International Journal of Research in Advent Technology (E-ISSN: 2321-9637) Special Issue
1st International Conference on Advent Trends in Engineering, Science and Technology
"ICATEST 2015", 08 March 2015

A Review on Adaptive Clustering Routing Protocol using Twice Cluster Head Selection

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Abstract— A wireless sensor network (WSN) consists of spatially distributed sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a Base station which communicates the data further for processing.Networking together thousands of cheap microsensor nodes allows users to accurately monitor a remote environment by intelligently combining the data from the individual nodes. The sensor nodes have limited battery power sources and bandwidth. LEACH protocol is one of the clustering routing protocols in wireless sensor networks which is able to distribute energy dissipation evenly throughout the sensors.In this paper, we develop and analyze low-energy adaptive clustering hierarchy (LEACH), a protocol architecture for microsensor networks that combines the ideas of energy-efficient cluster-based routing and media access together. The proposed protocol is an enhancement of Leach which selects the top ten percent of the total sensor nodes which have highest residual energies. The proposed protocol will optimize the energy of the WSN and increase the network lifetime as compared to Leach protocol. There are two phases of the protocol i.e. setup phase and steady phase.

Keywords :Wireless sensor networks, base station, Clustering, Leach protocol, network lifetime**.**

1. INTRODUCTION

The sensor nodes are scattered in an unattended environment to sense the physical world. The sensed data can be collected by sink nodes which have accesses to infrastructure networks like the Internet.An important challenge in the design of these networks is that two key resources—communication bandwidth and energy. The most straightforward application of wireless sensor network technology is to monitor remote environments for low frequency data trends. A wireless sensor network usually includes sensor nodes, sink node and management node. The data monitored by sensor nodes is transmitted along other nodes one by one, that will reachthe sink node after a multi-hop routing and finally reach the management node through the wired and wireless Internet.The energy, the ability of signal process, storage capacity and communication capability of sensor nodes are very limited. A primary design goal for wireless sensor networks is to use the energy efficiently.Cluster-based routing algorithm has a better energy utilization rate compared with non-cluster routing algorithm. In clustering routing the nodes forms the clusters and one node of the cluster will become the cluster head sends all gathered data from the nodes in its cluster to the base station. Hence it uses the information aggregation mechanism in the cluster head to reduce the amount of data transmission, thereby, reduce the energy dissipation in communication and in turn achieve the purpose of saving energy of the sensor nodes. In the clustering routing algorithms for wireless networks, LEACH (low-energy adaptive clustering hierarchy) is well-known because it is simple and efficient. LEACH divides the whole network into several clusters, and the network is broken into many rounds. In each round, the nodes in a cluster compete with each other to be cluster head according to a predefined criterion. This feature leads to a balanced distribution of the energy consumption and makes it possible to be longer lifetime for the entire network. Some works have been conducted on the performance and enhancement of LEACH protocol. This paper proposes an enhanced version of

Leach Protocol which aims at prolonging the lifetime of WSN by changing the criterion of selecting cluster heads.

2. Literature Survey

2.1 A survey on sensor networks

The authorspresent communication architecture for sensor networks and proceed to survey the current research pertaining to all layers of the protocol stack: Physical, Data Link, Network, Transport and Application layers.

A sensor network is defined as being composed of a large number of nodes which are deployed densely in close proximity to the phenomenon to be monitored. Each of these nodes collects data and its purpose is to route this information back to a sink. The network must possess self-organizing capabilities sincethe positions of individual nodes are not predetermined. Cooperation among nodes is the dominant feature of this type of network, where groups of nodes cooperate to disseminate the information gathered in their vicinity to the user.

Major differences between sensor and ad-hoc networks:

- Number of nodes can be orders of magnitude higher.
- Sensor nodes are densely deployed
- Sensor nodes are prone to failure.
- Frequent topology changes.
- Broadcast communication paradigm.
- Limited power, processing and power capabilities.
- Possible absence of unique global identification per node.

The authors point out that none of the studies surveyed has a fully integrated view of all the factors drivingthe design of sensor networks and proceeds to present its own communication architecture and designfactors to be used as a guideline and as a tool to compare various protocols. After surveying the literature,this is our impression as well and we include it in the open research issues that can be explored for futurework. The design factors listed by the authors:

- Fault Tolerance: Individual nodes are prone to unexpected failure with a much higher probability thanother types of networks. The network should sustain information dissemination in spite of failures.
- Scalability: Number in the order of hundreds or thousands. Protocols should be able to scale to such high degree and take advantage of the high density of such networks.
- Production Costs: The cost of a single node must be low, much less than $1.
- Transmission Media: RF, Infrared and Optical.
- Power Consumption: Power conservation and power management are primary design factors.

2.2 Directed Diffusion: A Scalable and Robust Communication

Problem

Sensor networks have different requirements than other wireless networks. The need for robustness andscalability leads to the design of localized algorithms, where sensors only interact with other sensors in restricted vicinity and have at best an indirect global view.

Approach

The authors argue in favor of designing localized algorithms and present directed diffusion as a set ofabstractions that describe the communication patterns underlying such algorithms. The design featuresdiffer from traditional wireless networks and are data-centric and application-specific.

Data-centric refers to the fact that in sensor networks we are mostly interested in retrieving informationmatching certain attribute values and very rarely we will be interested only in data from a specific node. Thisapproach decouples data from the sensor that produced it and unique identification of nodes is of secondary importance. Application-specific refers to the awareness across all layers of the specific application so thatintermediate nodes can perform data aggregation, caching and informed forwarding.

The authors proceed to describe a two-level cluster formation algorithm, where cluster heads are elected
based on available energy. They present a localized algorithm for object tracking to demonstrate the difficulties that arise. The design is difficult because localized algorithms need to produce a certain globalbehavior with at best indirect global knowledge. Furthermore, localized algorithms tend to be sensitive in
the choice of parameter values.

In order to overcome these difficulties, they suggest the design and prototyping of adaptive fidelity algorithms, where the fidelity of the retrieved data can be traded against energy efficiency, network lifetime and
network bandwidth. Furthermore, by developing techniques for characterizing the performance of localizedalgorithms it is possible to quantify those tradeoffs and produce the expected behavior.

The authors propose .directed diffusion. to be used as an abstraction to model the communication patternsof localized algorithms. The data that each sensor generates is characterized by a number of attributes.Other sensors that are interested in a certain type of data, disseminate this interest to the network (in theform of attributes and degree of interest). As the interests disseminate, gradients are established that directthe diffusion of data when it becomes available, i.e., reverse paths are established for data that matches aninterest.

2.3Energy-efficient communication protocol for wireless microsensor networks

The authors present a 2-level hierarchical routing protocol (LEACH) which attempts to minimize globalenergy dissipation and distribute energy consumption evenly across all nodes. This is achieved by theformation of clusters with localized coordination, by rotating the high-energy cluster heads and by locallycompressing data.

The model used in this paper makes the following assumptions:

- There exists one fixed base station with no energy constraints and a large number of sensor nodes that are mostly stationary, homogeneous and energy constrained.
- The base station is located at some distance from the sensor nodes and the communication between a sensor node and the base station is expensive.
- The purpose of the network is to collect data through sensing at a fixed rate (i.e. there is always something to send) and convey it to the base station. The raw data is too much and must be locally aggregated into a small set of meaningful information.

The nodes self-organize into local clusters with one node in each cluster acting as a cluster head. Once a cluster has formed, the cluster members send their data to the cluster head (low energy transmission) which in turn combines the data and sends it to the base station (high energy transmission). This organization of the nodes creates a 2-level hierarchy.

For their analysis, the authors compare their scheme with a direct communication protocol (each sensor sends data directly to the base station) and the minimum-energy routing protocol. In the latter, data destined for the base station is routed through many intermediate nodes that can each be reached with minimum energy transmission. A static clustering scheme is also used where cluster heads are not rotated. Their results indicate that LEACH reduces communication energy by as much as 8x. Also, the first node death inLEACH occurs over 8 times later and the last node dies over 3 times later.

2.4 A Transmission Control Scheme for Media Access in Sensor Networks

Problem

Media access control in sensor networks must be energy efficient and allow fair bandwidth allocation to all the nodes. The authors examine how CSMA based medium access can be adapted for sensor networks. CSMA strategies include listening to the channel before transmission, using explicit positive or negative acknowledgments to signal collision, relying on time synchronized slotted channels or performing collision detection. However, these approaches are not directly applicable due to the characteristics of sensor networks:

- Network operates as a collective structure. Its primary goal is the sampling of the environment and
the propagation of the samples, possibly processed and aggregated, toward one or more gateways.
- Traffic tends to be periodic and highly correlated. Conventional schemes make the assumption ofstochastically distributed traffic.
- Every node is both a data source and a router.
- Node capabilities are very restricted.
- Equal cost per unit time for listening, receiving and transmitting.

Approach

The authors outline a CSMA-based MAC and transmission control scheme to achieve fairness while being energy efficient. They categorize media access control mechanisms into listening, backoff, contentioncontrol and rate control mechanisms.Listening combined with backoff mechanism: Neighbouring nodes will sense the same event and attemptto transmit at the same time.

According to the proposed scheme, whenever nodes need to transmit theyintroduce random delay followed by a constant listening period. If the channel is free, then they transmit.Otherwise, they enter in a backoff period, during which the radio is turned off. This backoff period is alsoapplied as a phase shift to the periodicity of the application, aiming to desynchronize nodes.Contention control mechanism: Such a mechanism should use the minimum number of control packets. If the traffic load justifies it, then a combination of request-to-send (RTS) and clear-to-send (CTS) controlpackets can be used.

Rate control mechanism: MAC should control the rate of the originating data of a node in order to allow route-thru traffic to access the channel and reach the base station. The adaptive rate control proposed, usesloss as collision signal to adjust transmission rate in a manner similar to the congestion control in TCP.

- All CSMA schemes achieve good channel utilization and aggregate fairness is almost insensitiveto the presence of backoff. However, backoff plays an important role in maintaining proportional fairness when using a fixed window size or binary exponential decrease in window size.
- Randomness in the pre-collision phase provides robustness.
- Schemes with constant listen period achieve best energy efficiency.
- Following a transmission failure with a random shift in the sampling interval, allows the nodes tobreak away from synchronization which listening and back off fail to detect.

3. LEACH

All LEACH is the first hierarchical protocol in WSN. LEACH is an adaptive clustering routing protocol proposed by Wendi B. Heinzelman. In many later literatures, it has been considered as the benchmark for other protocols. It has some characteristics like self-reconfiguration, adjustment of communication range according to distance, schedule of data transmission of individual nodes etc. In LEACH, the nodes organize themselves into clusters, with one node acting as the cluster-head. All non-cluster-head nodes transmit their data to the cluster-head, while the cluster-head node must receive data from all the cluster members, perform signal processing functions on the data, and transmit data to the remote base station. Therefore, being a cluster-head node is having more energy than being a non-cluster-head node. In the scenario where all nodes are energy-limited, if the cluster-heads were chosen a priori and fixed throughout the system lifetime, as in a static clustering algorithm, the cluster-head sensor nodes would quickly use up their limited energy. Once the cluster-head runs out of energy, it is no longer operational.

The operation of LEACH is broken up into rounds, where each round begins with a setup phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase. Initially, when clusters are being created, each node decides whether or not to become a cluster-head for the current round. This decision is based on the suggested percentage of cluster heads for the network (determined a priori) and the number of times the node has been a cluster-head so far. This decision is made by the node n choosing a random number between 0 and 1. If the number is less than a threshold T (n), the node becomes a cluster-head for the current round. The threshold is set as:

$$T(n) = \begin{cases} \dfrac{P}{1 - P\left(r \bmod \dfrac{1}{P}\right)}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases}$$

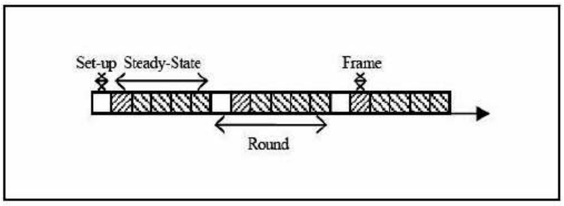


Figure 1: LEACH protocol phases

4. DESCRIPTION OF THE PROPOSED PROTOCOL

The proposed protocol is based on distributed clustering. In this protocol, all the nodes which are deployed randomly in the required environment to be monitored will be capable of communicating to every other node in the scenario. Every node will advertise its energy levels to all other nodes. The energy level of every node will be checked individually by each node and the nodes which are having energy more than the average energy level of the network are nominated for Cluster Head. The nodes which are at the top ten levels will be selected as Cluster Head initially. These Cluster Heads will advertise their selection to every other node in the network. Those nodes which are not capable of becoming the Cluster Head will wait for the advertisement made by the CH. These nodes will send a join request to the CH which is nearest to them on the basis of received signal strength. The Cluster Head will accept the cluster members and will prepare a TDMA schedule so that each node can communicate to CH without any collision. This TDMA schedule will be sent to the cluster members. Since the nodes will always have data to be send to CH, there are chances that these data may be correlated. The data collected at Cluster Head after the completion of one TDMA Cycle will be fused and aggregated. Now the communication between CH and the Base station will take place with the help of Direct Spread Spectrum so that no collision of data takes place. One by one the CH will be sending the aggregated data to the Base station for monitoring. After one round the process will be repeated again.

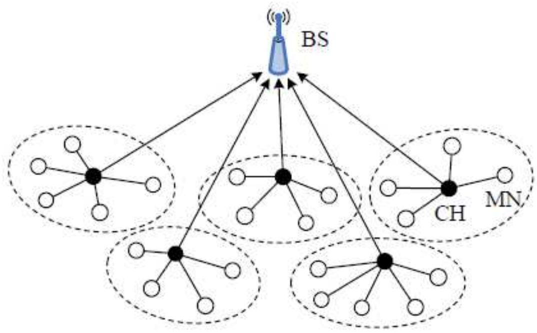


Fig: The Basic Topology of LEACH

5. FLOW OF THE PROPOSED PROTOCOL

This section describes diagrammatically the Phases of the proposed protocol. In the Phase 1 i.e. Set Up Phase, every node will advertise its energy level to the other nodes in the network. An average energy level of the network will be calculated in every node. All those nodes which are having energy level greater than or equal to the average energy level will be nominated for Cluster Head. The energy levels will be sorted in descending order by every live node in the network. Since all the nodes are identified by their Identification number, those nodes which are in the top ten level of the energy level will match their identification. After getting selected as cluster head, the CH nodes will advertise their selection and the rest of the non Cluster head nodes will send join request based on the received signal strength of the advertisement of CH nodes to the nearest CH. The Cluster Head will accept their request and will prepare a TDMA slot and the member nodes will send data accordingly. This data will be collected at Cluster Head and it will aggregate that that and will transmit this data to the Base station for monitoring.

5.1 SETUP PHASE

The setup phase consists of three parts i.e. Cluster Head Election, Cluster Formation and Schedule Creation. In the Cluster Head Election, nodes having energy level greater than the average energy level of network are nominated and then elected as Cluster Head on the basis of larger energy level. In the Cluster Formation, Non Cluster Head nodes join cluster head based on received signal strength and form the cluster. In the Schedule Creation, the Cluster Head prepares a TDMA schedule for its cluster members for data transmission. A node in the network checks whether it is selected as Cluster Head or not. If the node is not selected as Cluster Head, It will wait for the announcement to be made by the Cluster Head nodes. If the node is selected as Cluster Head, It will advertise its selection to the other nodes in the network so that the Non Cluster Head nodes can join it to become the cluster members. The Cluster Head will wait for the Join Request to be made by the non cluster heads for a time period known a prior. Non cluster head nodes will send Join Request to the Cluster Head which is nearest to them based on the received signal strength of the advertisement made by the Cluster Head nodes. The Cluster Head after getting the responses from the nodes will then prepare a TDMA schedule for its members and will again advertise this schedule only to its cluster members. This schedule will be saved by the cluster members and will send data on the basis of the allotted TDMA slot. After this the steady phase comes into play and after the completion of a round this process will be repeated again. In this way a complete round takes place.

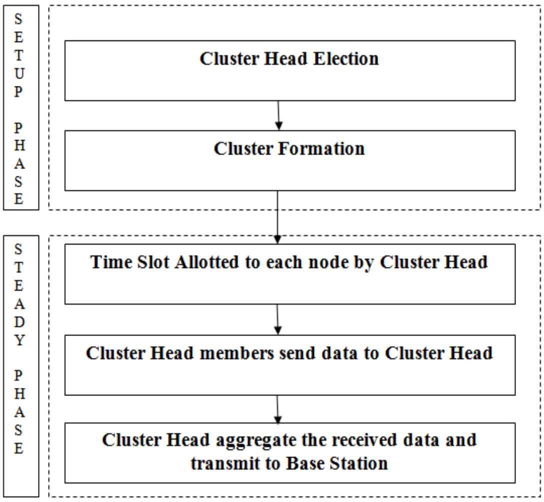


Figure 2: Workflow of the Proposed Protocol

5.1.1.Cluster Head Election

In this phase, every node in the network advertises its energy level to the every other node of the network. After this advertisement every node possesses the energy level of each and every node of the network. Now every node will arrange the received energy level of other nodes in the ascending order. The average energy of the network can be calculated as follows:

Those nodes whose energy level is less than the average energy level of the network will be discarded from the Cluster head nomination criteria. Now every node will match its ID with the top ten nodes having the highest energy level. If the ID matches, the node is selected as the Cluster Head. If the ID does not match, the node will wait for the Cluster Head announcements.

5.1.2. Cluster Formation

After getting selected as the Cluster Head, now the Cluster Heads will let the other nodes in the network know that they have chosen the role of Cluster Head for the current round. Now the Cluster head will advertise a Join Request message to all other nodes using a non persistent carrier sense multiple access (CSMA) MAC protocol [9]. This message consists of the Node ID and the Header of this message will be different from normal data messages. Each and every node which is non Cluster Heads will wait for this Join Request Message. The Cluster head will wait for the response for a time period known a prior. Every node will receive this announcement. Now the Non Cluster Head nodes will arrange the received announcements in the decreasing order of the received signal strength. Received Signal Strength is chosen because larger the received signal strength, more the node closer to it unless and until there is an obstacle in between the nodes. The nodes will check which Cluster Head is nearer to it i.e. whose received signal strength is strongest. And will select that Cluster Head. Now the node needs to inform the Cluster Head about its selection. The node will send a Join Response message which will consist of Node ID and a header differentiating it from data messages using a non persistent carrier sense multiple access (CSMA) MAC protocol back to the closest Cluster Head. The Cluster Head will accept the Response and add the node as its cluster member.

4.1.3. Schedule Creation

Since the Cluster Head also acts as Local data collection center, it will control and coordinate the data transmission between the cluster members. Now all the Cluster Heads will advertise their Cluster member information in between the Cluster Head nodes. The Cluster Head with the largest number of cluster member will set up a time period for the TDMA one cycle. For example, if one of the Cluster Head consists of 20 members and other Cluster Head consist of 10 members then the former Cluster Head will provide one second time allotment for each cluster member and the later Cluster Head will allot two seconds slot for each cluster member. This is done so that the TDMA cycle of each and every Cluster Head should complete at the same time. After the preparation of TDMA schedule by the Cluster Head, the Cluster Head sends this schedule to all its cluster members. Now the cluster members will send their data on the time slot allotted to them. Suppose there are 15 nodes in a cluster. After transmitting the data to the cluster Head, the node will go in sleep mode with its sensor active. Hence the energy of the node can be saved in sleep mode

5.2 STEADY STATE PHASE

This phase is the second phase of the proposed protocol. The steady phase consists of Data collection & Aggregation along with Data Transmission

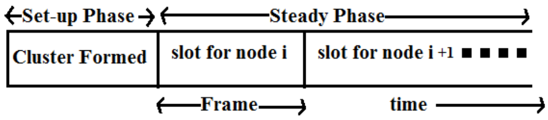


Figure3: steady phase

In Data collection, the cluster head gather data from every cluster member and fuse the data so that no redundancy left. In the data transmission, the Cluster Heads transmit the data one by one to the Base Station for monitoring.

5.2.1. Data Collection and Aggregation

Data Collection and Aggregation is important part of the Wireless Sensor Network. As the wireless sensor network is bounded by its limited energy supply, therefore emphasis should be made to transmit as less data as possible because transmission consumes most of the power of the wireless sensor network. Aggregation of data is required because if two homogeneous sensors are placed in a same geographical area, then the data sensed by them will be correlated or redundant. Hence Aggregation of data will reduce redundancy thereby decreasing the energy consumption of the network.

The Data collection operation is broken into frames where member nodes send their data to the cluster head at most once per frame during their allotted TDMA slot. The time duration for each slot is fixed where the node sends data to the Cluster Head. The data collected is then fused or aggregated by the Cluster Head so that less number of bits of data is to be sending to the Base Station. The time slot depends on the number of cluster members. It is presumed that the nodes are all time synchronized and the setup phase of the network is initiated at the same time. This is done so that each round of the clusters of the network should get completed at the same time.

5.2.2.Data Transmission

In this the data collected at Cluster Head is send to the Base Station. To reduce the energy dissipation, each node of the network uses power control mechanism. In this mechanism all nodes in the network can control their transmission and reception power as per the requirement. Suppose the maximum transmission range of a node is 200m, and the distance between the node and its Cluster Head is 35m, now if the node is transmitting the data with its maximum range, then it is dissipating its power uselessly in the environment. So the nodes can adjust the transmission power level as needed i.e. for above example the node and the Cluster head will be transmitting the data with a maximum transmission power range of 40m so that the energy could be saved.

The data to be sent to Base Station from Cluster Head is done by using fixed spreading code and CSMA. Whenever the Cluster Head has data to be sent to Base Station, it will first sense the channel to ensure that no other Cluster Head is sending the data to the Base Station. If the channel is busy or other Cluster Head are transmitting the data, then the Cluster Head will wait for a time period and then again sense the channel. Now if the channel is free the Cluster Head will send the data using DSSS. DSSS is used for data transmission because the number of cluster heads may vary after some rounds. Other channelization technique like FDMA can be used but it is harder to allot frequency dynamically. The drawback of DSSS is that it requires tight synchronization timing.

6. Parameters Description

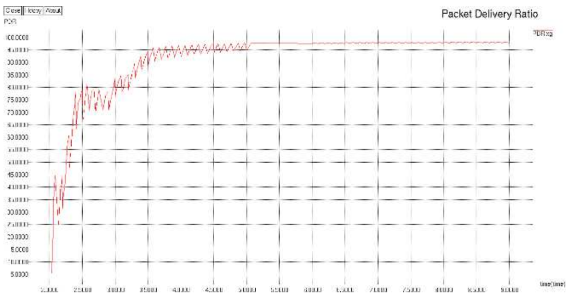
The simulation is carried out in a network grid of 100mX100m.There are two scenarios where the position of the Base station is varied. In one scenario, the location of the Base station is (50, 50) and in another scenario, the Base station is at (175, 50). The numbers of nodes taken are 100. But for the extension of protocol the number of nodes is changed to 200 to find out the proposed protocol behaviour. The percentage of Cluster Head is chosen 10 % of the live nodes in the wireless sensor network. This has been chosen 10% by the experimental analysis as shown in figure 6. The energy levels of each node are also varied in both the scenario. The energy levels are set as 0.25J, 0.50J, and 1J. In some of the experiments the energy level is chosen randomly for every sensor node in the network. It is done so that the proposed protocol should ensure it is more efficient than the LEACH protocol [4]. In some experiments the energy levels are set in multiples of 5 to 20 Joule to know about the lifetime pattern of the network as it will reveal that the network lifetime increases proportionately with the energy of the wireless sensor network. In this model the radio dissipates Eelec = 50 nJ/bit to run the transmitter or receiver circuitry and Eamp = 100 pJ/bit/m2 for the transmit amplifier. EDA=5nJ/bit/signal is the Energy required for data aggregation. €fs is the energy dissipated for free space and €mp is the energy dissipated for multi path fading in wireless sensor network. Different topologies are generated randomly for simulation. Each simulation result shows the average of independent experiments.

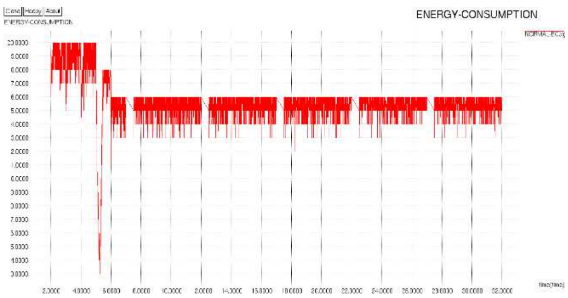
Simulation Parameters for Proposed Protocol

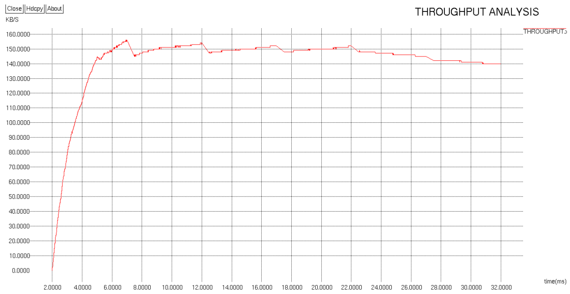
Parameters	Values
Network Grid	From (0,0) to (100,100)
Number of Nodes	100
Base Station Location	(175,50)m / (50,50)m
Initial Energy Eo	0.25 J/ 0.50J/1 J
€fs	10 pJ/bit/m4
€mp	0.0013pJ/bit/m4
Eelec	50 nJ/bit
EDA	5 nJ/bit/signal

7. CONCLUSION

The proposed protocol selects ten percent of the live node as cluster head for the cluster formation. These cluster heads possesses the highest energy levels in the wireless sensor network. This is done so because the cluster head uses more energy as compared to the other nodes in the network, cluster head receives the data packet send by its cluster member, it aggregates and fuses the gathered data and send the data to the Base Station. Thus the proposed protocol improves the network lifetime and hence is more energy efficient.







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