Secure Data Aggregation & Query Processing in Wireless Sensor Networks using Enhanced Leach Protocol

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Abstract— Data aggregation and storage has become very important issue in Sensor networks for future information retrieval. Storage nodes serve as an intermediate tier between sensors and a sink for storing data and processing queries in wireless sensor networks. The importance of storage nodes also makes them attractive to attackers. Data Storage is happens via the Forwarding nodes and Storage nodes. Storage nodes are introduced in this paper to store collected date from the sensors in their proximities, It reduce the energy cost and communication cost induced by network query. Aim of the project is to deploy the storage nodes and secure data transmission for cluster-based WSNs (CWSNs), where the clusters are formed dynamically and periodically. We propose two Secure and Efficient data Transmission (SET) protocols for CWSNs, called SET-IBS and SET-IBOOS, by using the Identity-Based digital Signature (IBS) scheme and the Identity-Based Online/Offline digital Signature (IBOOS) scheme, respectively. The cluster routing protocol LEACH (Low-Energy Adaptive Clustering Hierarchy) is considered and improved. We propose a clustering routing protocol named Enhanced LEACH, which extend LEACH protocol by balancing the energy consumption in the network. The simulation results show that Enhanced LEACH outperforms LEACH in terms of network lifetime and power consumption minimization.

Index Terms— LEACH, SET, SET-IBS, SET-IBOOS.

I. INTRODUCTION

A wireless sensor network is a collection of nodes organized into a cooperative network. Each node consists of processing capability (one or more microcontrollers, CPUs or DSP chips), may contain multiple types of memory (program, data and flash memories), have a RF transceiver (usually with a single omni-directional antenna), have a power source (e.g.,batteries and solar cells), and accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. Systems of 1000s or even 10,000 nodes are anticipated. Such systems can revolutionize the way we live and work. Currently, wireless sensor networks are beginning to be deployed at an accelerated pace. It is not unreasonable to expect that in 10-15 years that the world will be covered with wireless sensor networks with access to them via the Internet. This can be considered as the Internet becoming a physical network.

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This new technology is exciting with unlimited potential for numerous application areas including environmental, medical, military, transportation, entertainment, crisis management, homeland defense, and smart spaces. Since a wireless sensor network is a distributed real-time system.
Sensors integrated into structures, machinery, and the environment, coupled with the efficient delivery of sensed information, could provide tremendous benefits to society. Potential benefits include: fewer catastrophic failures, conservation of natural resources, improved manufacturing productivity, improved emergency response, and enhanced homeland security. However, barriers to the widespread use of sensors in structures and machines remain. Bundles of lead wires and fiber optic "tails" are subject to breakage and connector failures. Long wire bundles represent a significant installation and long term maintenance cost, limiting the number of sensors that may be deployed, and therefore reducing the overall quality of the data reported.

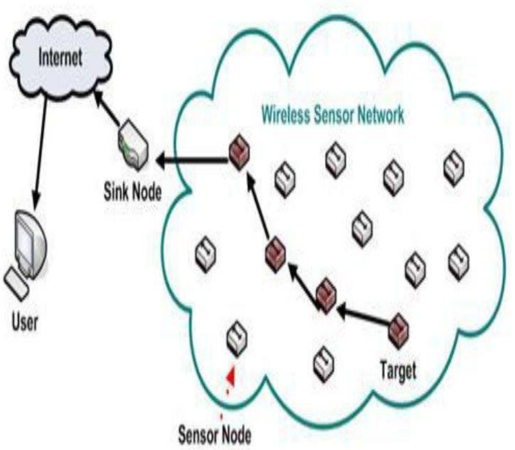

Fig.1 Architecture of Wireless sensor Networks

A wireless sensor network (WSN) generally consists of a base station (or "gateway") that can communicate with a number of wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway. The transmitted data is then presented to the system by the gateway connection. The purpose of this chapter is to provide a brief technical introduction to wireless sensor networks and present a few applications in which wireless sensor networks are enabling.
A WSN usually consists of tens to thousands of such nodes that communicate through wireless channels for information sharing and cooperative processing. WSNs can be deployed on a global scale for environmental monitoring and habitat study, over a battle field

for military surveillance and reconnaissance, in emergent environments for search and rescue, in factories for condition based maintenance, in buildings for infrastructure health monitoring, in homes to realize smart homes, or even in bodies for patient monitoring. After the initial deployment (typically ad hoc), sensor nodes are responsible for self-organizing an appropriate network infrastructure, often with multi-hop connections between sensor nodes. The onboard sensors then start collecting acoustic, seismic, infrared or magnetic information about the environment, using either continuous or event driven working modes.

Sensor networks have a wide variety of applications and systems with vastly varying requirements and characteristics. The sensor networks can be used in Military environment, Disaster management, Habitat monitoring, Medical and health care, Industrial fields, Home networks, detecting chemical, Biological, radiological, nuclear, and explosive material etc. Deployment of a sensor network in these applications can be in random fashion (e.g., ropped from an airplane) or can be planted manually (e.g., fire alarm sensors in a facility).

For example, in a disaster management application, a large number of sensors can be dropped from a helicopter. Networking these sensors can assist rescue operations by locating survivors, identifying risky areas, and making the rescue team more aware of the overall situation in the disaster area.

The Sensor node is sensing, processing, transmission, mobilizer, position finding system, and power units (some of these components are optional like the mobilizer). The same figure shows the communication architecture of a WSN. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station(s). A base-station may be a fixed node or a mobile node capable of connecting the sensor network to an existing communications infrastructure or to the Internet where a user can have access to the reported data. In general, classification of a WSN routing methodology can be done into two main categories; based on network structure or based on the protocol operation. Depending on the network structure, different routing schemes fall into this category.

A sensor network can be non hierarchical or flat in the sense that every sensor has the same role and functionality. Therefore the connections between the nodes are set in short distance to establish the radio communication. Alternatively, a sensor network can be hierarchical or cluster-based hierarchical model, where the network is divided into clusters comprising of number of nodes.

Sensors are small devices with limited storage and computing more power. Storage nodes are powerful wireless devices that are equipped with much more storage capacity and computing power less than sensors. The sink is the point of contact for users of the sensor network

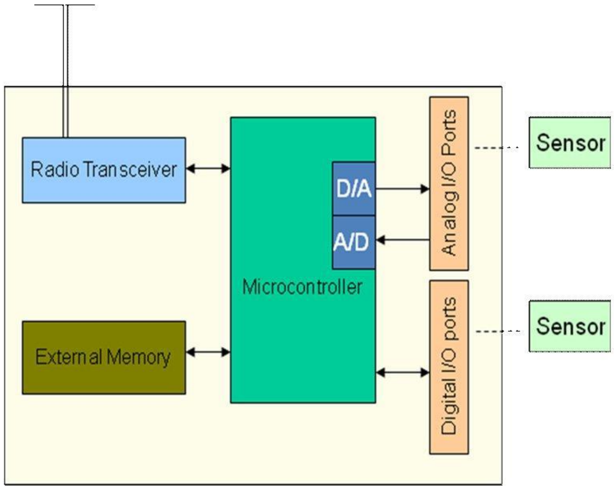

Fig 2.Building Blocks of Sensor Component

In wireless sensor networks, clustering is an essential way to minimize energy consumption incurred by wireless transmission between sensor nodes. Typically, existing clustering protocols have two kinds of phases in each communication round (Tround); one head selection phase (Tsp), and multiple data communication phases (Tdp). Each data communication phase is composed of intra communication phase (Tintra) and inter communication phase (Tinter).

The two phases of clustering protocol is,the first phase is a selection phase to vote and select head nodes The second phases are data communication phases to transmit sensed data to the sink node. The stages continue repeatedly. In the selection phase, an energy-aware cluster formation algorithm is required to balance energy consumption for all sensor nodes. Recently, many kinds of algorithms have been developed using probability, residual energy, and connectivity of the networks. After the selection phase, each node except cluster heads becomes a participant of a cluster. Then, each node transmits its sensed data to the head node in intra communication phase.

The head nodes aggregate data received from participants, and transmit it to the sink node in inter communication phase. In general, sum of Tdp in a round is longer than Tsp in the existing clustering protocols. If the sum of Tdp is too long, cluster heads consume too much power on aggregation and transmission. On the other hand, if it is too short, frequent head selection may spoil the energy-efficiency of the entire wireless sensor networks. The limited energy resources of sensor nodes pose challenging issues on the development of routing protocols for WSN. Introducing clustering into the network’s topology reduces number of transmissions in the network. It also provides energy efficiency as cluster heads aggregate the data’s from its cluster members, thereby reduce duplication of transmission and enhance the network lifetime.

II. RELATED WORK

In the literature, several schemes have introduced an intermediate tier between the sink and sensors. LEACH is a clustering-based routing protocol, where cluster heads can fuse the data collected from its neighbors to reduce communication cost to the sink. However, LEACH does not address storage problem. Data-centric storage schemes, as another category of the related work, store data on different places according to different data types. In the authors propose a data-centric storage scheme based on Geographic Hash Table, where the home site of data is obtained by applying a hash function on the data type. Another practical improvement is proposed in by removing the requirement of point-to-point routing. Ahn and Krishnamachari analyze the scaling behavior of data-centric query for both unstructured and structured (e.g., GHT) networks and derive some key scaling conditions. GEM is another approach that supports data-centric storage and applies graph embedding technique to map data to sensor nodes. In general, the data centric storage schemes assume some understanding about the collected data and extra cost is needed to forward data to the corresponding keeper nodes.

Data aggregation protocols are required in Wireless Sensor Networks (WSNs) to improve the data accuracy and extend the network lifetime by reducing the energy consumption. The existing Data Aggregation-Optimal LEACH (DAO-LEACH) protocol for WSN is enhanced in terms of security and fault-tolerance based on Gracefully Degraded Data Aggregation (GDDA) to ensure the integrity of the aggregated data and Hybrid Layer User Authentication (HLUA) to ensure the confidentiality of the aggregated data. This data aggregation scheme rejects the false data from compromised and malfunctioning Sensor Nodes (SNs). HLUA consists of a combination of Secret Key Cryptography (SKC) method such as Message Authentication Code (MAC) algorithm and Public Key Cryptography (PKC) method such as Elliptic Curve Cryptography (ECC). MAC algorithm is used between the Cluster Heads (CHs) and SNs to fulfill lower power demand, while ECC is applied for User Authentication (UA) between CHs and users. The enhanced DAO-LEACH protocol is resistant to security attacks such as, replay attacks, node compromising attacks and impersonation attacks. It performs better in terms of energy consumption, number of nodes alive, End-to-End Delay (EED), and false data detection and aggregation accuracy.

Wireless Sensor Networks (WSNs) can provide low cost solutions to various real world problems. WSN consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. To consider energy balancing for nodes is an important factor in wireless sensor networks. Many routing, power management and data dissemination protocols have been specifically designed for WSNs where energy consumption is an essential design issue. Owing to the limited resources available for sensor nodes, designing energy-efficient routing mechanism to prolong the overall network lifetime has become one of the most important technologies in wireless sensor networks (WSNs). The routing protocols for WSN can be classified in three main categories: data centric, hierarchical and location based. In this paper, we have proposed a cluster based routing protocol for heterogeneous WSN in order to minimize the energy consumption and increase the network survivability. As an active branch of routing technology, cluster-based routing protocols have proven to be effective in network topology management, energy minimization, data aggregation.

III. PROBLEM STATEMENT

In our paper, we do not assume any prior knowledge about the data indeed in many applications; raw data may not be easily categorized into different types. To transmit the collected data to a remote location is also considered expensive because the total collected data may be in a very large quantity. To facilitate data query. The operation of LEACH is divided into rounds. Each round begins with a setup phase when the clusters are organized, followed by a steady-state phase when data are transferred from the nodes to the cluster head and on to the Base Station (BS).

A. Setup Phase

All sensor nodes select a cluster head by threshold T(n) in equation 1. The threshold value depends upon the desired percentage (p) to become a cluster head, the current round r, and the set of nodes that have not become the cluster-head in the last 1/ p rounds, which is denoted by G.

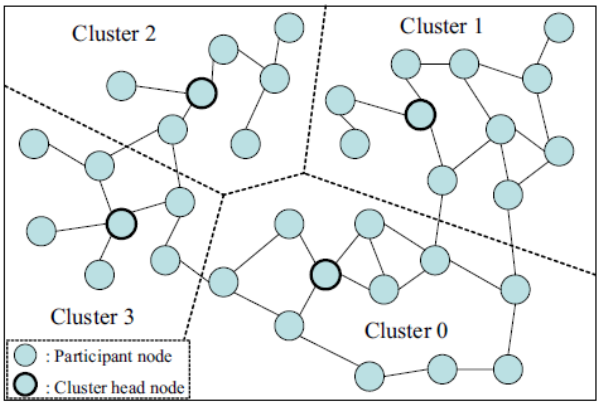

Fig 3.An Example of Cluster in Wireless Sensor Network

Formula for Leach Protocol

$$T(n) = \{ \begin{matrix} \frac{p}{1-p(r mode \frac{1}{p})} & n \in G \\ 0 & otherwise \end{matrix}$$

p : Probability of node becoming CH.
r : Round Index
G: Set of nodes not perform as CHs in last *1/p* rounds

The selected CH informs about its selections as CH among the group. Non cluster-head nodes decide their cluster for current round by choosing the CH that requires minimum communication energy, based on the received signal strength of the advertisement from each CH.

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After the selection each non-CH informs the CH by transmitting a join request message (Join-REQ) back to the CH. Then the CH node sets up and broadcast a TDMA schedule to all member non-CH nodes.

B. Steady State Phase

The Steady Sate Phase is broken into many frames, in which nodes can send their data to the CH at most once per time slot. CH sends the aggregated data to BS in single hop manner. The LEACH provides better results compared to earlier existing protocols e.g. direct communication protocol, minimum-transmission-energy protocol and static clustering protocol in Wireless Sensor Network. The available redundant information is subsequently cancelled during aggregation process performed by CH.

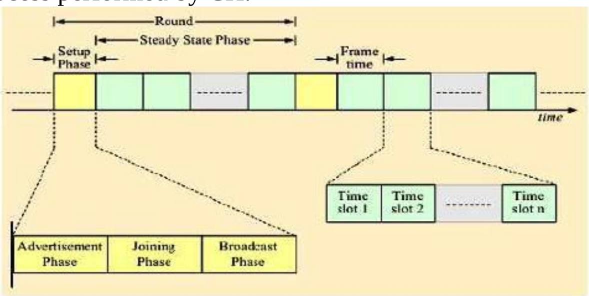

Fig 4.Timeline Diagram for Leach Protocol

Then the CH will broadcast an advertisement message to inform all others that it is the new cluster-head. The nodes send the join-request message containing their IDs by using CSMA (carrier sensing multiple access) to join a cluster. The node joins that cluster from which they received strongest strength signal. After that, each CH knows its own cluster members information. Based on the message, the CH creates TDMA schedule table and broadcasts it to the cluster members. So all the member nodes know their idle slots, and then the steady-state phase begins.

IV. PROPOSED ALGORITHM

The goal of the proposed secure data transmission for CWSNs is to guarantee a secure and efficient data transmission between leaf nodes and CHs, as well as transmission between CHs and the BS. Meanwhile, most of existing secure transmission protocols for CWSNs in the literature, however, apply the symmetric key management for security, which suffers from the orphan node problem that is introduced, In this paper, we aim to solve this orphan node problem by using the ID-based crypto-system that guarantees security requirements, and propose SET-IBS by using the IBS scheme. Furthermore, SET-IBOOS is proposed to reduce the computational overhead in SET-IBS with the IBOOS scheme. The propose two novel Secure and Efficient data Transmission (SET) protocols for CWSNs, called SET-IBS and SET-IBOOS, by using the IBS scheme and the IBOOS scheme, respectively. We first present SET-IBS in this section. The proposed SET-IBS has a protocol initialization prior to the network deployment and operates in rounds during communication, which consists of a setup phase and a steady-state phase in each round. We introduce the protocol initialization, describe the key management of the protocol by using the IBS scheme, and the protocol operations afterwards.

V. PROTOCOL OPERATION

After the protocol initialization, SET-IBS operates in rounds during communication. Each round consists of a setup phase and a steady-state phase. We suppose that, all sensor nodes know the starting and ending time of each round, because of the time synchronization.

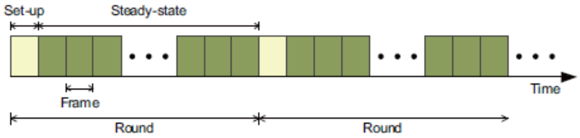

Fig 5. Operation in the proposed secure data transmission

The operation of SET-IBS is divided by rounds as shown in Figure 1, which is similar to other LEACH-like protocols. Each round includes a setup phase for constructing clusters from CHs, and a steady-state phase for transmitting data from sensor nodes to the BS. In each round, the timeline is divided into consecutive time slots by the TDMA (time division multiple access) control.

Sensor nodes transmit the sensed data to the CHs in each frame of the steady state phase. For fair energy consumption, nodes are randomly elected as CHs in each round, and other non-CH sensor nodes join clusters using one-hop transmission, depending on the highest received signal strength of CHs. In order to elect CHs in a new round, each sensor node determines a random number and compares it with a threshold. If the value is less than the threshold, the sensor node becomes a CH for the current round. In this way, the new CHs are self-elected based by the sensor nodes themselves only on their local decisions, therefore, SETIBS functions without data transmission with each other in the CH rotations. The steady-state phase consists of the latter two steps. In the setup phase, the time-stamp T_s and node *ID*s are used for the signature generation. Whereas, in the steady-state phase, the time-stamp t_i is used for the signature generation securing the inner cluster communications, and T_s is used for the signature generation securing the CHs-to-BS data transmission.

The proposed SET-IBOOS operates similarly to that of SETIBS. SET-IBOOS works in rounds during communication, and the self-elected CHs are decided based on their local decisions, thus it functions without data transmission in the CH rotations. For the IBOOS key management in SET-IBOOS, the offline signatures are generated by the CHs, which are used for the online signing at the leaf nodes.

A.OPERATIONS OF SET-IBS

Setup phase			
Step 1.	$BS \Rightarrow G_s$	:	$\langle ID_{bs}, T_s, nonce \rangle$
Step 2.	$CH_i \Rightarrow G_s$	:	$\langle ID_i, T_s, adv, \sigma_i, c_i \rangle$
Step 3.	$L_j \rightarrow CH_i$	:	$\langle ID_i, ID_j, T_s, join, \sigma_j, c_j \rangle$
Step 4.	$CH_i \Rightarrow G_s$	:	$\langle ID_i, T_s, sched(\ldots, ID_j/t_j, \ldots), \sigma_i, c_i \rangle$
Steady-state phase			
Step 5.	$L_j \rightarrow CH_i$	:	$\langle ID_i, ID_j, t_j, C, \sigma_j, c_j \rangle$
Step 6.	$CH_i \rightarrow BS$	:	$\langle ID_{bs}, ID_i, T_s, F, \sigma_i, c_i \rangle$

B.OPERATIONS OF SET-IBOOS

Setup phase

Step 1.	$BS \Rightarrow G_s$	:	$\langle ID_{bs}, T_s, nonce\rangle$
Step 2.	$CH_i \Rightarrow G_s$	:	$\langle ID_i, T_s, adv, \sigma_i, z_i\rangle$
Step 3.	$L_j \rightarrow CH_i$	:	$\langle ID_i, ID_j, T_s, join, \sigma_j, z_j\rangle$
Step 4.	$CH_i \Rightarrow G_s$	:	$\langle ID_i, T_s, alloc(\ldots, ID_j/t_j/\bar{\sigma}_j, \ldots), \sigma_i, z_i\rangle$

Steady-state phase

Step 5.	$L_j \rightarrow CH_i$	:	$\langle ID_i, ID_j, t_j, C, \sigma_j, z_j\rangle$
Step 6.	$CH_i \rightarrow BS$	:	$\langle ID_{bs}, ID_i, T_s, F, \sigma_i, z_i\rangle$

/* The BS broadcasts its information to all nodes. */

/* The elected CHs broadcast their information. */

/* A leaf node joins a cluster of CH_i. */

/* A CH i broadcasts the allocation message. */

/* A leaf node j transmits the sensed data to its CH i. */

/* A CH i transmits the aggregated data to the BS. */

C.ENHANCED LEACH PROTOCOL

Enhanced leach is a T-LEACH stands for threshold-based LEACH because it replaces cluster heads based on the threshold value of residual energy on the sensor nodes. In traditional protocols relating to cluster optimization, the authors proposed that the number of cluster heads be reduced to decrease energy consumption or that energy efficiency-based optimal cluster sizes be constructed to extend the survival time of the network. LEACH algorithm has a structure where cluster heads are selected according to probabilistic values and the collection and transmission of messages occur during each round. Consequently, the number of cluster heads and rounding periods come to be closely related to energy consumption.

In these algorithms, nodes play the roles of cluster heads periodically, and these are not considering energy cost of that time. When arbitrary sensor nodes become cluster heads through the performance of rounds, nodes selected as cluster heads must broadcast to member nodes of the clusters to which they belong that they have become cluster heads. Consequently, as the frequency of rounding and of cluster head replacement increases, energy consumption increases due to message transmission for broadcasting. All the nodes start with initial power. It's impossible that sensor nodes recharge energy and replace battery in ubiquitous sensor networks. Thus, it's very important that sensor nodes expense energy efficiently. To calculate the whole energy consumption of the networks, we have to consider two parts. One is quantity of energy as roles of sensor nodes. Another is a volume of energy when role of sensor nodes is exchange. There is a significant disparity of energy consumption between cluster heads and member nodes. All member nodes are transmitting perceived data to cluster head on allocated time slot periodically. And then cluster head transmit data aggregated in the cluster.

VI. SIMULATION RESULTS

Enhanced LEACH which improves the energy distribution between sensor nodes in each round and prolong the network lifetime. The implementation process of Enhanced LEACH is divided into rounds and each round is divided into three phases, **Setup phase, Pre-Steady phase and Steady State phase**; each sensor knows when each round starts using a synchronized clock.

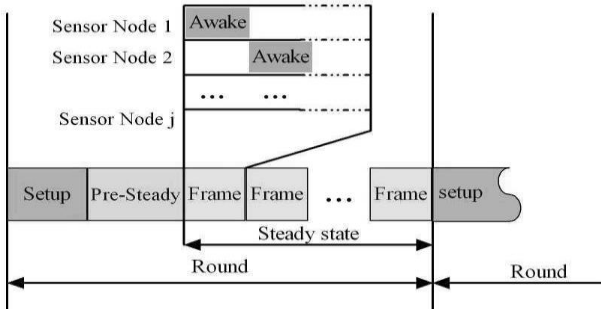

Fig 6 shows the time line for one round of Enhanced LEACH.

A.SETUP PHASE

The setup phase operation of Enhanced LEACH is as the setup phase operation of LEACH. Enhanced LEACH starts with the cluster setup phase. During this setup phase the cluster head nodes are randomly elected from all the sensor nodes and several clusters are constructed dynamically.

B.PRE-STEADY PHASE

The main idea of this phase is to calculate the cluster Workload (which include aggregate the sensed data from cluster members and send the aggregated data to the base station) in one frame, then try to elect cluster member node that can handle the aggregation processes through all frames in the round. If not exist such a node, try to elect cluster member nodes that can handle the aggregation processes for each one frame in the round and the cluster head will handle the aggregation process for frames that there are no aggregator nodes for them.

In this phase, each cluster head CH executes the following steps:

1. Calculate the number of times (NAggregator) each cluster member node (cmi) can work as aggregator node according to the remaining energy (cmi.Eremaining) of cmi and the energy cost (cmi.Eframe) that cmi will consumed during one frame to handle the aggregation processes
2. Elect aggregator node for all frames in the current round by executing algorithm
3. Given the cluster members list M, the number of frames (NServe- Frames) that need to serve by aggregator node and the current round number, algorithm 2 work by these parameters as follows:

– Elect a sensor node from the list M and check if the elected node (say CMaggregator)can serve and handle the aggregation process in these frames or not.

– If CMaggregator can serve the aggregation process in these frames, decrease NAggregator by NServeFrames and return $CM_{aggregator}$.

– If $CM_{aggregator}$ cannot serve the aggregation process in these frames, repeated the same steps and do not consider the previous elected node in the election processes.

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C.STEADY STATE PHASE

In Steady State phase, the operation is divided into frames, in each frame, cluster member nodes send their data to the aggregation node NAggregator according to their time slots. The aggregation node must keep its receiver on to receive all the data from the nodes in the cluster. When all the data has been received, the aggregation node sends it to the base station after performs data aggregation.

VII. EXPECTED RESULTS

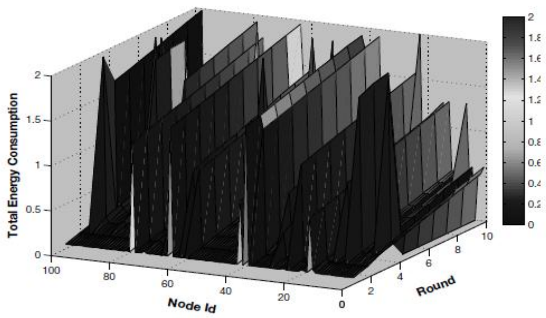

Fig7. Energy Consumption of Leach

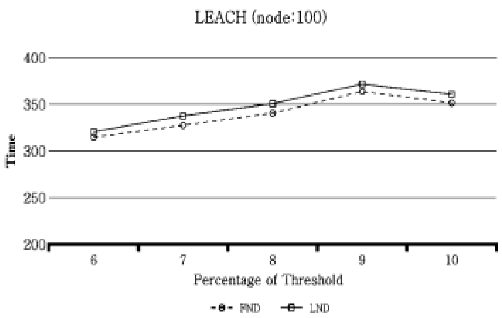

Fig8.Network Lifetime of Enhanced Leach when changing Threshold(Node-100)

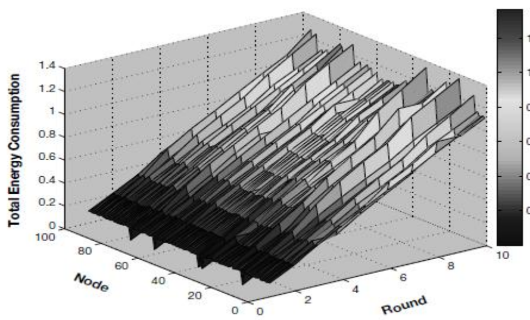

Fig9.Energy consumption of Enhanced Leach protocol

VIII. CONCLUSION

In this paper, the data transmission issues and the security issues in CWSNs. We then presented two secure and efficient data transmission protocols respectively for CWSNs, SET-IBS and SET-IBOOS. In the evaluation section, we provided feasibility of the proposed SET-IBS and SET-IBOOS with respect to the security requirements and analysis against routing attacks. SET-IBS and SET-IBOOS are efficient in communication and applying the ID-based crypto-system, which achieves security requirements in CWSNs, as well as solved the orphan node problem in the secure transmission protocols with the symmetric key management. Lastly, the comparison in the calculation and simulation results show that, the proposed SET-IBS and SET-IBOOS protocols have better performance than existing secure protocols for CWSNs. With respect to both computation and communication costs, we pointed out the merits that, using SET-IBOOS with less auxiliary security overhead is preferred for secure data transmission in CWSNs.

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