Load balancing.
- Energy consumption.
- Network Throughput.

#### 4.1.1 Simulation Setup

Network size is considered as 100m X 100m and the number of nodes are 100 which are scattered randomly in the sensor field. BS is located at (50,175). Parameters for our simulation is as follows:

Parameters	Values
Network Size	(0,0) to (100,100)
Number of nodes	100
Base Station Location	(50,175)
Cluster Radius r	20 m
Initial Energy Of Nodes	0.3J
Data Packet Size	500 Bytes
Broadcast Packet Size	25 Bytes
$E_{elec}$	50nJ/bit
$\epsilon_{fs}$	100pJ/bit/m <sup>2</sup>
$\epsilon_{amp}$	0.0013pJ/bit/m <sup>2</sup>
$d_0$	87.7 m
$E_{DA}$	5 nJ/bit/signal

Table 4.1: Simulation Parameter

### 4.1.2 Simulation Result And Analysis

#### Load Balancing

The percentage of Remaining energy of the network,when the first node dies is defined as Load Balancing.Following figure shows the total remaining energy of the network when the first node dies:

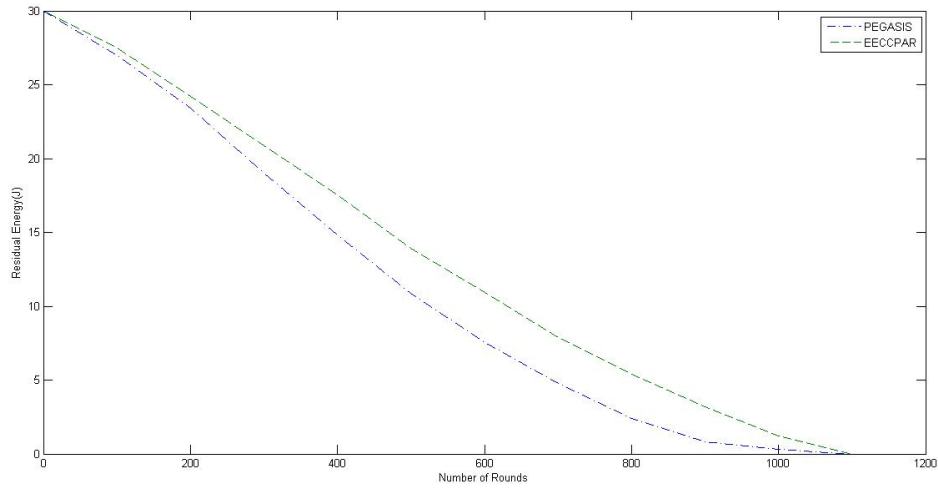


Figure 4.1: The Remaining Energy of The Network Over Round

#### Energy Consumption

Figure 4.2 shows the energy consumed by all the nodes during the simulation run. From fig. it is clear that EECCPAR uses less energy as compared to PEGASIS protocol. This is possible because each node transmits to its close neighbor in the chain and then to the CHs. Then the CHs send the data to their next neighbors till the BS but other protocol sends the data directly to BS through the CH. EECCPAR doesn't perform clustering in each round thus it reduces the energy consumption of the Network.

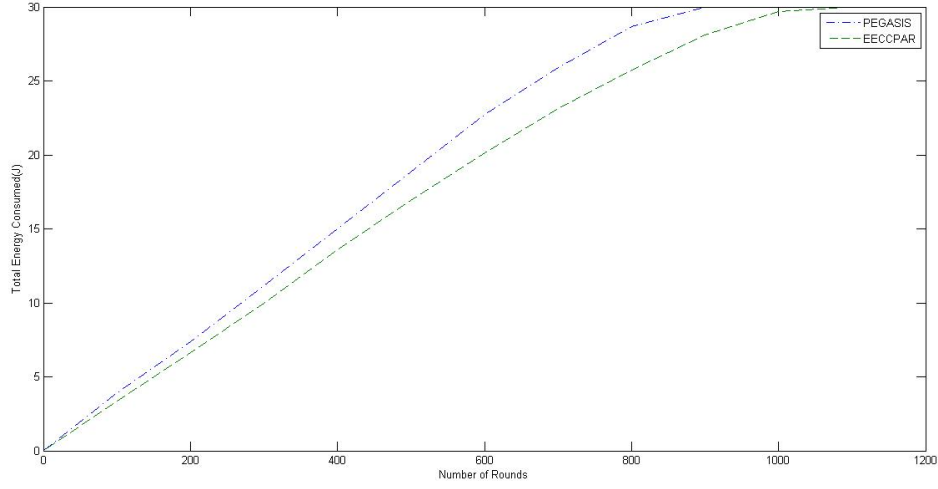


Figure 4.2: The Total Energy Consumed of The Network Per Round

### Network Throughput

The total number of packets recieved at the base station is known as network throughput. Figure 4.3 and 4.4 shows the number of data buckets received at the base station. Figures shows that EECCPAR performs better than other protocols. Fig.4.4 shows that the number of messages received at the BS Over energy is more than the PEGASIS protocol. This happened because of the less distance between sensor nodes and CH.



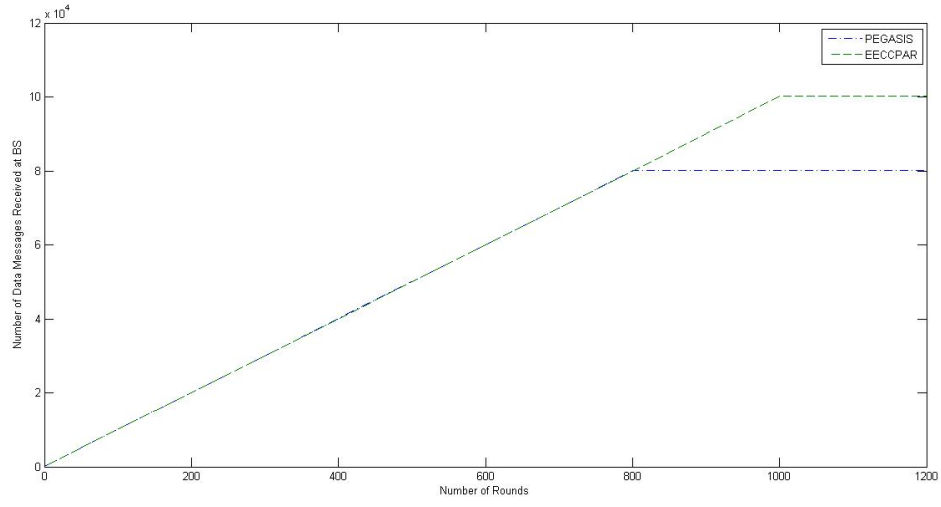


Figure 4.3: The Number Of Data Messages Received At BS over Round

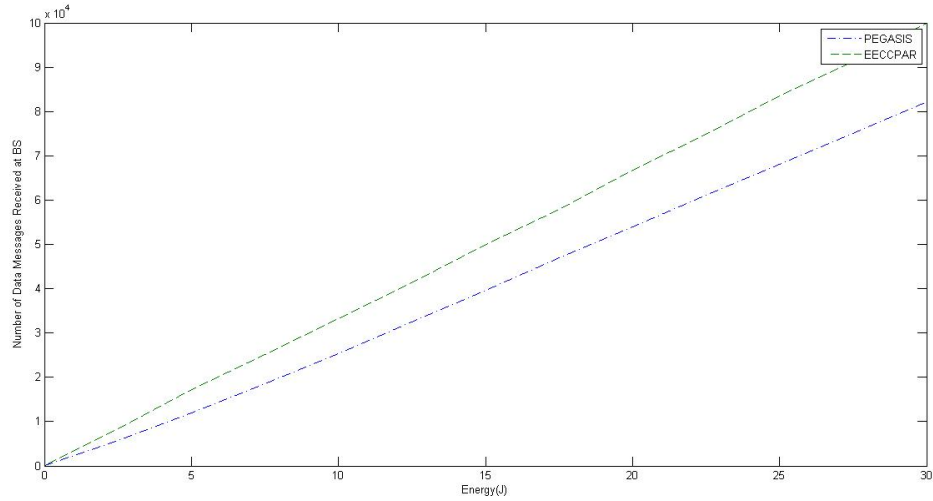


Figure 4.4: The Number Of Data Messages Recieved At BS over Energy

## Chapter 5

# Conclusion and Future work

In this paper we proposed Energy Efficient Clustered Chain Based Power Aware Routing protocol (EECCPAR) which maximizes the network lifetime and balances the energy consumption among the sensor nodes of the network. EECCPAR organises the whole network into clusters and selects cluster heads. Then it constructs chain within the clusters so that each node transmits data to its next neighbor and receives data from its previous neighbor. In this protocol we also construct chain among cluster heads (CHs). Thus data are sent to the BS through the chain. Thus it helps nodes to transmit data to a smaller distance and thus increases the lifetime of the network. In this protocol we don't form clusters in each round. But in LEACH protocol, in each round clustering is done. Thus it (LEACH) suffers from clustering overhead. Simulation results show that EECCPAR performs better than PEGASIS protocol in terms of Network Throughput, Load Balancing and number of data messages transmitted to the BS. It performs better than other protocols like LEACH, since in our protocol clustering is not done in each round but in LEACH it is done in each round. In our protocol we also consider time critical data, which is not considered in other routing protocols. Time critical data should reach the destination quickly without much delay. For this we have introduced the concept of MAX threshold.

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