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Full Length Research Paper

Mobile data collector based routing protocol for wireless sensor networks

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In the era of New Generation Networks (NWGN) many emerging and future enable technologies accomplish the requirementsofubiquitous communication networks. Mobile wireless sensor network (mWSN) is one of the rising and emerging technologies for various application of NWGN, the enormous concerns of these networks are data gathering with energy efficiency. Routing protocol act as middleware, which is responsible to enhance the network performance with less energy consumption. In this paper we propose, analyze and validate mobile data collector (MDC) based LEACH routing protocol for environmentalapplicationwhich is based on multi-hop routing strategy. MDC based LEACH routing protocol utilizes self-organized sensor nodes with distributed cluster formation technique, randomly selection of cluster heads to equally balance the energy consumption among the sensor nodes and finally forward the data to base station by the support of MDC. Moreover, our approach shows the significant improvement in terms of energy consumption of sensor nodes, enhance network lifetime and data gathering at base station areoutperform when compared with LEACH protocol.

Key words: Mobile wireless sensor networks, wireless sensor networks, network protocol, cluster based routing, data gathering technique.

INTRODUCTION

Wireless sensor network (WSN) is a latest emerging technology during the last decades, a lot of researchers doing effort to find a low cost and low power way out for wireless sensor networks. WSN can connect information world with physical world together. Nowadays WSN using in different applications such as battlefield surveillance, remote healthcare, land monitoring for smart farming and environmental monitoring (Akyildiz et al., 2002; Chunguo et al., 2007; Arshad et al., 2010). While designing algorithms and protocols of WSNs, several challenges occurs like maintaining connectivity and maximizing network lifetime are the severe considerations. Mobile devices are the best approach to resolve the WSNs problems in an efficient way; number of existing WSN scenarios using mobile platforms, such as animal monitoring, traffic monitoring and battlefield surveillance applications. mWSN is a specified category of WSN where mobility actingaprimarypart in the application execution.In recent years, researchers and vendors are entirely focused to retain mobility in WSN (Eylem et al., 2006). Major mWSN parameters over WSN are nodes location, utilization of energy, sink/gateway and topology of the network (Qin et al., 2006; Gandham et al., 2003).

Mobile WSN architecture

mWSNs can be classified into a flat, two-tier or three-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.

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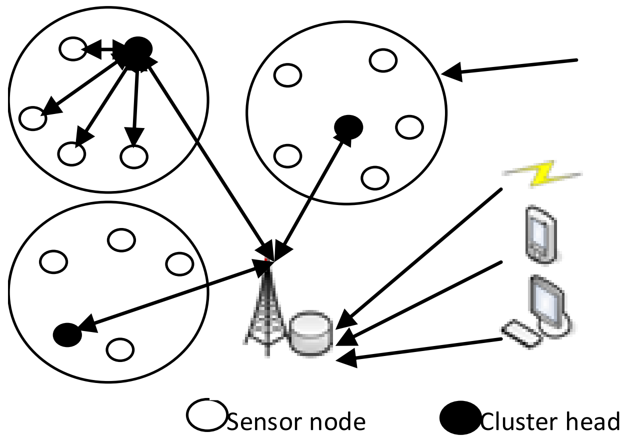

Figure 1. Cluster based wireless sensor network.

Two-tier architecture consists of a set of nodes in place and a set of mobile nodes. Moving nodes form an overlay network or the role of data mules to transfer data across the network. In the three-tier architecture, a set of fixed sensor nodes transmit data at a set of mobile devices, which then transmits data to one set of access points. The heterogeneous network is designed to cover large areas and be compatible with several applications simultaneously. At the level of node, wireless sensors can be classified according to their role in the network. a) Mobile embedded sensor: The integrated mobile nodes do not control their own movement, but his movement is led by an external force, such as when connected to an animal, or connected to a shipping container. b) Mobile actuated sensor: Sensor nodes may also have the ability to motive power, which allows them to move in a sensitive region. With this type of controlled mobility, the implementation specification may be more accurate, the coverage can be optimized, and specific events can be targeted and controlled. Data mule: Often, the sensors should not be mobile, but you may need a mobile device to collect data and deliver them to a base station. These types of mobile entities are considered as mule's data. It is generally accepted that data mules can recharge their power sources automatically. Access points: In low density networks, or when you drop a node on the network, mobile nodes can be placed to maintain network connectivity. In this case, it acts as an access points to the network (Munir et al., 2007; Amundson et al., 2008).

Clustering techniques

Several research papers and projects explains that the hierarchical routing and in particular the clustering techniques make an immense enhancement on WSNs. These approaches reduce the energy utilization and network performance when the entire sensor nodes of the network are sending a data to base station or central collection center. Figure 1 explains the general architecture ofcluster based WSN, and to investigate how the phenomenon of clustering is an integral part of organizational structure (Arboleda and Nasser, 2006; Akkaya and Younis, 2005; Arshad et al., 2011). The core components of the cluster based WSN are sensor nodes, clusters, cluster heads, base station and end user. Sensors nodes are an essential part of the WSN. Organizational unit of WSN are clusters. Cluster heads (CH) are the leader of the cluster. In hierarchical WSN the upper levels is the base station (BS) and it establishes 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 (Akyildiz et al., 2002). Energy awareness routing protocol for sensor networks can be classified into four categories: Data centric, Hierarchical cluster based, Location based and Network flow and QoS-aware protocols. Much of the research and potential models for sensor networks are formed but not addressed enhance network lifetime, efficient data gathering and latency time control or maintain in one protocol. This paper explains a new multi-hop routing protocol by the help of MDC which is moving in a pre-defined trajectory within the network for environmental applications. The MDC moves from top to bottom in each corner of the network and sends beacon message for every 5 s to CH and BS. When CH received the beacon message from MDC, then CH calculate the distance by received signal strength of the MDC's and select the shortest distance to deliver the sensed

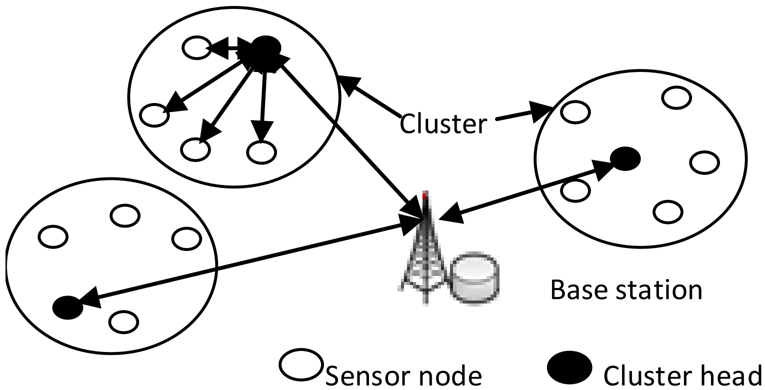

Figure 2. Single hop LEACH routing protocol.

aggregated data of sensor nodes towards the base station. The basic parameters of networks are: Fixed base station which is located far from the sensors, homogenous and energy controlled sensor nodes and no high-energy nodes during the communication. Data fusion is the best approach to avoid information overload which is used in different hierarchical cluster based routing protocols.

The rest of the paper organized as follows: summary of the related works of Hierarchical cluster based routing protocols, mobile data collector based LEACH routing protocol, results and discussion, and finally conclusion and future works.

RELATED WORKS

The main purpose of hierarchical routing is to maintain efficient energy utilization by multi-hop communication.The data aggregation and fusionis to reduce the number of messages transmitted towards the sink. Clustering technique is usually the energy maintain of sensors which is near the cluster head. This section provides a brief introduction about different hierarchical cluster based routing protocol.

Low energy adaptive clustering hierarchy (LEACH)

Construction of low energy adaptive clustering hierarchy (LEACH) is one of the first significant developments to conventional clustering approaches in WSN (Figure 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 balancing of energy consumption in a random rotation of cluster heads. The Algorithm is self organized; employs single-hop routing strategy and data combination technique can decrease the rate of data transfer (Heinzelman et al., 2000).

Two levels-low energy adaptive clustering hierarchy (TL-LEACH)

Two levels of the 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 when data is transmitted from source to the base station and reducing total energy consumptionis topological diagram described in Figure 3 (Loscri et al., 2005). In assessing the data reliability of both LEACH and TL-LEACH protocols some of the important aspects that are included in the protocol. To avoid collision by CSMA method and CDMA used to eliminate interference between clusters. TL-LEACH two-level hierarchy does not provide direct improvements in the reliability of the standard LEACH (Loscri et al., 2005).

Adaptive sensitive energy efficient sensor network protocol (APTEEN)

Adaptive sensitive energy efficient sensor network protocol (APTEEN) is a new version of cluster based hierarchical and reactive protocol based on single-hop routing protocol, which is planned to be sensitive to unexpected modification in the perceived elements such

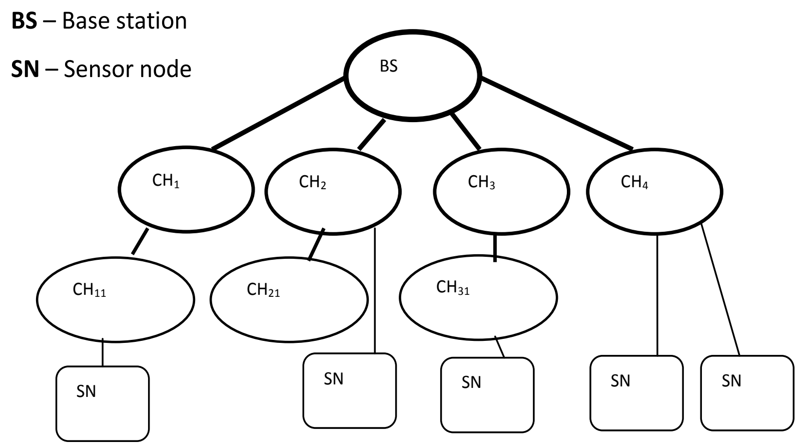

Figure 3. Topology of two-tier hierarchy. CH_i and CH_{ij}: First and second level cluster head.

as habitat monitoring and measuring the temperature. The main objectives are to capture the regular collection of data and respond to critical events within time. APTEEN architecture is similar to TEEN, all nodes receive the attributes, threshold values and communication schedule from cluster heads, while the cluster is created by the base station. To save energy, data aggregation is the best method which is performed by the cluster heads. The simulation results of APTEEN shows better than LEACH because APTEEN's offers the best performance in terms of network lifetime and energy consumption, but APTEEN is not suitable for high-quality applications which require periodic reports. Moreover, the main disadvantages of APTEEN are the complexity and overhead of the multiple cluster levels based on the implementation of threshold functions and features according to the description of the query (Manjeshwar and Agrawal, 2004).

Mobile agent based LEACH

Mobile agent based LEACH is a multi-hop intra-cluster algorithm, where the clustering technique uses a 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 died and provide reliable data. Mobile agent based LEACH save more energy through neglecting the redundant data and delivers the data with reliability at the base station (Jeong et al., 2008).

MOBILE DATA COLLECTOR BASED ROUTING PROTOCOL

The framework of proposed MDC based routing protocol for wireless sensor networks is expressed in Figure 4, this architecture reduce the energy consumption of the sensor nodes, enhance the network lifetime and increase traffic received at base station. MDC based routing protocol uses three-tier network architecture and multi-hop communication for data aggregation and transmission from sensor node to base station. Figure 5 explains the topological architecture of MDC based routing protocol. It has been observed this type of architecture enhance the network scalability for large scale environmental applications. Multi-hop 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.

Energy model for data transmission

In recent years lot of research has been done into low-energy propagation radio models. MDC based LEACH routing protocol employs a simple First Order Radio Model demonstrate in Figure 6, 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

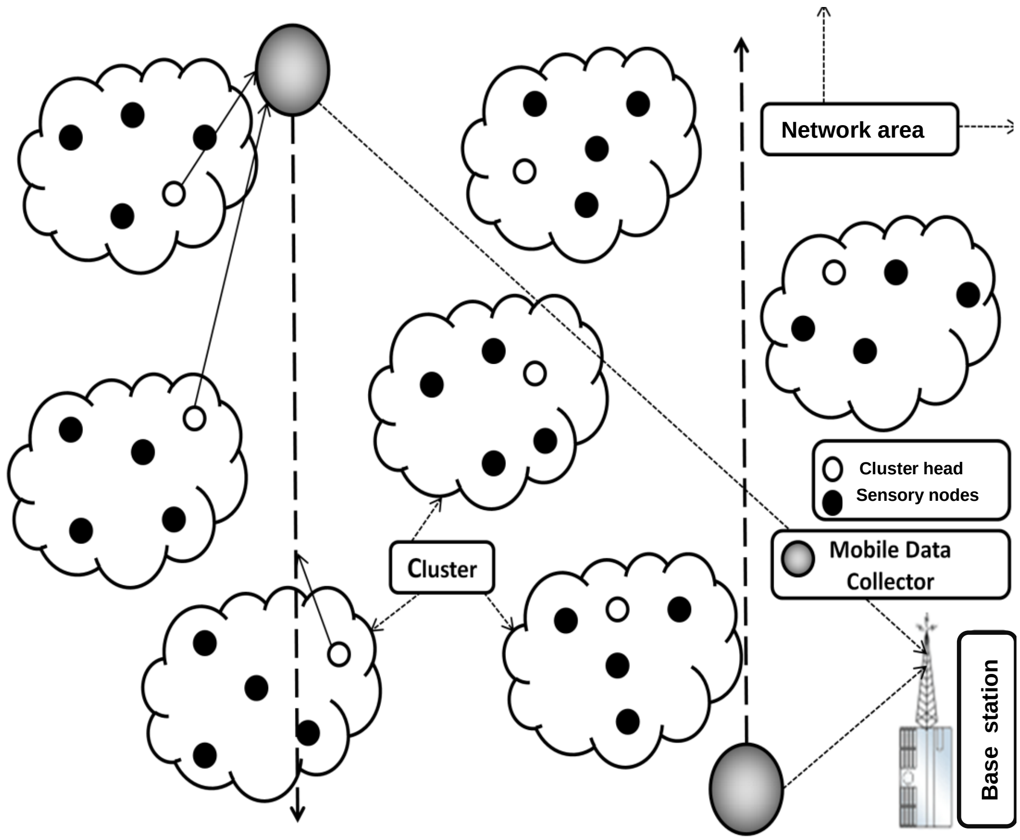

Figure 4. Proposed framework.

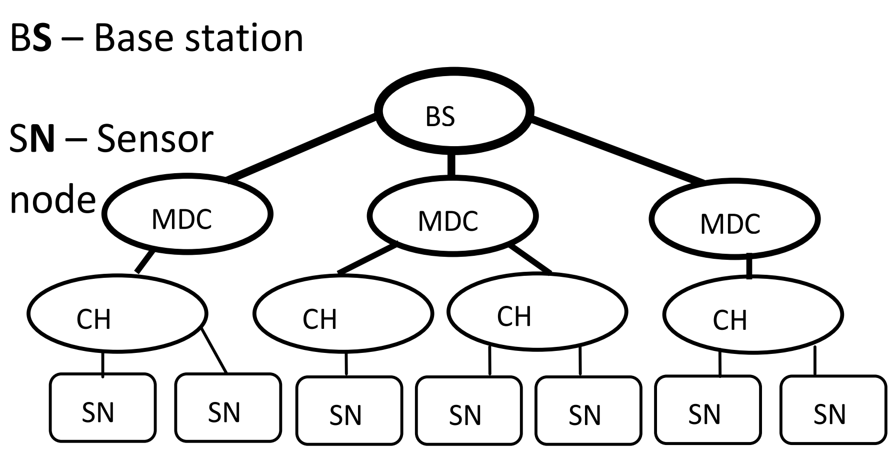

Figure 5. Topology of MDC based LEACH hierarchy.

the other models. Suppose r^2 is energy loss within channel transmission, when send a k-bit message at a distance d by the help of radio model, the transmission end calculations are in equations 1 and 2 [Heinzelman et

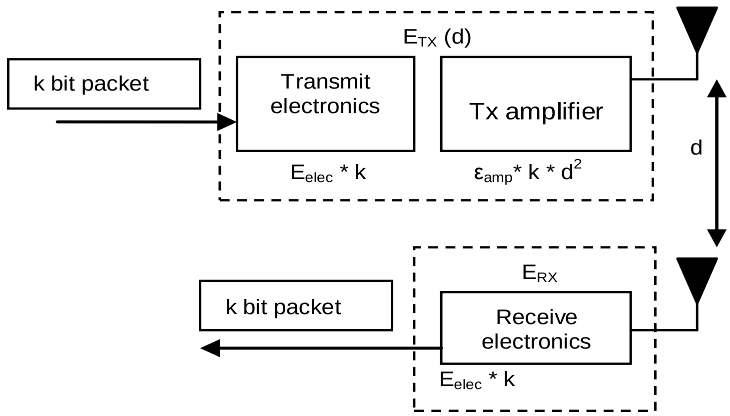

Figure 6. First order radio model.

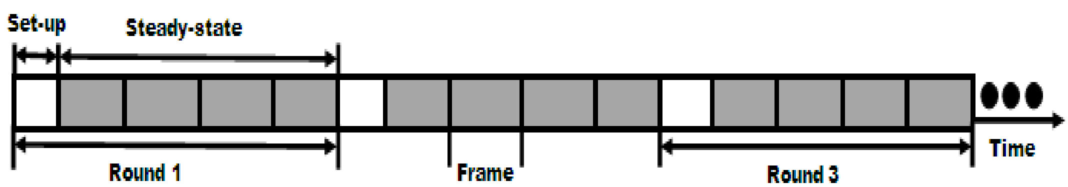

Figure 7. LEACH operation time line.

al., 2000; Shah and Rabaey, 2002]:

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

And receiving end calculations are:

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

Inter and intra cluster communication

The end-to-end data transmission process of MDC based routing protocol is divided into many rounds and each round is followed by a set-up and steady phase for cluster formation and data transfer from sensor nodes to MDC and then finally to the base station. The operation time line of LEACH protocol is shown in Figure 7.

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) and 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 (Heinzelman et al., 2000).

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

At the beginning of the set-up phase every node uses 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 selected 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 be selected as a CH for the next round. All CH in the network broadcast announcement from all nodes through CSMA MAC protocol, this message contains CH node position and message type that indicates it as short

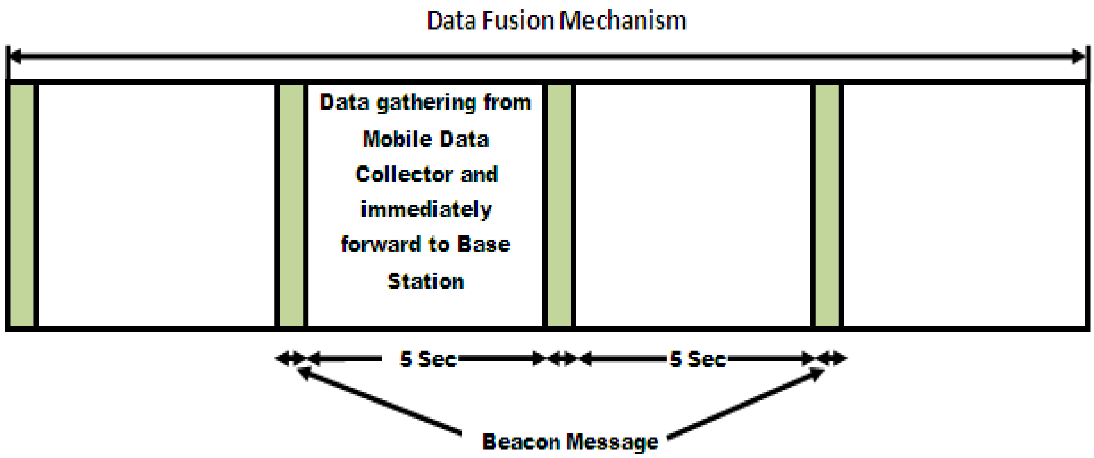

Figure 8. MDC beacon message.

message. After time t_1, nodes receive many broadcast announcement messages from many CHs, and then member node decides to close the 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) schedules every node to send data towards CH. This scheduling is 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 informs all member nodes within the cluster to transmit their data using this spreading code. In data fusion mechanism towards the base station, MDCs transmit a beacon message for all CHs contained by the network to update their current position. Figure 8 makes clear a MDC beacon message mechanism. According to inverse square law the transmission energy is directly proportional to the square of the distance, thus the sensor node A calculates the least distance by squared distance function S (M) to reach the base station through MDCs as mentioned in Equations 4 and 5.

$$S(M) = s^2_{A\text{-}M} + s^2_{M\text{-}BS} \quad (4)$$

M denotes MDC. Then there is the least of them is taken, and in relation to the square of the distance from the head node A to BS.

$$\text{Min}(S(M)) < s^2_{A\text{-}BS} \quad (5)$$

When a CH received sufficient data from its members then it will change the spreading code for MDC and return back to receive the sent data messages from its members after successful transmission. Figure 9 explains the flow chart of CH to MDC message.

During the transmission from cluster head to MDCs, all CH broadcast the messages within the network through another assigned spreading code and uses CSMA/CA employed as a MAC layer protocol to avoid possible collision between them. When MDC's received the data from any CH, then it will directly and immediately route the data towards the base station by the help of MDC distance calculation formula. The overall contributions of this paper are:

i) According to best of my knowledge first time introducesindividually Mobile Data Collector for data collection from cluster heads and forward towards base station in hierarchical cluster based routing protocol.
ii) Sensor nodes are Mobile within the network.
iii) Increase energy efficiency of sensor node.
iv) Enhance the overall network lifetime.
v) Improve Data gathering at base station.
vi) Cluster head selection based on probability P_i *(t)* and *N/k* formula.

RESULTS

The network parameters of simulation are explained in Table 1, forty sensor nodes are randomly deployed in both routing protocol architectures because the number

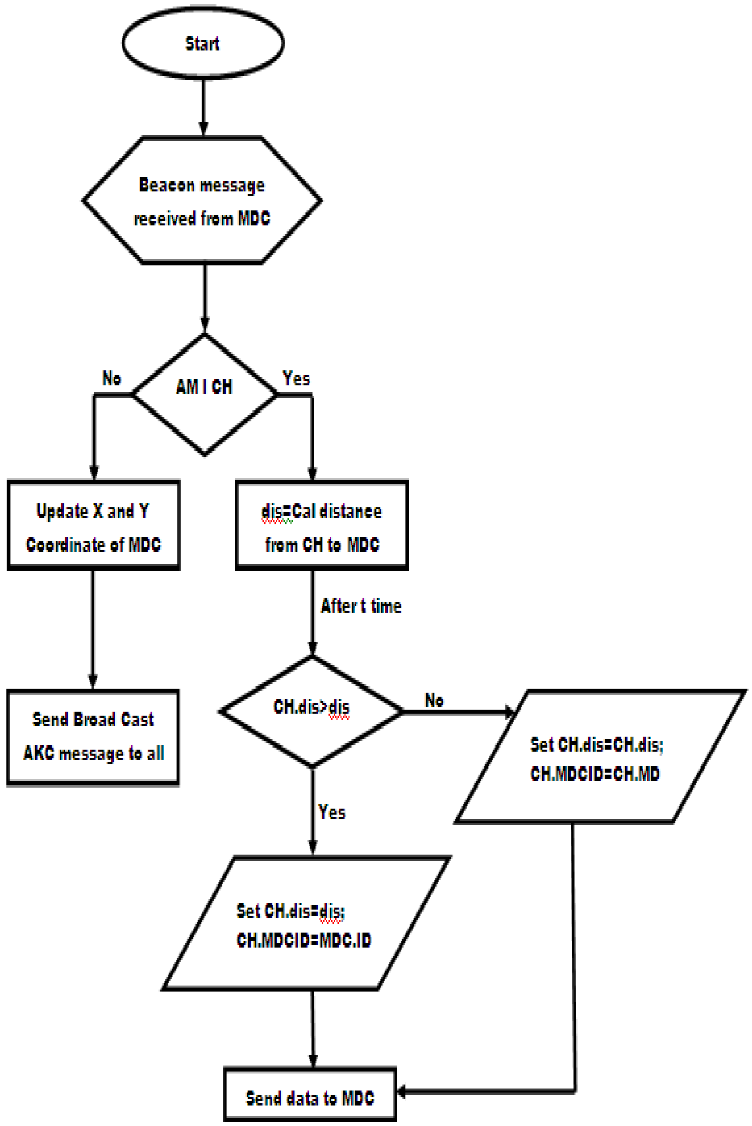

Figure 9. CH to MDC transmission.

of sensor nodes ranges from 25 to 100 per region in habitat monitoring application (Akyildiz et al., 2002). MDC based LEACH routing protocol uses 2 MDCs for data collection from CHs and then forward to BS, these MDCs are moving in pre-defined trajectory from top to bottom and bottom to top and the characteristics of these MDCs are different than other normal sensor nodes in terms of energy. According to Equation 3, LEACH and MDC based LEACH routing protocol formed 10 clusters in each round, in every round the CHs are different and member nodes of the CHs are also different due to the node mobility. 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.

Energy consumption of sensor nodes and network lifetime

In Figures 10, 11 and 12 shows the energy consumption of sensor nodes after the multiple simulations runs over LEACH routing protocol and MDC based LEACH routing protocol. Network lifetime of LEACH and MDC based routing protocol are expressed in Figure 13.

Table 1. 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 MDCs	2
MDC beacon message rate	5 s
MDC velocity	0.054 m/s
MDC energy	30 joules
Packet size	160 bits/packet

Traffic received, average channel access delay and end-to-end delay

The number of packets received by the base station in MDC based LEACHrouting protocol are much higher than LEACH routing protocol. As illustrated in Figures 15 and 16, the average channel access delay and end-to-end delay of MDC based LEACH routing protocol and LEACH routing protocol with different speeds during the simulation.

DISCUSSION

In LEACH and MDC based LEACH routing protocol the sensor nodes are randomly distributed in the network and utilizes MDC for communication towards the base station. As we fixed, the energy limit of each node is 2j, the energy consumption of node 17 in LEACH routing protocol died after the simulation of 2 h but in MDC based LEACH routing protocol remained alive and died after 4 h. On the other hand, the energy consumption of node 11 and 36 lived longer than node 17 in MDC based LEACH routing protocol, but in LEACH routing protocol nodes 11 and 36 died after the simulation of 4 and 1 h, respectively. Based on the previous result, there is a significant difference in energy consumption of sensor nodes within the network, which has direct impact on the performance of the network or network lifetime. The simulated result of Figure 13 exposes the considerable variation in network lifetime. Therefore, multi-hop MDC based LEACH 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. The sensor nodes in MDC based LEACH routing protocol stays alive longer and generate packets are higher than LEACH routing protocol, but in LEACH routing protocol the sensor nodes dies earlier and are not able to generate packets. Figure 14 demonstrates the number of traffic received at base station over time in MDC based LEACH routing protocol and LEACH routing protocol. Channel busyness or latency time of a data packet, when it is entered in the network layer and getting out is measured by channel access delay, the result shows that the channel access delay of MDC based LEACH routing protocol is slightly higher than the LEACH routing protocol due to increased traffic load between sensor nodes to base station by applying MDC based multi-hop routing. The main metric of network latency is end-to-end delay; it is defined as the time latency of data packet, channel access delay and other potential delays from source to destination. Figure 16 explains the graph

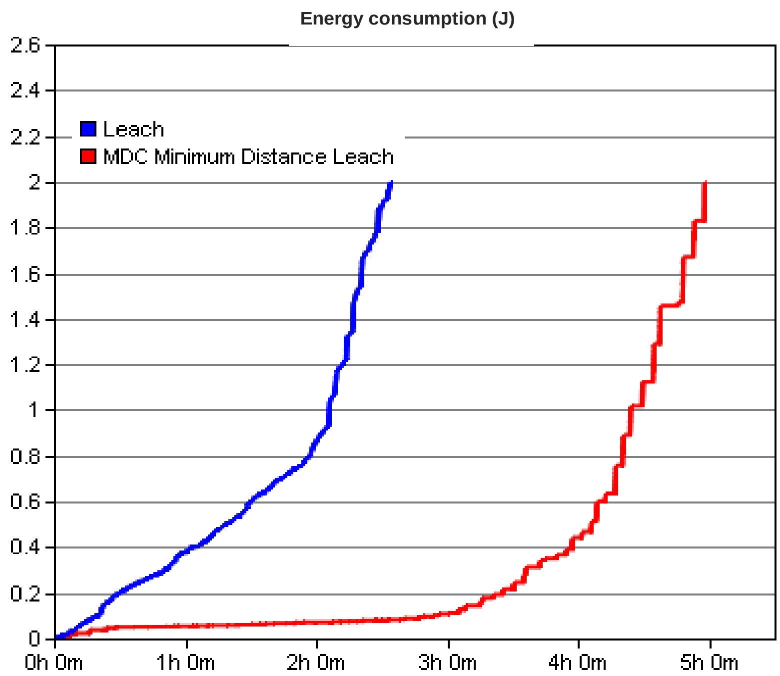

Figure 10. Energy consumption of node 17.

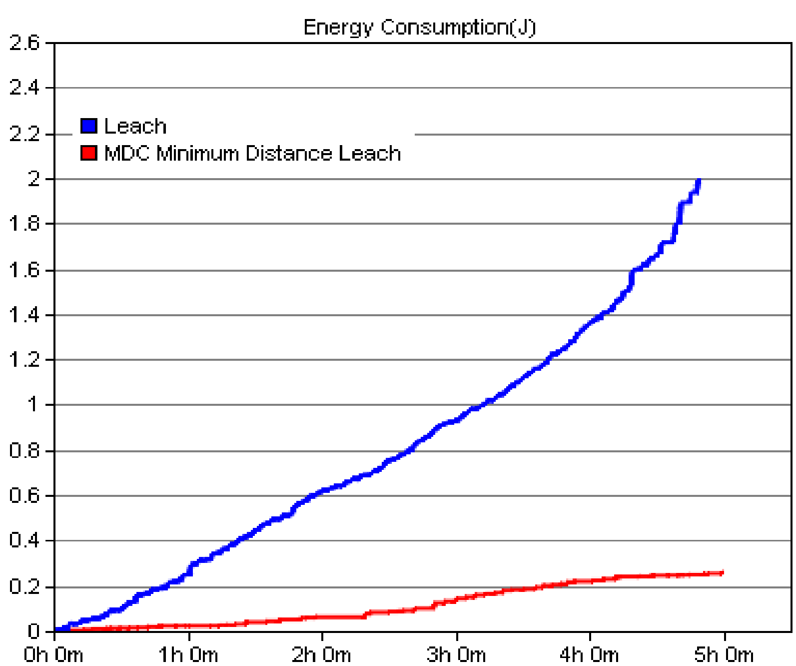

Figure 11. Energy consumption of node 11.

of average end-to-end delay over time using MDC based LEACH routing protocol and LEACH routing protocol. The end-to-end delay of MDC based LEACH routing protocol is higher than LEACH routing protocol due to aggregated

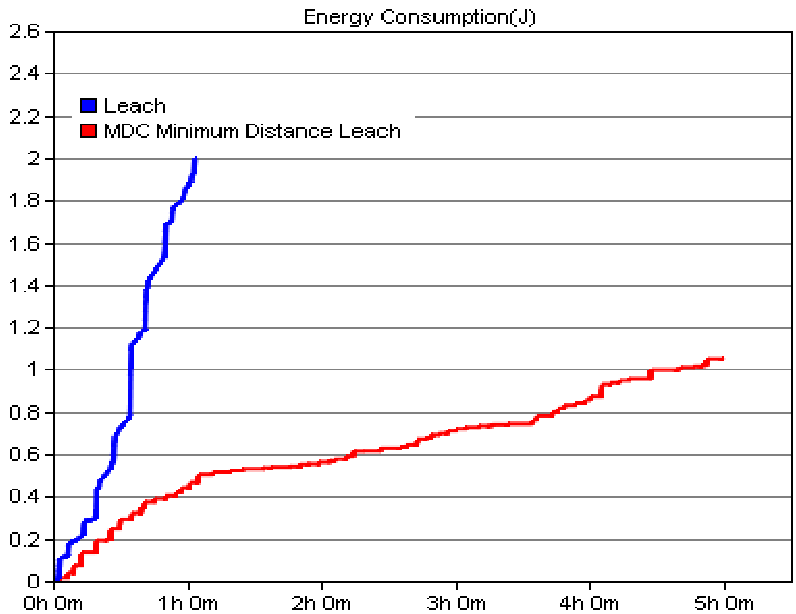

Figure 12. Energy consumption of node 36.

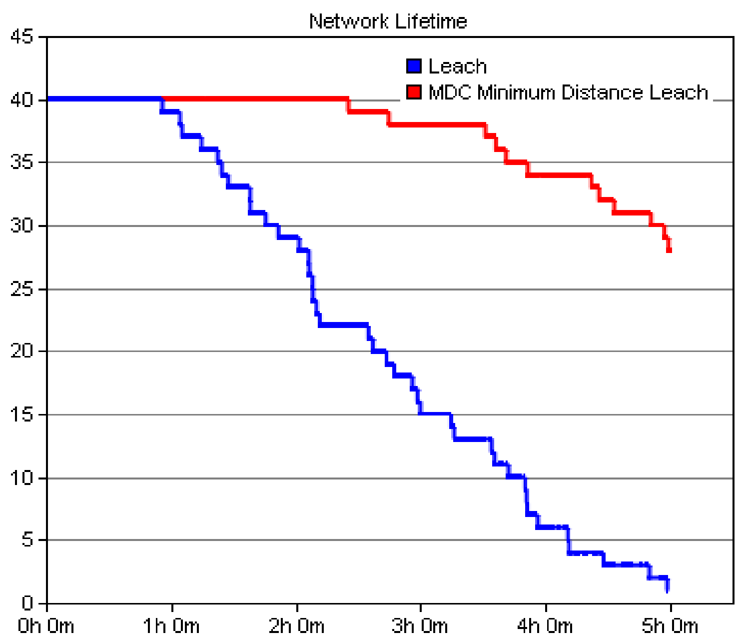

Figure 13. Network lifetime.

data packets in MDC based LEACH take multi-hops to reach the base station which is nearly same as channel access delay.

Table 2 summarizes the simulation result of MDC based LEACH routing protocol and LEACH routing protocol. This guides energy consumption of sensor

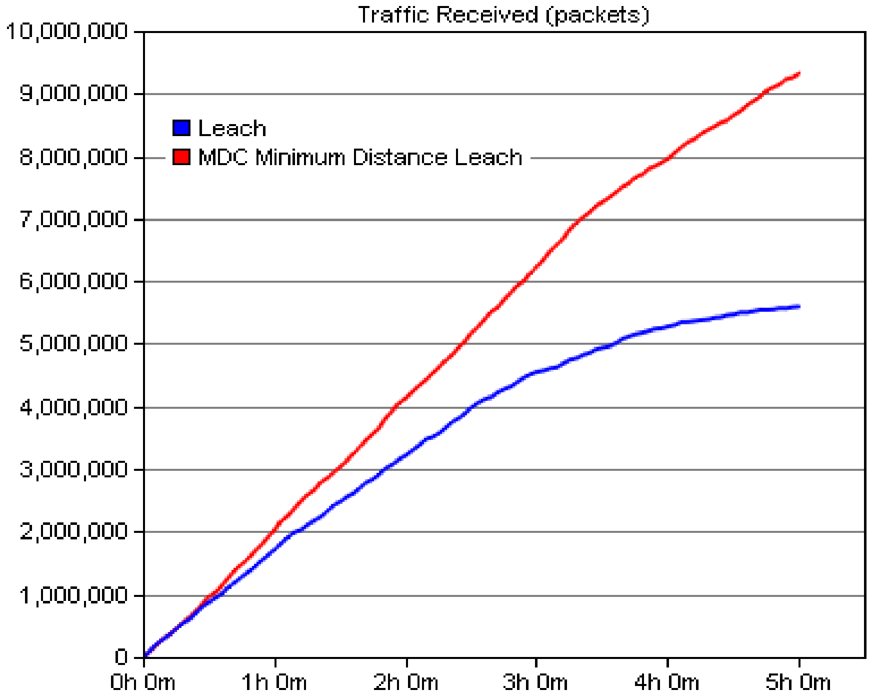

Figure 14. Traffic received (BS).

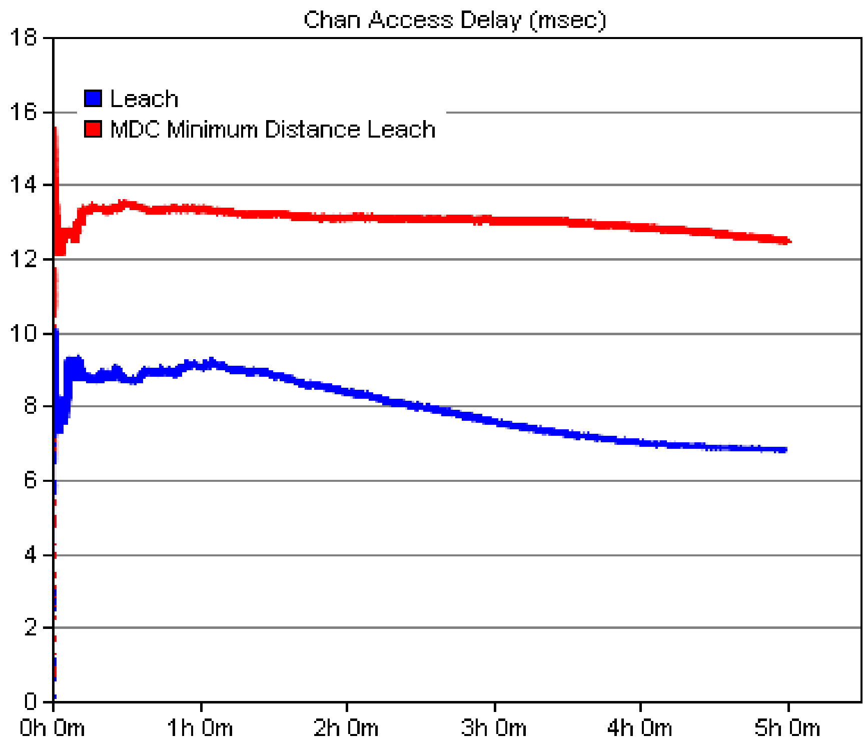

Figure 15. Average channel access delay.

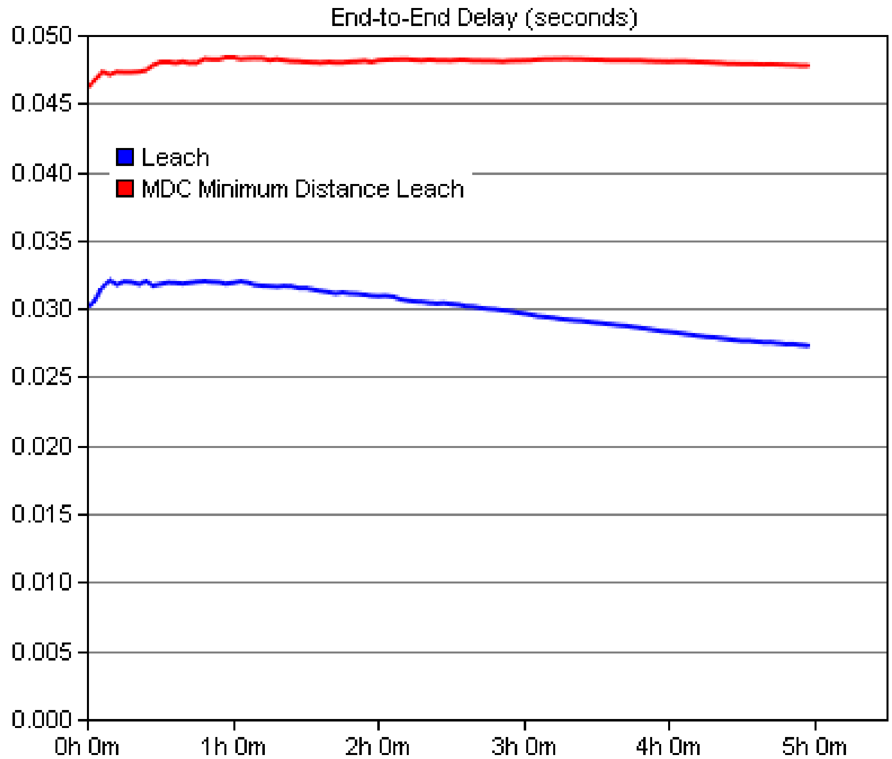

Figure 16. End-to-end delay.

Table 2. Simulation comparison chart.

Attributes	MDC multi-hop based LEACH	Single-hop LEACH
Sensor node energy consumption	Low	High
Network lifetime	High	Low
Traffic received	High	Low
Channel access delay	Little high	Low
End-to-end delay	High	Low

nodes, network lifetime, and traffic received at base station, channel access delay and end-to-end delay between the sensor nodes to base station.

Conclusion

This paper addresses the considerable comparison in single and multi-hop routing protocol for cluster based LEACH protocol. According to aforementioned simulated results, the evidence for MDC based LEACH routing protocol is better than LEACH routing protocol in terms of energy consumption of sensor nodes, network lifetime, traffic received, channel access delay and end-to-end delay from sensor node to base station. But MDC based LEACH routing protocol is not very effective solution for delay sensitive environmental applications, where end-to-end delay are essential. For the achievement of end-to-end delay within the network, multi-hop routing protocol for all nodes is a most viable solution for cluster based LEACH protocol.Where compressed data is collected at cluster head and finds a best possible route from all nodes of the network or used by another CH or find the least distance MDC to deliver the data to base station. In our future work, we enhanced and validate MDC based LEACH routing protocol by selection of remaining maximum energy MDCs to transmit the data, and another technique is to employ multi-channel concept at base station for number of MDCs.

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