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EFFICIENT ENERGY UTILIZATION USING DE-LEACH CLUSTERING APPROACH AND PROLONGING NETWORK LIFETIME IN WIRELESS SENSOR NETWORKS

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Abstract - The advent of wireless sensor networks has radically changed the advancement of efficient short-range radio communication and miniaturization of computing devices paving way to the future Internet of Services and more aptly the Internet of Things. The autonomous sensors are densely deployed in wireless sensor networks to monitor physical or environmental conditions such as temperature, pressure and sound. This network of devices called nodes, sense the external environment and gathers the information through wireless links. These nodes are redistributed with limited battery energy and therefore enhancement and prolonging of network lifetime by minimizing energy-usage is of utmost importance. One of the solutions to abate such energy-usage is clustering of network nodes. The crux of this work proposes an enhanced clustering scheme called DE-LEACH, where cluster heads communicate directly with the sink, towards keeping the network alive for an extended period of time by balancing energy consumption among the cluster heads and chaining of sensor nodes for proximity towards the sink. Clustering has significantly proven to be the most efficient and effective approach in Wireless Sensor Networks, for organizing the network into a connected hierarchy and choosing the optimal and sub-optimal braided multipath, free from any failure of nodes. The contribution is measured not only based on transmission energy of the nodes but also on their relative positions in the cluster. Performance of the scheme is measured in terms of throughput and network delay. Exhaustive simulation is performed varying different parameters like energy, time delay and throughput that greatly influence network lifetime. Results in each case are plotted in graphs, showing that energy is balanced among cluster heads in the wireless sensor network, thus prolonging the network lifetime.
Keywords -Wireless Sensor Networks, Energy Efficient, Clustering, Data Aggregation,DE-LEACH,Network Lifetime,OMNeT++

1. INTRODUCTION

Wireless sensor network (WSN) is one of the most promising areas, which consists of densely distributed autonomous sensors that play vital role in monitoring the physical or environmental conditions, such as temperature, sound, pressure, etc. WSN is designed such that it cooperatively passes the data through the network to a chosen main location. It has gateway that provides wireless connectivity back to the wired world and distributed nodes. Wireless sensor networks have the potential to revolutionize telecommunications in a way similar to what we call the Internet of Things (IoT) by offering a wide range of different applications some of which remain to be unearthed or discovered [1].

A sensor node is also known as a ‘mote’. The role of a mote (sensor node) in a wireless sensor network is its capability to perform all the necessary processing, gathering sensory information and communicating with other gateway sensor node. A wireless sensor network is a conglomeration of nodes organized into a cooperative network. The nodes in WSN form the sensor field and a dedicated sink, to which all nodes communicate. These large numbers of nodes are embedded with the circumambient ability to sense their surroundings, perform limited computation and communicate wirelessly with other nodes in the network [1].

There are 5 layers in WSN: Physical, Data link, Network, Transport and Application. A WSN can be defined as a network of devices. The data is forwarded, possibly via multiple hops, to a sink (sometimes denoted as controller or monitor) that can use it locally or is connected to other devices denoted as nodes, which can sense and perceive the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless networks (e.g., the Internet) via a gateway. The characteristics of such nodes can be constant (stationary) or moving, can be homogeneous or heterogeneous and can be either aware of their location or not [2].

Energy Efficiency is of prime importance in the design and implementation of WSNs. Specifically, the design of energy efficient communication protocols is a very peculiar issue of WSNs, without significant precedent in wireless network history [2]. So such a new architecture requires a foundation of a new clustering technique that, that enhances the overall network lifetime and thereby providing effective solution for efficient energy utilization of sensor nodes in the wireless network.

This paper is organized into various sections, which commences with an Introduction giving an overall idea of the concept of Wireless Sensor Networks. Section II describes the need for clustering for efficient energy utilization of WSN. Section III presents the overall objective of the manuscript. Section IV describes the proposed system architecture.Section V presents the

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Dimensionally Enhanced LEACH (DE-LEACH) algorithm. Section VI describes the simulation results. Finally, Section VII presents with the conclusion of the paper.
The prime objective of this manuscript is to sharply focus on an enhanced novel clustering approach that aid in enhancing the network life time and in-turn provide with efficient energy utilization of the overall wireless network.

2. THE NEED FOR CLUSTERING IN EFFICIENT ENERGY UTILIZATION OF WSN

The need of the hour for WSN is energy efficient network. Clustering plays a significant role for energy saving in WSN. The process of grouping the sensor nodes in a densely deployed large-scale sensor network is known as clustering. Sensor nodes are battery-powered and hence are most likely to drain out of power, which affects the overall lifetime of the wireless network. A sensor network can be made scalable by assembling the sensor nodes into groups i.e. clusters. Every cluster has a leader, often referred to as the cluster head (CH). A CH is either elected by the neighboring member nodes in a cluster or it may be pre-assigned by the network designer.
The cluster members may be fixed or variable. A number of clustering algorithms have been specifically designed for WSNs for scalability and efficient communication. The idea behind the cluster based routing concept is also utilized to perform energy efficient routing in WSNs. In gradient-based or hierarchical architecture, higher energy nodes (cluster heads) can be used to process and send the information while low energy nodes can be used to perform the sensing. The main target of hierarchical routing or cluster based routing is to efficiently retain or preserve the energy usage of sensor nodes by involving them in multi-hop communication within a particular cluster [3]. Cluster formation is generally based on the energy reserve of sensors and sensors proximity to the Cluster Head (CHs).
With clustering in WSNs, energy consumption, lifetime of the network and scalability can be significantly improved as only one cluster head node per cluster is required to perform routing task and the other sensor nodes just forward their data to cluster head [4].
Grouping sensor nodes into clusters has been widely used to obtain this objective. The clustered network is composed of member nodes, which act as slaves to master nodes, also called as cluster heads. The clustering concept is carried out as follows: The member nodes in each cluster communicate and transmit data to their respective cluster head and in turn the cluster head forwards the data after aggregation or fusion to the dedicated sink node through single or multi-hop transmission. The clustering process ensures efficient utilization of limited energy of sensor nodes and hence prolongs or extends the overall life time of the network. In general, clusters create hierarchical WSNs which incorporate efficient utilization of constrained (limited) resources of sensor nodes and thus saving considerable energy [5].

3. THE OBJECTIVE

The main aim of this manuscript is to concentrate (focus) on a novel clustering approach that aid in extending the network life time and in-turn provide with efficient energy utilization of the overall wireless network.
To achieve this objective, the following needs to be done:

i. To choose a novel and enhanced energy efficient clustering approach called Dimensionally Enhanced LEACH (DE-LEACH) algorithm that tries to augment the overall life time of network.
ii. To implement data gathering and energy efficient routing, by selecting the optimal cluster heads in each cluster that achieves in minimizing the overall energy consumption among the sensor nodes that is the dire need of wireless sensor networks.
iii. To provide a good balancing of energy consumption by random rotation of CHs and trying to evenly distribute the energy consumption among all the nodes of the network, thereby reducing energy consumption in the network nodes.

WSNs consume power in three parts:
i) Sensing: This is almost fixed power.
ii) Data communication: major power is used in this part. A sensor transceiver comprises of transmitter and receiver, followed by mixer, frequency synthesizer, voltage control oscillator and finally the PLL, power amplifier.
iii) Data processing: power consumption in data processing is meagerly less than power consumption for Data communication.
All these consume node power in addition to the startup power. Given the restrictions of the equipment and the physical environment and levels of high needs sought after with which the nodes must operate, algorithms and protocols must be designed to provide strong and efficient energy consumption.

4. SYSTEM ARCHITECTURE

In our proposed system, we have the densely deployed Sensor Network with the abundant (numerous) Sensor Nodes distributed in the network as shown in Figure 1. The nodes are clustered and the cluster members are sent to the corresponding Cluster Head (CH) of each cluster, which are used to ultimately communicate with the sink. Hence multi hop communication between the clusters and the sink takes place. We assume a corona based wireless network with a single sink node and many nodes, which are to be clustered and cluster heads are chosen based on randomized rotation of the high-energy cluster-head position such that it rotates among the various sensors in order to not drain the battery of a single sensor.

The number of nodes needed to execute and implement the wireless sensor networks is deployed in the network model. Here, the deployment of 200 nodes for message transmission takes place.

The optimal cluster is the one that is sized such that routing data from the cluster members to cluster heads and subsequently to base stations incurs the minimal communication overhead. Clustering has been shown to improve network lifetime, a primary metric for evaluating the performance of a sensor network [6]. Another method employed to choose optimal cluster is finding the communication overhead. If the communication overhead is minimal, then the cluster that is selected is the optimal cluster required for message passing. Nodes can be segregated or partitioned into a number of small groups called clusters. Each cluster has a coordinator, referred to as a cluster head, and a number of member nodes [7].

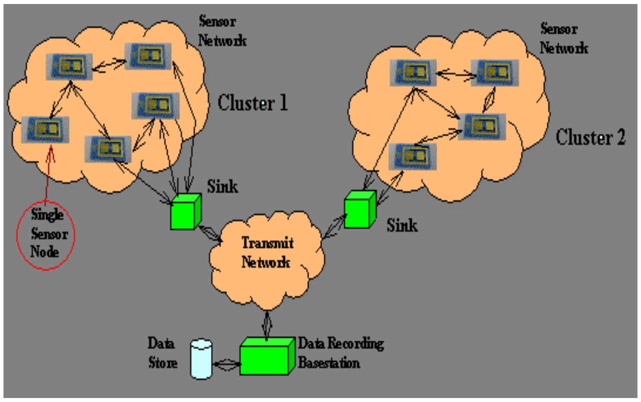

Figure 1. System Architecture (Overall Design)

Clustering results in a two-tier hierarchy in which cluster heads (CHs) form the higher tier while member nodes form the lower tier. The member nodes report their data to the respective CHs. The CHs accumulate the data received from member nodes and dispatch them to the central base through other CHs. Because CHs often dispatch or transmit data over longer distances, they lose more energy compared to member nodes. The network may be re clustered periodically in order to select energy- abundant or bountiful nodes to serve as CHs, thus distributing the load uniformly on all the nodes. Besides achieving energy efficiency, clustering curtails channel contention and packet collisions, resulting in better network throughput under high load [8].

5. DE-LEACH ALGORITHM

The Dimensionally Enhanced Low Energy Adaptive Clustering Hierarchy (DE-LEACH) Algorithm is proposed. The clustering scheme involved here is carried out as an enhancement to the LEACH algorithm [8]. A novel enhancement is done in terms of throughput and network delay. A comparative analysis is performed between two cluster heads namely CH1 and CH2. The optimal cluster head is chosen based on the performance. Based on the number of tasks it depends, sensor nodes are deployed. Autonomous densely distributed sensor nodes are gathered and grouped together to form clusters. Chain based node selection and aggregation is performed. Based on the number of nodes in the cluster, starting from farthest node from sink, the chain is incrementally constructed with no repeating nodes linked or added in the chain. DE-LEACH algorithm presents with aggregation at each node in the chain, which thereby limits the number of transmissions and saves considerable energy in the network that ultimately prolongs the overall network lifetime. Data Fusion is applied to considerably large fraction of wireless sensor networks and the node produces a more accurate output, on the whole. The communication overhead is another important factor considered in DE-LEACH implementation. If the communication overhead is minimal, then the cluster is chosen as the optimal cluster. With respect to optimal paths in the network, if there are ‘k’ numbers of alternate disjoint paths present, then failure of any ‘k’ nodes in the path, ensures that it does not affect and remove all paths and are disjoint from each other. In case of braided multi- paths present, DE-LEACH approach selects sub-optimal paths to recover from failures. This failure-free network ensures energy efficiency and subsequently enhances the network lifetime. DE-LEACH approach enhances the traditional clustering mechanism in wireless sensor networks by efficiently prolonging the network lifetime and leads to energy savings in the battery-powered nodes in the sensor network. The DE-LEACH algorithm is defined and described as follows.

5.1 Algorithm: Dimensionally Enhanced LEACH (DE-LEACH)

Step 1: Call Set_nodes() ; based on the number of tasks on which it depends, sensor nodes are deployed.

Step 2: Call Cluster(nodes) ; autonomous densely distributed sensor nodes are gathered and grouped together to form clusters.

Step 3: Call ClusterMember(cm) ; spatially distributed sensor nodes when present within the cluster are assigned as cluster members, which are slave nodes that are grouped together to communicate with only one cluster head, within the cluster.

Step 3: Call ClusterHead(ch) ; one cluster head is selected per cluster to act as master node and communicates all the messages from slave nodes tosink or base station.
Step 4: for each task t1; every tasks present in each cluster.
Step 5: Call chaining_nodes(); based on the number of nodes in the cluster, starting from farthest node from sink, the chain is incrementally constructed with no repeating nodes linked or added in the chain.
Step 6: Set aggregation (DE-LEACH); performs aggregation at each node in the chain which limits the number of transmissions and saves considerable energy.
Step 7: Set Data_Fusion (nodes); applied to considerably large fraction of wireless sensor networks and the node produces a more accurate output.
Step 8: if (communication_overhead) is minimal; the optimal cluster is chosen.
Step 9: if (k alternate disjoint paths) are present; ensures that the failure of any k nodes cannot remove all the paths, but are disjoint from one another.
Step 10: if(braided multipath) is present; alternatively selects sub-optimal paths to recover from failures and ensures energy efficiency.
Step 11: End

6. SIMULATION RESULTS

The analysis is performed using OMNeT++ (Objective Modular Network Test-bed in C++) simulation tool. Here, deployment of 200 nodes is considered as experimental setup for initiating simulation. Models are assembled from reusable components termed modules. Well-written modules are truly reusable, and can be combined in various ways like LEGO blocks. Modules can be connected with each other via gates, and combined to form compound modules. The modules communicate through message passing, where messages may carry random, arbitrary data structures. Modules can pass messages along pre-defined paths via gates and connections, or directly to their destination; the latter is useful for wireless simulations. Modules may have some guidelines or criterion, which represent the parameters that can be used to customize module behavior and/or to parameterize the model's topology. Modules at the lowest level of the module hierarchy are called simple modules, and they encapsulate model behavior. Simple modules are programmed in C++, and make use of the simulation library. OMNeT++ simulations can be run under various user interfaces. Graphical, animating user interfaces are highly useful for validation and debugging purposes, and command-line user interfaces are best for batch execution.

NED language topology description(s) (.ned files) depict the overall module structure and can be written using any text editor. Similarly, the Message definitions (.msgfiles) in OMNeT++ aid in providing the definition of various message types and data fields, which can be added to them efficiently. The simulation kernel and user interface aid in providing the code to manage the simulation and ultimately the execution, thereby facilitating debugging, demonstration and batch execution of various simulations generated [9].

OMNeT++ uses messages to represent events. Each event is represented by an instance of the cMessage class or one its subclasses; there is no separate event class. Messages are sent from one module to another. This means that the place where the “event will occur” is the message's destination module, and the model time when the event occurs is the arrival time of the message. Events like “timeout expired” are implemented by the module sending a message to it.

The comparative analysis is performed by considering two main metrics like energy consumption and time delay between two cluster heads (CHs) chosen. These metrics are used to correlate the overall performance of the wireless sensor network, on the whole. This comparison is efficiently performed using Gnu Plot tool. Gnuplot is a very popular command-line program that can generate two- and three-dimensional plots of functions and data. The program runs on all major platforms, and it is well supported in OMNeT++ [10].

Analyzed simulation results show that the CH1; that is cluster head 1 (region 1) consumes less energy compared to CH2; that is cluster head 2 (region 2). In terms of time delay, the cluster head 1 takes more time (in seconds) in comparison to cluster head 2. These two metrics are essential to wireless sensor networks, which helps us to determine the overall network lifetime, by significantly balancing the energy efficiency of cluster heads.

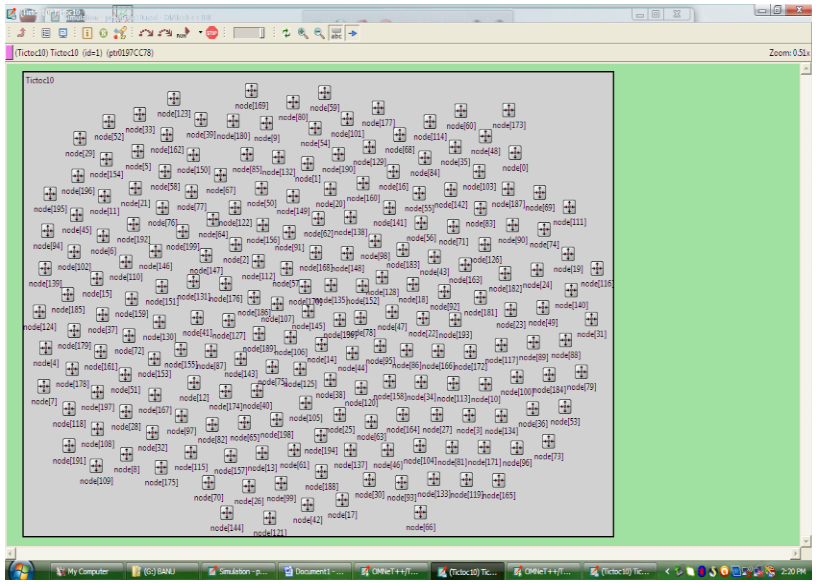

Figure 2.ScreenShot of Deployment of 200 nodes in OMNeT++

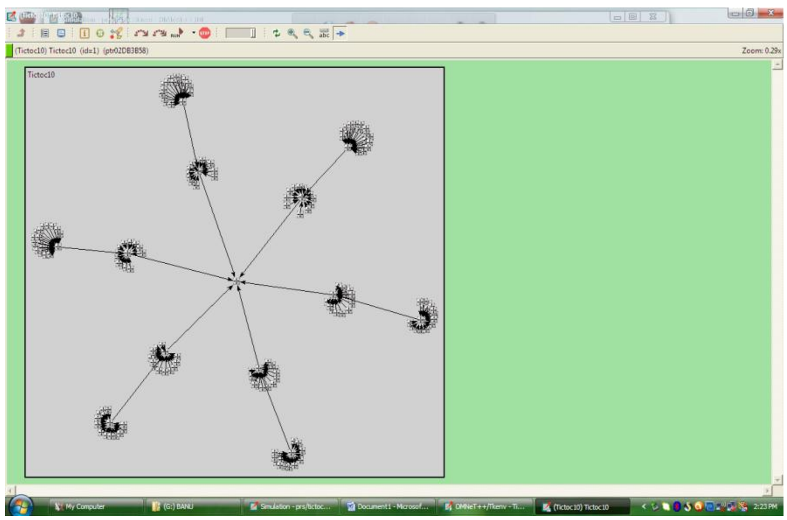

Figure 3.ScreenShot of Clustering of all the 200 nodes with cluster heads and one central node as sink.

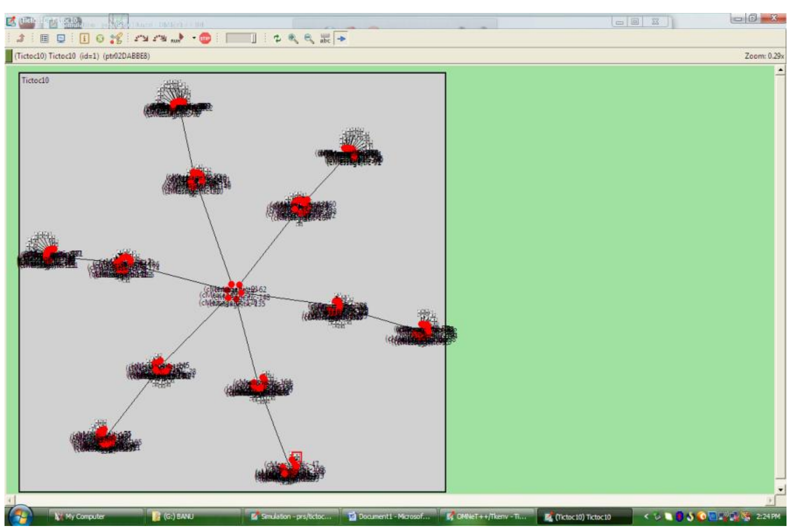

Figure4. ScreenShot of Message Passing among nodes with the sink in OMNeT++.

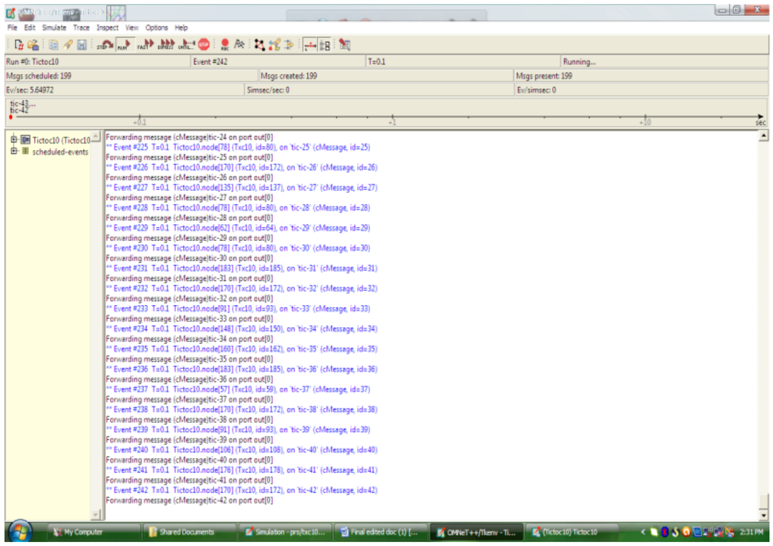

Figure 5.Screenshot of the output window showing Message Passing in events and the corresponding time taken in OMNeT++.

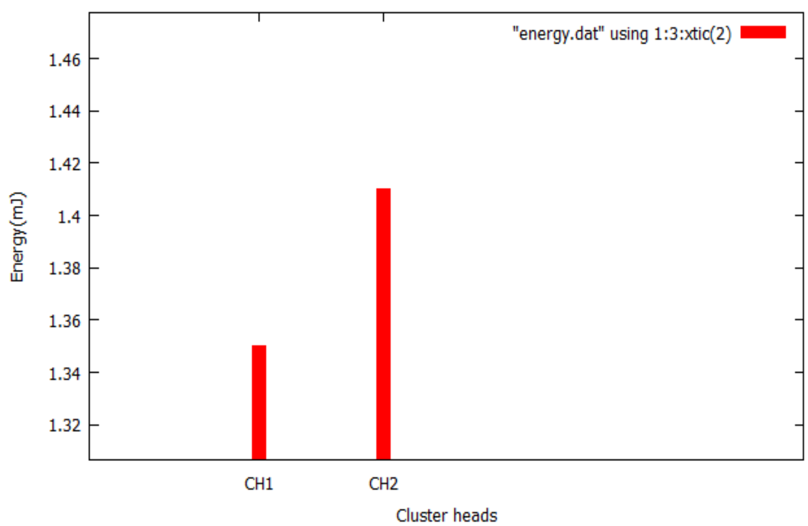

Figure6.Energy comparison of cluster head1 and cluster head2

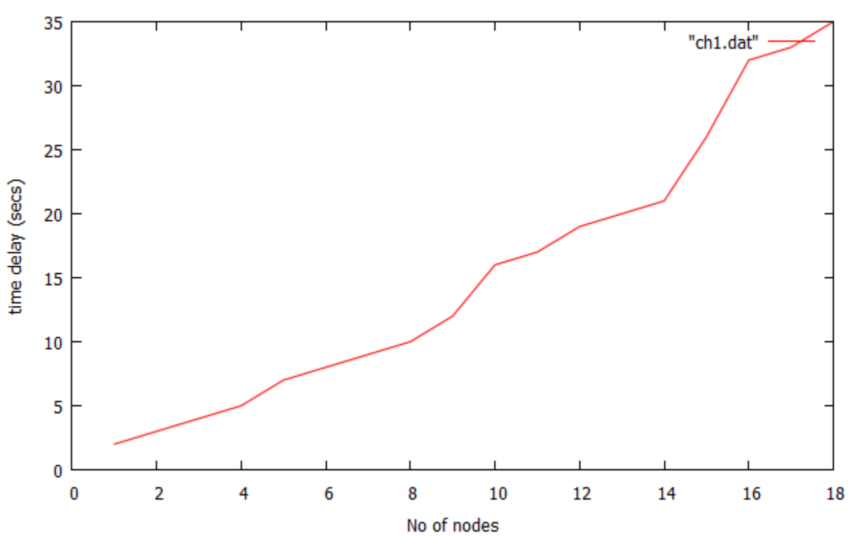

Figure 7. Time delay in cluster head1

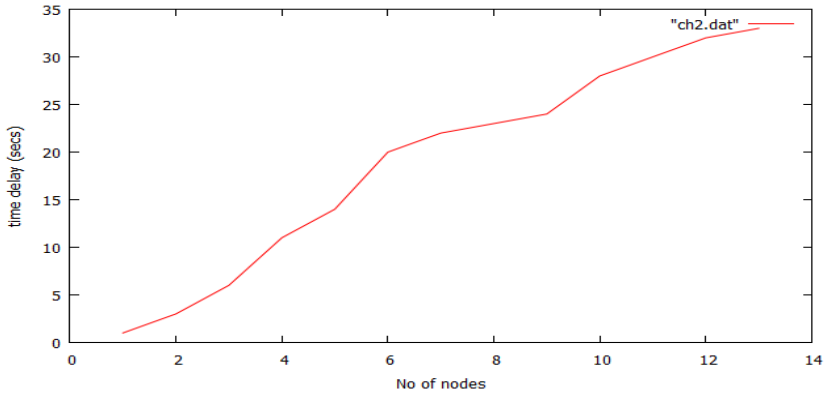

Figure 8. Time delay in cluster head 2

Table 1
Comparative result of cluster head 1 and cluster head 2 in terms of Energy consumption considered for the same data size of requests (Unit of Energy is mJ).

Metric	CH1	CH2
Energy Consumption (mJ)	1.35	1.41

Table 2
Comparative result of cluster head 1 and cluster head 2 in terms of Time Delay considered for the same data size of requests (Unit of Time Delay is seconds).

No. of Nodes	CH1	CH2
0	1	1
2	3	2
4	5	8
6	7	20
8	9	22
10	11	24
12	15	28
14	20	34
16	32	--
18	35	--

7. CONCLUSION AND FUTURE WORK

This paper focuses on energy efficiency in wireless sensor networks, which are composed of large number of communication nodes that are powered by energy reticent or constrained non-rechargeable batteries. With time elapsing, some nodes will run out of battery and let the WSN in a disconnected state. This makes the energy consumption a critical factor in the design of WSN, which directly calls for energy-efficient communication protocols that maximize the lifetime of the network and thereby balancing the energy consumption of the sensor nodes in the network. Thus, we conclude that DE-LEACH based clustering approach significantly balances the energy consumption of both the cluster heads and prolongs the network lifetime.

Regarding clustering for WSNs, comprehensive, large scale extensive research time has been invested to develop efficient energy among sensor nodes. Many different assumptions are made about the network properties such as size of the cluster, number of nodes, communication reliability, communication overhead, etc., are considered, since the execution often suffers resulting in incomplete evaluation. Hence the future work calls for implementing in a large sized network under real sensor network test bed using data fusion technique combined with the time scheduling algorithms for minimizing the transmission energy and further extending and enhancing the network lifetime.

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