Data Fusion in Mobile Wireless Sensor Networks

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***Abstract*—During the last decades, Wireless Sensor Networks (WSNs) arises as an emerging and future enable technology due to the latest development in the field of wireless communication, computing and storage devices. Cluster based routing is an immense solution to enhance the energy efficiency of nodes in wireless sensor networks. In this paper we propose, simulate and authenticate Mobile Data Collector (MDC) based cluster routing protocol for environmental applications, which is based on multi-hop routing strategy, self-organized sensor nodes, distributed cluster formation technique, randomly selection of cluster heads and finally forward the data to base station by the support of maximum residual energy MDC. Moreover, our approach explains the considerable enhancement than LEACH protocol in terms of energy consumption of sensor nodes and overall network lifetime.**

***Index Terms*—Mobile Wireless Sensor Networks, Power Aware, Cluster Based Routing and Data Gathering Technique.**

I. Introduction

WIRELESS Sensor Networks (WSNs) is a low-cost computation, storage capacity and radio technologies that assemble economical micro-sensor nodes. Micro-sensor nodes are not powerful devices like macro-sensor, but provide fault-tolerant and high quality sensor networks by the deployment of hundreds and thousands sensors within the networks region [1, 2].

Data fusion protocols were designed for network configuration and collect the data from desired environment. Each round of data collection protocol nodes must be collected and transmitted data towards BS, that helpful for end user to use this information. An easy way to do that is a combination (sum, average, min, max, count) data from different nodes. The aim is efficient transmission of all data at the base station, so the lifetime of the network is optimized in terms of rounds. Where a round is defined as the process of collecting all data from sensor nodes towards the base station, no matter how much time it takes [3, 4].

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Mobile devices are also the best approach to resolve the data gathering issues in an efficient way. Number of the existing WSNs scenarios using mobile platforms, such as animal monitoring, traffic monitoring and battlefield surveillance applications. Mobile Wireless Sensor Network (mWSN) is a specified category of WSNs where mobility acting a primary part in the application execution. In recent years, researchers and vendors are entirely focused to retain mobility in WSNs [5].

A. Mobile WSN Architecture

mWSN can be classified into a flat, 2-tier or 3-tier hierarchical architecture: *Flat or level-like*, the network architecture contains a set of heterogeneous devices to communicate in ad hoc mode. These devices are mobile or fixed, but to communicate within the same network. *Two-tier* architecture consist set of nodes in place, and set mobile nodes. Moving nodes form an overlay network or the role of data mules to transfer data across the network. In *three-tier* architecture, a set of fixed sensor nodes transmit the data towards set of mobile devices and then transmits to one set of access points.

B. Data Collection Techniques in mWSN

Various approaches to exploit the mobility of data collection methods for WSNs have been proposed. The classification of these approaches according to the characteristics of sink mobility, and wireless data transfer methods: *Mobile Base Station (MBS):* MBS is a mobile sink, which amend the location through transmission. The sensors data transmit to MBS without delay. *Mobile Data Collector (MDC):* MDC act as mobile sink which visits individually all sensors in the network. Sensor generated data buffered at source until the MDC visits and retrieves the information by single hop transmission. *Rendezvous Solution:* Hybrid solution of WSNs mobility, where sensor data is collected at designated point near the mobile devices. Then mobile devices downloaded the buffered data from appointed points [6, 7, 8].

C. Clustering Techniques

In many research papers and projects explains that the hierarchical routing especially the clustering techniques make an immense enhancement on WSNs. These approaches to reduce the energy utilization and network performance when the entire sensor nodes of the network sending a data to base station or central collection center. The core components of the cluster based WSNs are sensor nodes, clusters, cluster heads, base station and end user [9, 10].

Fig. 1 explains the general architecture of cluster based WSNs. *Sensors nodes* are an essential part of WSNs. Organizational unit of WSNs are *clusters. Cluster heads* (CH) are the leader of cluster.

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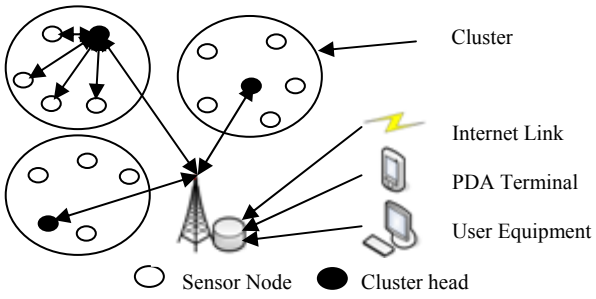


Fig 1 Cluster Based Wireless Sensor Network

In hierarchical WSNs the upper levels is *base station* (BS) and establish a communication link between end user and sensor network. In networks, the issue of a sensor marks (where data are collected from a query sent by the network). This request is generated by an *end user* [11, 12].

This paper explains a new multi-hop routing protocol by the help of maximum residual energy MDC which is moving in pre-defined trajectory for environmental applications network. The MDC is moving from top to bottom in each corner of the network and transmit beacon message in every 5 sec for CH and BS. When CH received the beacon message from MDC, then CH measure the MDC's energy and selects the maximum residual energy MDC to deliver the sensed aggregated data towards the base station.

The rest of the paper organized as follows: section II summarizes the related works of Hierarchical cluster based routing protocols; section III presents a Mobile Data Collector based LEACH routing protocol; section IV describes the results and discussions and finally conclusion and future works presented in section V.

II. Related Works

The main purpose of hierarchical routing is to maintain energy utilization by multi-hop routing communication. Data aggregation and fusion is to reduce the number of messages transmitted towards the sink.

A. LEACH:

Construction of Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the first significant developments to conventional clustering approaches in WSNs, shown in Fig. 2. Traditional approaches such as MTE (Minimum Transmission Energy) or a direct transfer does not lead to dissipation of energy through the network. LEACH provides balanced energy consumption in a random rotation of cluster heads [13].

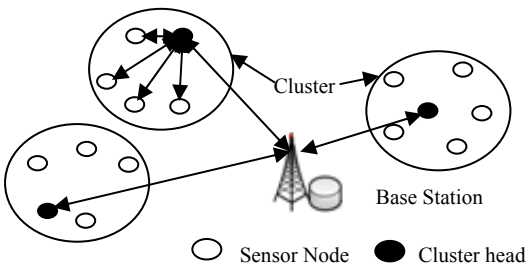
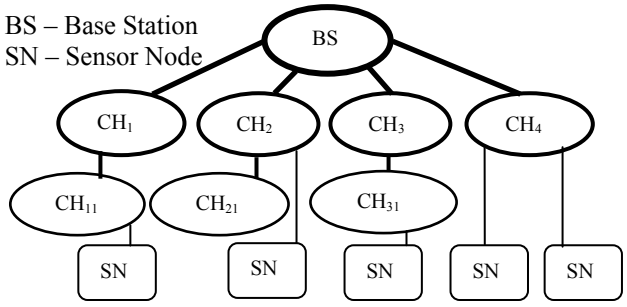


Fig 2 Single Hop LEACH Routing Protocol

B. TL-LEACH:

Two levels hierarchy LEACH (TL-LEACH) is a proposed extension of the algorithm of LEACH which support parent child combination and then transmits data to base station by single hop fashion. It uses two levels of cluster heads (primary and secondary), and other simple detection nodes. In this algorithm, the primary cluster head in each group communicates with the secondary and then contact with corresponding nodes in their sub-cluster. The structure of two levels of TL-LEACH reduces the number of nodes and total energy consumption, when data is transmitted from source to the base station. The topological diagram of TL-LEACH is described in Fig. 3 [12]. In assessing the data reliability improvements of both LEACH and TL-LEACH protocols are almost same [14].



CH_i & CH_{ij} – First & Second Level Cluster Head

Fig 3 Topology of Two-Tier Hierarchy

C. Mobile Agent Based LEACH:

Mobile agent based LEACH is a multi-hop intra-cluster algorithm, where the clustering technique using mobile agent. Local management of mobile agent is technically controlled by clustering approach, mobile agents are dynamically moved in the network and they are able to share the information among the sensor nodes. The characteristics of mobile agents are judge itself, calculates the average data, share the information between the nodes, reduce the redundant data, find the alternate path when any node is died and provide reliable data delivery [15].

III. Mobile Data Collector Based Routing Protocol

Fig. 5 explains the topological structure of MDC based routing protocol.

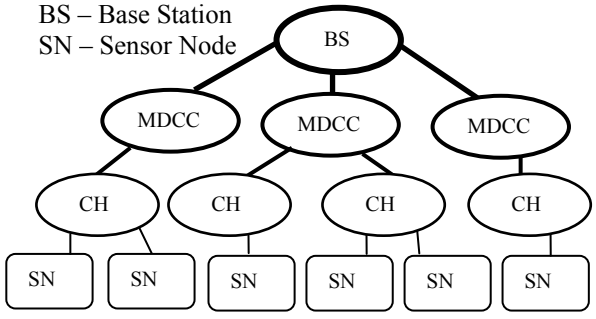


Fig 4 Topological Hierarchy of MDC based LEACH

This protocol uses three-tier network architecture and multi-hop routing communication for data aggregation and

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transmission, from sensor node to base station. It has been observed this type of architecture enhances the network scalability for large scale environmental applications. Multi-hop routing communication is to reduce the channel disputation area and prospective energy saving by the help of long and multi-hop communication from source to destination.

A. Energy Model for Data Transmission:

In recent years a lot of research has been done into low-energy propagation radio models. MDC based LEACH routing protocol with maximum residual energy employs a simple First Order Radio Model, where the transmitter and receiver dissipate E_{elec} 50 nj/bit and transmit amplifier circuit ε_{amp} 100 pj/bit/m^2 to achieve an acceptable E_b/N_o. The current state-of-the-art in radio design, the First Order Radio Model parameters are slightly better than the other models.

Suppose r^2 is the energy loss within channel transmission, when sending a *k*-bit message at a distance *d* by the help of radio model, the transmission end calculations are in equation 1 and 2:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec} * k + \varepsilon_{\text{amp}} * \text{k} * \text{d}^2 \quad (1)$$

And receiving end calculations are:

$$E_{Rx}(k) = E_{Rx-elec}(k)$$
$$E_{Rx}(k) = E_{elec} * k \quad (2)$$

B. Inter and Intra Cluster Communication:

The end-to-end data transmission process of MDC based routing protocol is divided into many rounds, each round followed by set-up phase and steady phase for cluster formation and data transfer respectively from sensor nodes to MDC and then finally towards base station. The operation time line of LEACH protocol is shown in Fig. 5.

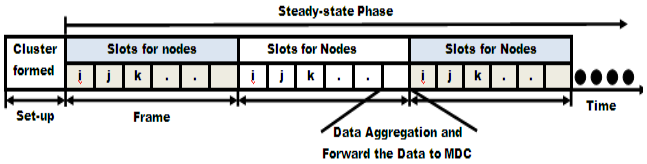

Fig 5 LEACH Operation Time Line

Set-up Phase and Cluster Head Selection:

In period of cluster formation, all nodes are autonomous; self-organized and arranged into clusters through short messages using by Carrier Sense Multiple Access (CSMA) Medium Access Control (MAC) protocol. Every nodes of the network have to make a decision to become a cluster head or not with the probability of P_i, *Pi* is calculated according to LEACH algorithm as shown in equation 3.

$$P_i(t) = \begin{cases} \frac{\text{k}}{\text{N-k}\div\left(\text{r mod } \frac{\text{N}}{\text{k}}\right)} \\ 0 \end{cases} \quad (3)$$

At the beginning of set-up phase every node using this formula to calculate the probability *Pi*. This equation ensures that the expected number of CH for every round is ***k*** this means that the whole network divided into ***k*** cluster and ***N*** is the total number of nodes. Every node has been elected once as a CH after ***N/k*** rounds on average and ***r*** shows the round number.

Those nodes selected as a CH for the current round, these nodes are not eligible to select as a CH for the next round. All CH in the network broadcast announcement short message for all nodes through CSMA MAC protocol, this message contains CH node position. After time t_1 nodes receive many broadcast announcement messages from different CH's, then member node decides to closest CH on the basis of received signal strength of the packet announcement and pick the closest CH with the smallest distance.

Steady Phase Using Mobile Data Collector:

After the cluster formation CH set up the Time Division Multiple Access (TDMA) schedule for every node to send data towards CH. This scheduling to avoid collisions and reduce energy consumption between data messages in the cluster and enables each member of the radio equipment off when not in use. To reduce inter cluster interference every cluster uses a unique spreading code, when the node is selected as a CH it selects that unique code and inform all member nodes within the cluster to transmit their data using by assigned spreading code.

When a CH received sufficient data from its members then it will change the spreading code for MDC and return back to receive the sensed data messages from its members after successful transmission. During the transmission from cluster head to MDC's, all CH's broadcast the messages within the network through another assigned spreading code and uses CSMA/CA is employ as a MAC layer protocol to avoid possible collision between them. When MDC's received the data from any CH's, then it will directly and immediately route the data towards the base station by the help of MDC maximum residual energy approach.

Maximum Residual Energy (RE) of MDC:

In data fusion mechanism towards the base station, all MDC's transmits a beacon message for all CH's which contained their current position and residual energy level. When CH received the beacon message from MDC, then CH measures the MDC's energy and selects the maximum residual energy level MDC to route the data towards the base station in each round. Fig. 6 explains the detailed data fusion mechanism by the approach of maximum residual energy of MDC, in current round cluster head S_1 and S_2 received the residual energy level from MDC 1 and MDC 2 that is 25j and 23j respectively. Cluster head $S_1$and S_2 select MDC 1 for transmitting the data because the RE level of MDC 1 is higher than MDC 2. In next round all cluster heads again received residual energy information along with MDC current location by beacon message from number of MDC's. At this round the RE level of MDC 2 is 23j and MDC 1 is 22j, every cluster head select MDC 2 as a relay node for data collection at the base station. Same procedure will follow for data collection within the network at the base station till the residual energy of sensor nodes and MDC's are accessible.

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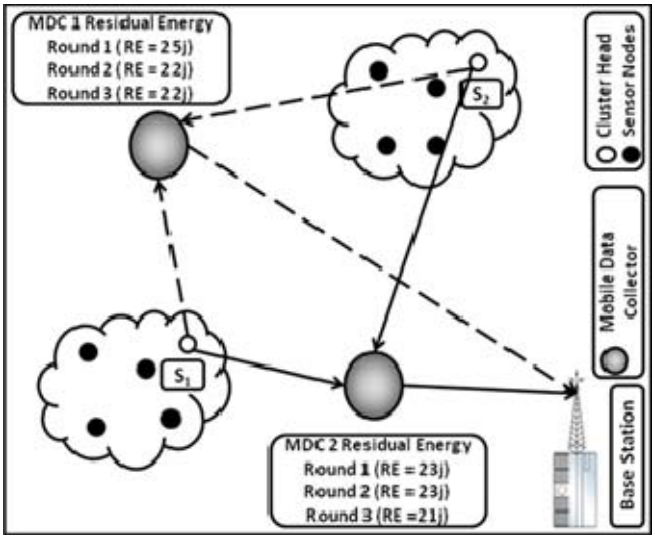

Fig 6 Data Fusion Mechanism

- *Route 1 at Round 1*: S1 and S2 – MDC 1 – Base Station
- *Route 2 at Round 2*: S1 and S2 – MDC 2 – Base Station
- *Route 3 at Round 3*: S1 and S2 – MDC 1 – Base Station

This approach clearly maintains the energy level of relay nodes that is MDC's throughout the network till the sensor nodes and MDC's are alive.

IV. Results and Discussion

The network parameters of simulation are explained in Table I, following performance metrics are measured: Energy consumption of sensor node, Network lifetime, Traffic received at base station, Channel Access Delay and End-to-End Delay measured by computer simulation.

Table I
Simulation Parameters

Parameters	Values
Number of Nodes	40
Simulation Area	1 Km^2
Transmission Electronics ($E_{TX-elec}$) **Receiver Electronics ($E_{RX-elec}$)**	50 nj/bit
Transmit Amplifier (ε_{amp})	100 pj/bit/m^2
Node Energy	2 joules
Number of MDC's	2
MDC Beacon Message Rate	5 sec
MDC Velocity	0.054 m/sec
MDC Energy	30 joules
Packet Size	160 bits/packet

A. *Energy Consumption of Sensor Nodes and Network Lifetime*:

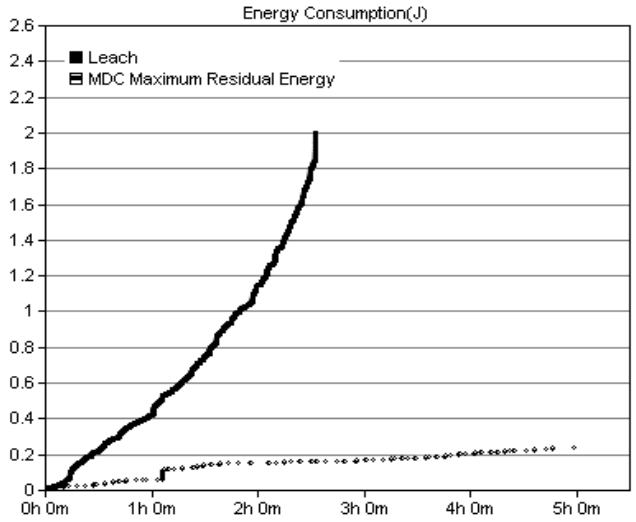

Fig 7 Energy Consumption of Node 19

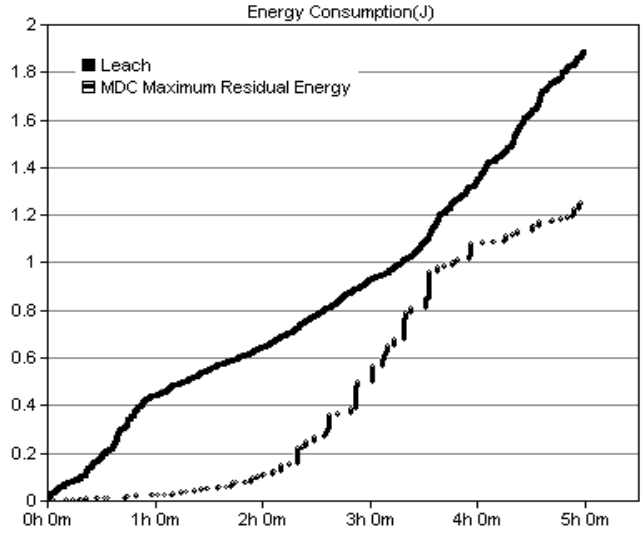

Fig 8 Energy Consumption of Node 33

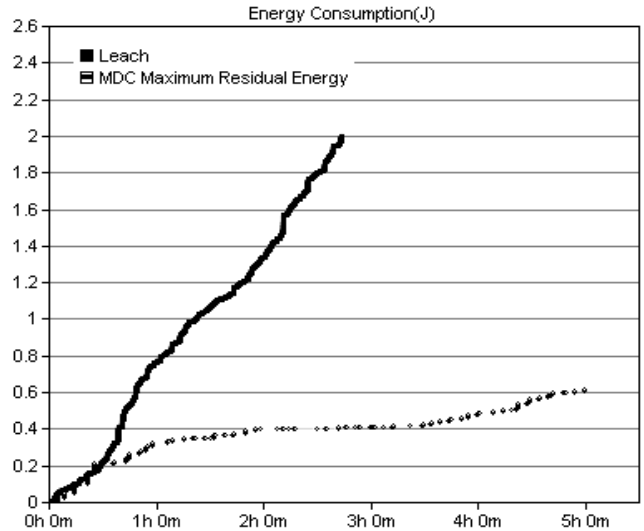

Fig 9 Energy Consumption of Node 36

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Fig. 7, 8 and 9 results show the energy consumption of sensor nodes after multiple simulations runs over LEACH and MDC based LEACH maximum residual energy routing protocol. As we fixed the energy limit of each node is 2j, the energy consumption of node 17 in LEACH routing protocol is died after the simulation of 2 hours but in MDC based LEACH maximum residual energy routing protocol is still alive longer and consumed only 0.2j after the simulation of 5 hours. On the other hand the energy consumption of nodes 33 and 36 are alive longer in MDC based LEACH maximum residual energy routing protocol, after 5 hours simulations consumed only 1.2 and 0.6 respectively. But in LEACH routing protocol 2j energy consumed of node 33 and 36 after the simulation of 2 hours. In these graphs there is significant difference in energy consumption of sensor nodes in the network, which is directly impact on the performance of the network or network lifetime.

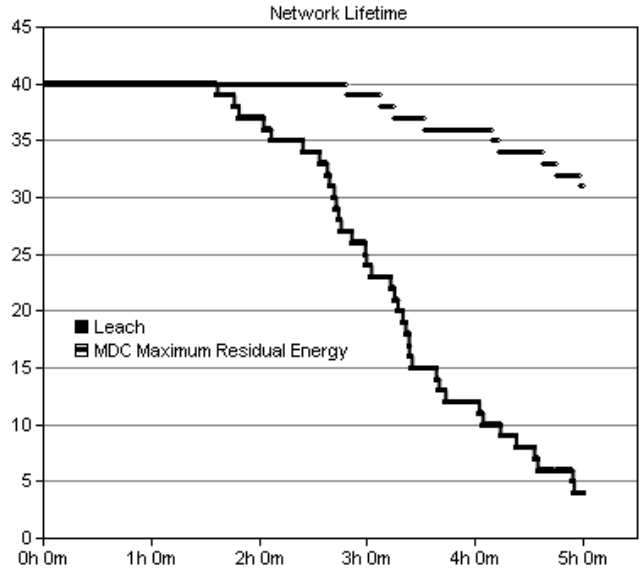

Fig 10 Network Lifetime

The simulated result of Fig. 10 is exposed the considerable variation in network lifetime. Therefore, multi-hop MDC based LEACH maximum residual energy routing protocol is better than single hop LEACH routing protocol in terms of network lifetime because it stays active as a whole longer, and falling slightly faster.

V. Conclusion And Future Work

This paper addresses the considerable comparison in single and multi-hop routing protocol for cluster based LEACH protocol. According to aforementioned simulated results is the evidence for MDC based LEACH routing protocol with maximum residual energy is better than LEACH routing protocol in terms of energy consumption of sensor nodes and extensively improve the network lifetime for cluster based LEACH protocol. In our future work, we enhanced and validate the MDC based LEACH routing protocol by selection of another technique is to employ Multi-channel concept at base station for directly allocate the channel for number of MDC's.

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