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A Reliable and Energy Efficient Enhancement of Data MULEs Protocol for Wireless Sensor Network

Poojarini Mitra*, Sinthia Roy
CSE Dept, GNIT, WBUT
West Bengal, India

Abstract — Wireless Sensor Network (WSN) requires to achieve energy efficiency during routing as the sensor nodes have very limited energy resource. The nodes' mobility in Mobile Wireless Sensor Networks poses a challenge to design an energy efficient routing protocol. This paper explores a reliable and energy efficient routing protocol based on Data MULEs. An enhancement on 'Data MULEs: modeling and analysis of a three-tier architecture for sparse sensor network' protocol has been explored where Data MULEs are mobile devices that carries computers to create a communication link. The data gathered by the sensor nodes are sent to the access point via these Data MULEs. Our main contribution is the performance analysis of the discovery of Data MULEs and the data transfer phases of the data collected. Although the algorithm is iterative and involves only local communication, its convergence rate is quite fast and is independent of the size of the network. We prove the effectiveness of the proposed algorithms through simulations.

Keywords—Wireless Sensor Network, Data MULEs, Access Points, Energy Efficiency, Network Lifetime

I. INTRODUCTION

Wireless Sensor Networks consists of a large number of low cost, low-power, low maintenance sensor nodes [1]. Sensor nodes usually consist of sensing, communicating, computing, storing and power components. The sensor nodes are capable of storing data sensed from the environment according to their specific application, collaborating and computing the data to perform some specific task and communicating those data to the higher level or the base station (BS) for decision making. BSs have enhanced capabilities over simple sensor nodes and can do complex data processing. Sensor nodes are often randomly deployed in huge numbers over a large area to monitor physical conditions like temperature, humidity, intensity, vibration, pressure, motion, pollutants etc. They are also deployed in military battlefield to track enemy movements.

Recent researches have shown that introducing mobility in wireless sensor network is advantageous as the mobile nodes can relocate after initial deployment to achieve the desired density requirement and reduce the energy holes in the network thereby increasing the network life time. Mobile wireless sensor networks (MWSNs) can simply be defined as a wireless sensor network (WSN) in which the sensor nodes are mobile. MWSNs are a smaller, emerging field of research in contrast to their well-established predecessor. MWSNs are much more versatile than static sensor networks as they can be deployed in any scenario and cope with rapid topology changes.A mobile wireless sensor network also consists of tiny sensor nodes which has three basic components: a sensor, processor and communicator. Mobility of these nodes can be achieved by equipping the sensor nodes with mobilizers, springs[2] and wheels [3] or they can be attached to transporters like vehicles, animals, robots [4] etc.

Wireless sensor networks are energy-limited and application- specific. Fixed-sink sensor networks suffer from a severe problem of high duty-load in the nodes around sinks. On the other hand, with a mobile sink, multi-hop transmission can be avoided since it is realistic to assume that a node transmits to the sink only when they are physically near to each other. As such, the nodes energy consumption in the sink information retrieval is reduced by the factor of hop number. Mobility in wireless sensor network is also very taxing [5] as path breakage happens frequently due to node movement. Frequent location updates from a mobile node is needed to establish routing which eventually leads to excessive drain of sensor node's battery supply and also increases collisions [6]. Lifetime of a sensor network depends on energy supply. Therefore it is necessary to design energy efficient routing protocol.

II. RELATED WORKS

Greedy Perimeter Stateless Routing (GPSR) [7] is a routing protocol for wireless datagram network which basically needs router's position and packet's destination forwarding decision. GPSR makes greedy forwarding decision that is, using the best local information to route IP datagram over the network. When a packet reaches a region where greedy forwarding is impossible it recovers by patrolling around the path. Here Greedy approach means that under frequent mobility change it basically concern the local topological information by knowing the forwarding node immediate successor which is geographically closest to the destination. On the other hand, Perimeter rule implies that the packet will be routed around the region when there is no path between the forwarding node's successor and destination. Let us take a packet which moves from A to B, this protocol mainly looks on current's forwarding node i.e. A and sees many successor but it will locally choose that node that is geographically closer to B but when a situation arises where greedy approach fail it will send packet by around the void region. There are many advantages of this routing protocol such as the GPSR scales are better in per router-state as compared to shortest path as well ad-hoc routing protocol when number of destination increases. Moreover, it uses local topological information in order to find correct new state quickly and relies on the forwarding nodes immediate successor. However, scalability is still an issue here when the no. of destination nodes in the domain is more. Location inaccuracy in the planarization graph disconnects the graph and hence the packets don't get routed, which causes decreased packet delivery ratio. There are certain problems like edge problem in which if an edge is repeated twice the GPSR protocol drops the packet.

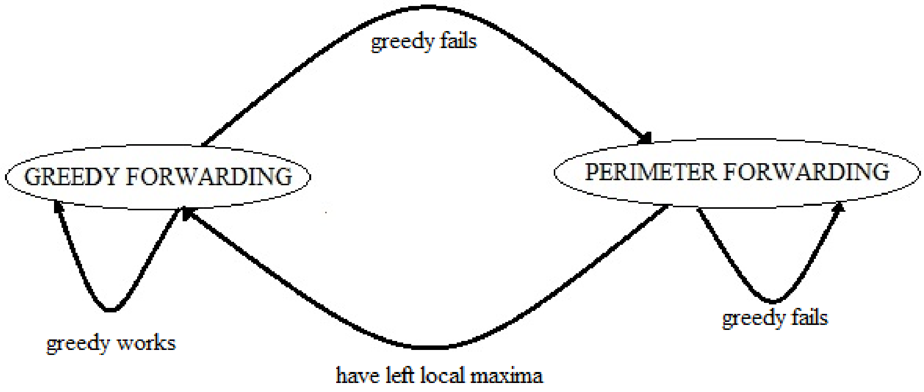

Fig. 1 Greedy Perimeter Stateless Routing (GPSR) Protocol

Content And Context Based Routing Protocol (CCBR) [8] is explicitly designed for multi-sink mobile WSN. Here all the nodes may act both as a sink and a sensor. CCBR adopts a probabilistic mechanism to decide if and how packets are forwarded. To forward data from source to sinks each node maintains a distance table which consists the distance of the node from each sink and a content table which consist the interest of sink that is crucial for node as shown in fig. 2.

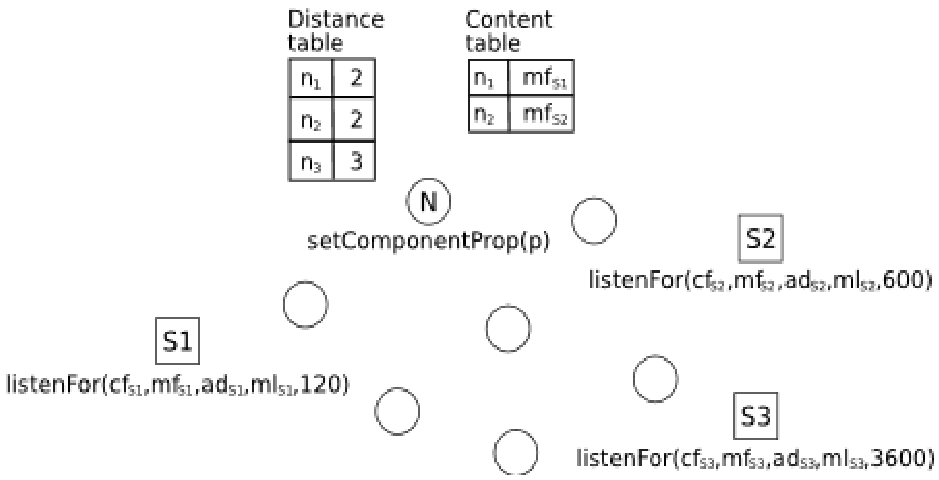

Fig. 2 Content and distance tables in CCBR

Whenever a packet needs to send, the node calculates the set of sinks those are interested in receiving those packets. After that it builds a forwarding header (destination vector and distance vector) and a forwarding packet and put it together to broadcast it. The node who receives a packet p compares the detail of forwarding header of p with its content table. If the receiving node is closer to at least one of the sinks listed in p's forwarding header, it updates the distance vector in p putting its own distance for those sink it is closer and it schedules the packets for transmission. In CCBR, nodes are very robust and intelligent. CCBR is capable of optimizing routing and power consumption and it uses energy in an efficient manner. But in spite of that CCBR face a lot of problems. We know that CCBR is context aware protocol so some information is added with the message that results in increase of the message size. Moreover, since we know that at every instance nodes may change their position so the nodes have wrong estimates of its distance from sink and as a result they face some problem regarding forwarding of packets.

CES: Cluster-based Energy-efficient Scheme for Mobile Wireless Sensor Networks [9] increase the lifetime of networks by electing a cluster-head to evenly distribute energy consumption in the overall networks. It calculates weight based on k-density, residual energy and mobility of the sensor and broadcast it to its 2-hop neighborhood. A sensor node having greatest weight in its 2-hop neighborhood will become the cluster-head and neighboring sensor will then join it. CES performs better in terms of the amount of data packets received at the sink. By using this theorem we can manage the life of sensor nodes and increase the duration of the mobile wireless sensor networks and equally distribution of energy in over all sensor nodes.

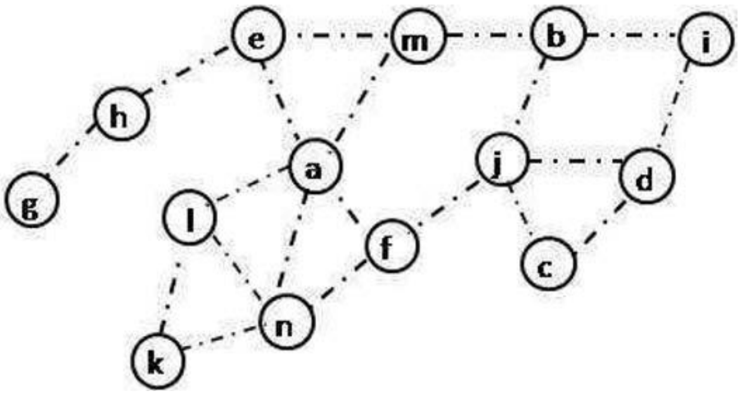

Fig. 3 Example of an abstracted wireless network

In Data MULEs: modeling and analysis of a three-tier architecture for sparse sensor network [10], mules refer to the mobile entities. Mules pick up data from the sensors when in close range, buffer it and drop off the data to wired access points. The architecture is shown in fig. 4.

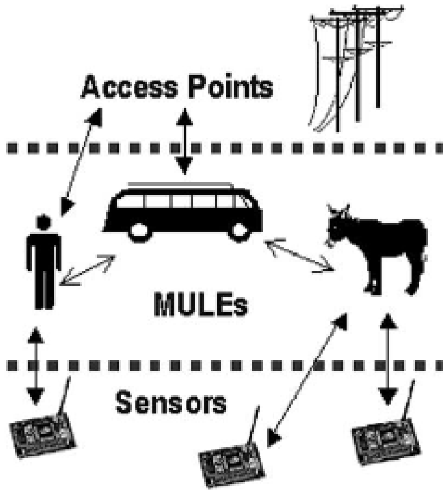

Fig. 4 The MULEs three tier architecture

Upon three tiers, the top tier is composed of access point which can be set up at convenient location where network connectivity and power are present. It receives data from mules and also sends acknowledgement to the mules. The intermediate layer consists of mobile mules having high scalability and flexibility. The key traits of mules are large storage capacities, power and the ability to communicate with the sensors and networked access points. In addition, mules can communicate with each other to improve system performance. The bottom tier consists of sensors. The mule's architecture is very robust and have high scalability. No sensor depends on any single mule and hence failure of any mule does not disconnect the sensor from the network. Moreover, storage overhead is not an issue here.

In our project we propose an enhancement on the Data MULEs protocol.

III. PROPOSED MECHANISM

A. Discussion

MULEs refers to the data MULEs which pick up data from static, fixed sensor nodes when in close range and carry that information to the access points. Though the Data MULEs protocol has many advantages but it suffers from a number of drawbacks. There is a problem regarding static sensor nodes, as they have limited energy and had to wait for mules to send information to the access point, it can drain away the energy of the sensor nodes. It is also not sure of the fact whether the data packet has reached the access point. There is another problem associated that when sensor has send data to the mules but at that point of time mules move out of the region, then arise a situation that the packet may get lost.

B. Problem Formulation

Here we are considering that access point and data mules have unlimited amount of energy and memory capacity in contrast to fixed sensor nodes. In this protocol, every node keeps sensing the network when an event occurs and when there is need to transfer the data it waits for some mule to enter its connectivity range. For other periods of time it remains in sleeping mode.

C. Procedure

1) The sensor nodes are deployed and initialized.
2) Initially the sensor nodes are in sleep mode

3) The Data MULEs while travelling broadcasts an advertisement after every, say t, instant of time.
4) The sensor nodes on receiving the advertisement turn on the radio to 100% activity.
5) Sensor nodes send the data to the Data MULEs and wait for an acknowledgement from the access point. The data are arranged in a sliding window format where size of the sliding window is set according to Go-Back-N-ARQ protocol. The size of the send window is less than 2^m, where m is equal to the number of bits in the sequence number of the frame.
6) The MULEs on receiving the data forwards the data immediately to the access point.
7) If the MULE is going out of the coverage area of the access point, it sends the data to another MULE within its range. Then it is the responsibility of the new MULE to forward the data to the access point.
8) The access point on receiving the data sends the acknowledgement back to sensor node from which the data came. As the access point has unlimited energy so it does not pose any problem to communicate directly with the sensors.
9) The sensor nodes on receiving the acknowledgement forwards the sliding window to as many acknowledgements received.
10) If the sensor node does not receive a particular acknowledgement then only that data is again forwarded.
11) If the sensor node has no more data to send then it again switches back to sleep mode.

IV. SIMULATION

In this section, we use simulations to study the performance of our scheme. We have implemented Energy Efficient Approach on Cut Detection in Wireless Sensor Networks in OMNeT++ [11], a discrete event simulator. We chose OMNeT++ as a base platform and it's MiXiM [12] [13] framework as a starting point for our implementation. OMNeT++ is a public-source, component-based, modular and open-architecture simulation environment. In general, OMNeT++ is a discrete event simulator which can be used for wide variety of purposes like modelling of traffic of telecommunication networks, protocols, queuing networks, multiprocessors and distributed hardware systems, validating hardware architectures, evaluating performance of complex software systems and so on. An OMNeT++ model consists of hierarchically nested modules. Modules communicate through message passing. They can send messages either directly to their destination or along a predefined path, through gates and connections. Modules can have their own parameters, which can be used to customize module behaviour and to parameterize the model's topology. OMNeT++ simulation can make use of several user interfaces for different purposes. In our simulation we use Tcl/Tk graphical user interface for debugging and presentation and faster command-line interface for simulations of large networks. The simulator and user interfaces and tools are portable – they work on Windows, Mac OS and several Unix-like systems, using various C++ compilers. MiXiM is an OMNeT++ modeling framework created for mobile and fixed wireless networks.

The environment settings are shown in Table 1.

Table 1 environmental settings for simulation

Parameters	Values
WSN area	70 X 70
Number of nodes	200
Deployment	Uniform
Transmission power consumption	0.002 * dist J
Reception power consumption	0.02 J
Initial energy	5 J
* dist is the transmission distance	

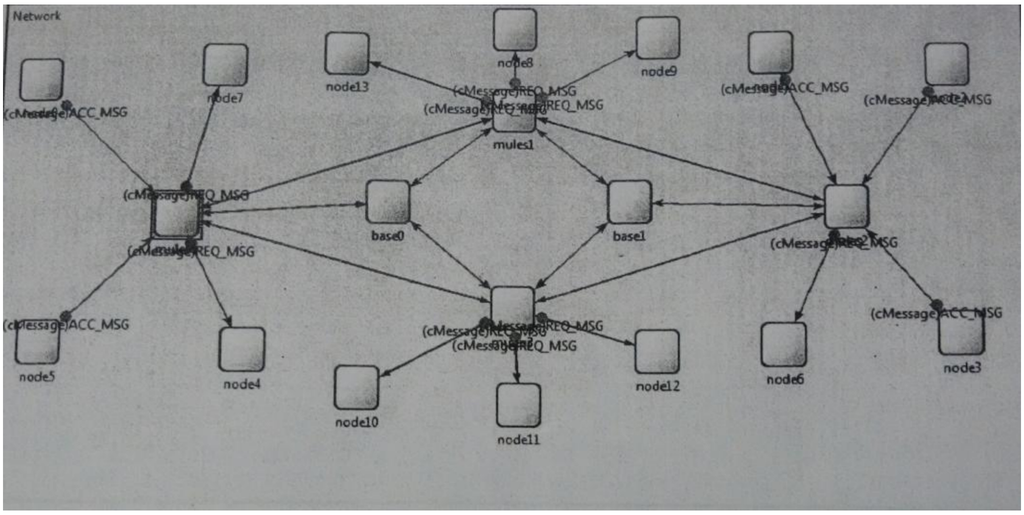

Fig. 5 Simulation result to demonstrate acceptance of request by Data-MULEs

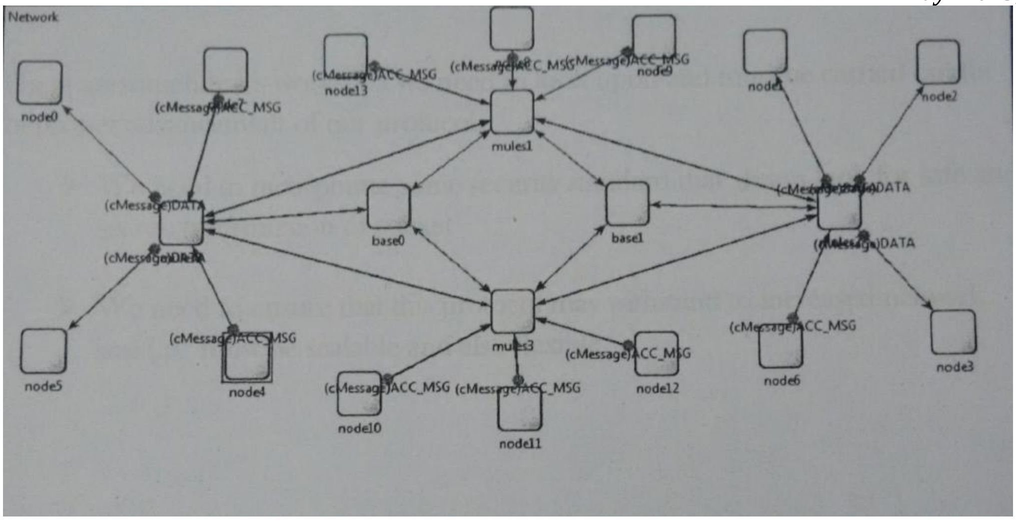

Fig. 6 Simulation result to demonstrate relaying of data to Data MULEs

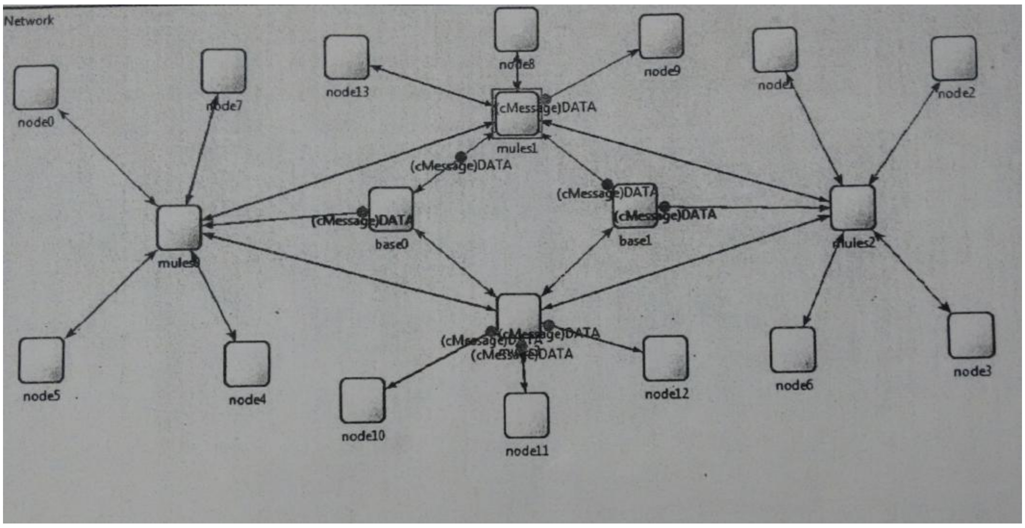

Fig. 7 Simulation result to demonstrate relaying of data to access points

The performance of Reliable and Energy Efficient Enhancement of Data MULEs Protocol is compared with Data MULEs: modeling and analysis of a three-tier architecture for sparse sensor network. The Network Lifetime is used as an evaluation measure.

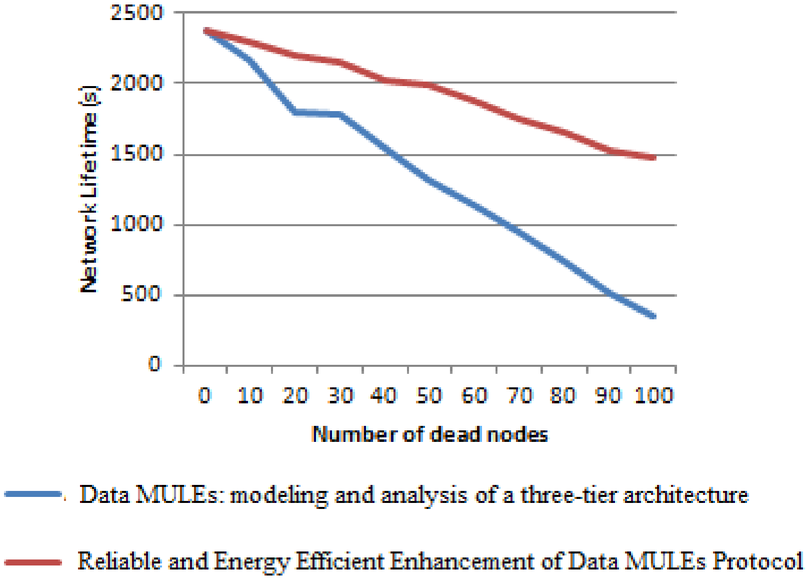

Fig. 8 Comparing Network Performance between Reliable and Energy Efficient Enhancement of Data MULEs Protocol and Data MULEs: modeling and analysis of a three-tier architecture in WSN to show the Network Lifetime

From Fig. 8, it can be observed that on implementing our algorithm the network lifetime increases.

V. CONCLUSIONS

In this paper we have analyzed the problem of optimal data transfer in sensor networks with Data MULEs. Currently used protocols are inefficient from an energy consumption view. We have proposed the protocol, showing that its energy consumption is better with respect to the former protocol. We have performed our analysis by considering sparse sensor networks where nodes are considerably far apart from each other. Currently, we are extending our protocol to manage the more general case where sensors are deployed in such a way to form local clusters (with a cluster-head in charge of collecting data from other nodes in the cluster, and transferring them to the mule), and the amount of data to transfer may be different in different passages.

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