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Minimum Hop Energy Efficient Routing Protocol

G.Sandhya Devi
CS & SE Department
Andhra University
A.P, India

G.Suvarna Kumar
CSE Department
M.V.G.R.C.E
A.P, India

P.V.G.D Prasad Reddy
CS & SE Department
Andhra University
A.P, India

ABSTRACT
Wireless sensor networks find wide applicability today. Sensor nodes are generally energy resource constrained which operate with battery power. In this paper, we propose Minimum hop Energy Efficient Routing protocol. Its main objective is to include minimum number of hops in the routing path for the transmission of packets from source to sink (destination) at the same time, to minimize the total energy spent on the delivery of data, thereby increasing network's lifetime without any performance degradation. Simulation results and comparisons(with appropriate metrics) show that our proposed protocol has better routes and also less energy utilization compared to small state small stretch protocol.

General Terms
Wireless sensor networks (WSN), Routing in WSN

Keywords
Energy efficient routing, Minimum hop network protocol

1. INTRODUCTION
A **wireless sensor network** (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations

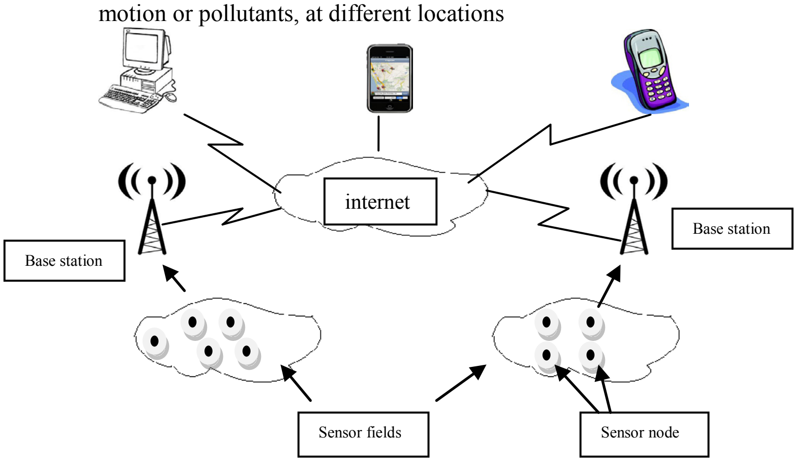

Figure 1: A wireless sensor network

Routing is a process where the data packets are routed from source to the sink node. Micro sensors which have low battery power are generally equipped with data processing and communication capabilities. The network's scalability and reliability are directly affected by the efficiency and effectiveness of the routing protocol that is employed.

Several routing protocols have been proposed in the current decade that considers the energy consumption problem attempting to balance the energy consumption in the sensor network and maximize the network lifetime. For example, Low Energy Adaptive Clustering Hierarchy(LEACH) protocol [1], Threshold-sensitive Energy Efficient Network (TEEN) Protocol [2],Energy-Aware On-Demand Routing [3], Energy-Aware Routing [4], Power Aware Organization protocol [5] and Minimum-Hop Routing [6].

In a cluster-based routing protocol like LEACH [1], a given number of nodes are selected and treated as cluster heads. This role is circulated evenly to distribute or balance the energy load of sensor nodes. In TEEN [2], the medium is sense by the sensor nodes continuously. The data transmission is done less frequently to reduce the energy consumption. A cluster head sends its members to two thresholds namely, the hard threshold and the soft threshold. The node will transmit data only when the current value of the sensed attribute is greater than the hard threshold. In the Energy-Aware On-Demand Routing protocol [3] the lifetime of a network is increased by routing around the nodes that have low battery levels. The protocol is designed in such a way that the radio interfaces are turned off dynamically during the periods when the nodes are idle. In Energy-Aware Routing [4], a set of sub-optimal paths are used. Here, a probability function is used to choose various paths, which depends on the energy consumption of each path. In Power Aware Organization protocol [5], the area to be monitored is divided into disjoint sets covering all the sensor nodes. In every set a single node can be activated while other nodes are set to a low-energy sleep state. With the Minimum-Hop Routing [6], an optimal path to the sink node is determined based on two metrics, the hop count and the energy level. The node with minimum hop count to the sink node is selected. In S4 protocol [10], pertaining to a cluster, irrespective of the position and distance of the nearest beacon to the destination, route path is determined. This may not yield shortest as well as less energy utilized paths under all conditions. Thus, the network life time will be potentially decreased [7], [8]. Secondly, from both the energy consumption point of view and the capacity point of view, it is better to communicate using short multi-hop routes than using a long single hop route [9]. Therefore, we are motivated to propose our MEER (Minimum hop energy efficient routing) protocol that overcomes the above mentioned shortcomings of the Small state small stretch protocol. In this paper, we propose an energy-efficient, routing protocol for wireless sensor networks. Our proposed routing protocol is considered as an enhanced version of the Small state small stretch protocol [10]. The rest of the paper is organized as follows: Section 2 is a brief review on the related work. In section 3 we present our proposed routing scheme. Section 4 discusses about the simulation environment and experimental results. Section 5 gives the conclusion.

2. RELATED WORK

We make the following assumptions about the network:
1) Each sensor node has a unique pre-configured id.
2) The transmission range of each sensor node is fixed.
3) There exists a contention free MAC protocol which provides channel access to all the nodes.

Small state Small stretch (S4) is a routing protocol that simultaneously achieves the following design goals[10].

Small routing state: Using small amounts of routing state is essential to achieve network scalability. Many wireless devices are resource constrained. For example, mica2 sensor motes have only 4KB RAM. Limiting routing state is necessary for such devices to form large networks. Moreover, limiting routing state also helps to reduce control traffic used in route setup and maintenance, since the amount of routing state and control traffic is often correlated.
Small routing stretch: Routing stretch is defined as the ratio between the cost of selected route and the cost of optimal route. Small routing stretch means that the selected route is efficient compared to the optimal route. It is a key quantitative measure of route *quality* and affects global resource consumption, delay, and reliability.

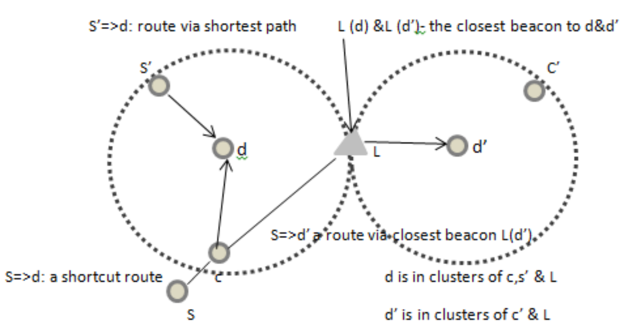

Fig2: Routing in S4 protocol [10]

This is a cluster based protocol where a cluster of 'n' nodes is organized by $\sqrt{n}$ beacon nodes. Beacon is a low battery operated node which aids in the determination of the desired routing path from source to the sink node. According to the protocol, in a cluster where source and sink are not neighbours (multihop communication is done) the routing is done via the nearest beacon to the destination irrespective of distances and positions of the surrounding nodes. This may not yield shortest as well as less energy utilized paths under all conditions.

Due to the above limitations, we are motivated to propose our Minimum hop Energy Efficient routing protocol which is considered an enhanced version of the small state small stretch protocol. The proposed protocol over comes the shortcomings of the Small State Small Stretch protocol.

3. PROPOSED MINIMUM HOP ENERGY EFFICEINT ROUTING PROTOCOL

The Minimum hop energy efficient routing protocols, which in the process of determining a routing path, minimum number of hops are used so that less energy will be utilized, thereby increase the network's lifetime considerably. This protocol makes routing decisions by forming routing paths considering the distances (between source and sink nodes) and positions respectively.

In this protocol, each sensor node maintains a routing table which aids in the selection of next nearer node or beacon in formation of the routing path. To clarify this, let us consider an example network scenario.

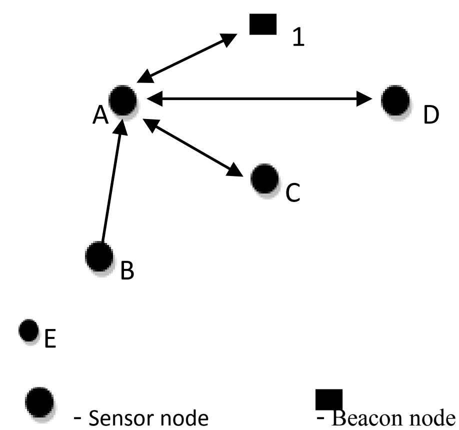

Figure 3: A sample network

The above given network comprises of 5 sensor nodes and 2 beacons. The routing table maintained at each node is organized in a matrix format. Rows and columns denote the neighbor nodes and beacons of the corresponding node. The intersection of row and column denotes the distance between them. The next hop is selected based on the distance between the current and the subsequent hop in the route. The size of the routing table depends on the number of nodes or the size of the network. Based on the audible range of the signal from a sensor node, the neighboring nodes and beacons will be registered in the routing table of the corresponding sensor node. So, the routing table matrix maintained at A is as follows:

Table 1: Routing table matrix at 'A'.

	B	C	1	D
B	0	w	∞	∞
C	w	0	x	y
1	∞	x	0	z
D	∞	y	z	0

In the above matrix, B, C, D is neighbor nodes and 1 is neighbor beacon to A. ∞' indicates that the corresponding row and column nodes are not reachable. w, x, y, z are the distances between corresponding nodes.

If the source and the sink nodes are neighbors (radio signal from source can be directly heard by the sink node without bypassing any intermediate beacon and non-beacon nodes), a direct path exists and routing is done. If they are not neighbors, routes with minimum number of hops and energy can be defined as below :

Case 1: when distance between the source and nearest beacon(to the sink) is greater than the distance between source and destination.

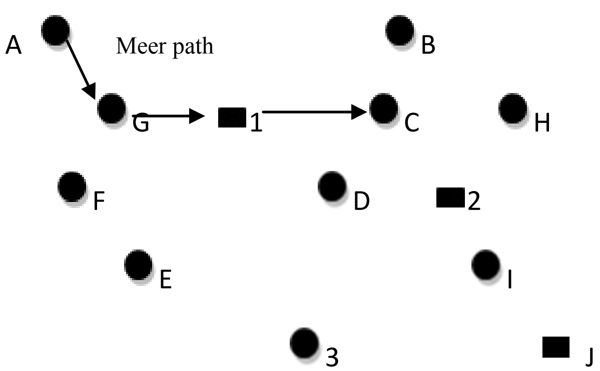

Figure 4: Case 1: Source-A, Sink-C

Nearest beacon to C is 2 and d(A,2)>d(A,c). So, a path is found between source(A) and sink(C) without going through nearest beacon(2). Thus, S4 path is A->G->1->D->2->C and improved MEER path is A->G->1->C. The energy utilized for S4 path is 5 units whereas for MEER path , it is 3 units.

Case 2: when destination is neighbor to a node while finding a path to nearest beacon.

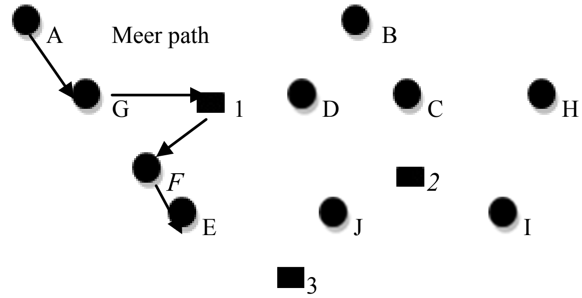

Figure 5: Case 2: Source-A, Sink-E

Nearest beacon is to E is 2. Sink is neighbor to F and beacon 2. So, a path is established between F and E without going through 2. Thus, S4 path is A->G->1->F->2->J->E. and improved MEER path is A->G->1->F->E. The energy utilized for S4 path is 6 units whereas for MEER path, it is 4 units.

In the above cases, number of hops included between source and sink are minimized considerably (without any performance degradation) . Also the total energy spent on the routes is lesser compared to S4 protocol which prolongs the network's lifetime.

Therefore, we conclude that even though the main advantage of small state small stretch protocol is to achieve minimum state and minimum stretch of the routing paths, it may not result in minimum number of hops inclusion from source to sink thereby consuming more energy per successful transmission. On the other hand, Minimum hop energy efficient routing protocol chooses the routes in such a way to include minimum number of hops and less energy dissipation in the network.

4. EXPERIMENTAL RESULTS

In this section, we show the simulation results and also compare the performance of the proposed protocol with that of the small state small stretch protocol [10]. It is well known that in wireless sensor network communications, idle listening or signal transmitting/receiving consumes much more energy of a sensor node than does the calculation of an optimal path or memory accessing. Therefore, in simulations, the energy consumption of calculation and memory accessing is not considered [11]. In this model, we have assumed that, for a pure transmission, the energy spent is 1.0 unit. So, the energy spent in relaying(transmitting and receiving) is 2.0 units.

Experiments were carried out in a random network topology. The number of sensor nodes can be changed from 25 to 200. The maximum transmission range of a sensor node is up to 10m. The routing table matrix is setup priory at every sensor node before the data delivery. The same network topology has been used for both the schemes for fair comparison.

The simulation results are shown in figures 6 & 7 for case 1 & 2 respectively. The MEER improved paths are shown in both the figures for cases 1 & 2 respectively.

The performance metrics that are used are the path length increase of the routes, total energy consumption in the transmission and the node density or the number of nodes. The corresponding results are shown in the figures' 8 9 & 10. The results in the figures 8 and 9 demonstrate that with S4 protocol, increase in node density increases the path length or number of hops quiet more than that of our proposed model. This is because routing process in S4 follows the same principle in routing the data from source to sink irrespective of their positions with respect to their nearest beacon.

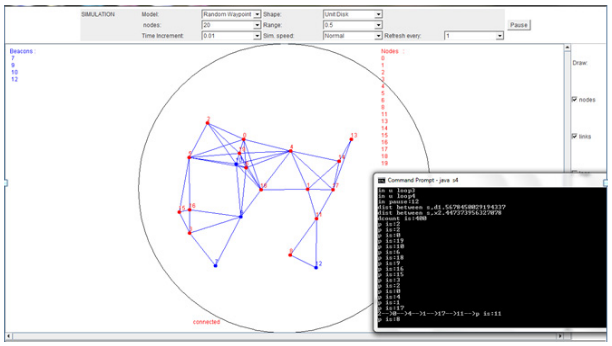

Figure 6 : case 1 result

Source node is 2, sink is 11. Nearest beacon to destination is 12. But d(2,12) > d(2,11). So a path is found between source, sink without going through nearest beacon. Path is: < 2 → 8 →4→1→17→11>

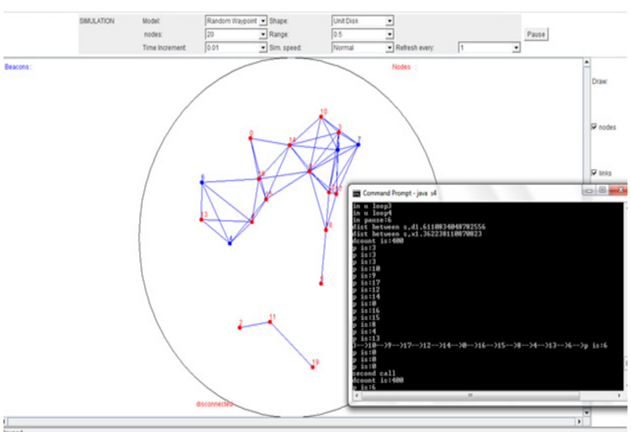

Figure 7: case 2 result

source node: 3 destination node: 13 Nearest beacon (6) and destination (13) are neighbors are to node4. So a path is established between 4, 13 without going to 6. Output Path is: < 3 → 10 →9 →17 →12 →14 → 0 →16 →15 →8 →4 →13>

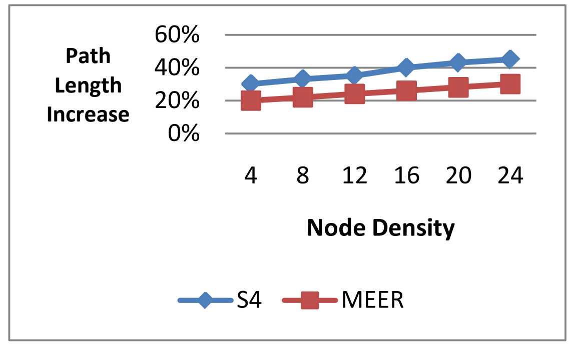

Figure 8: case 1

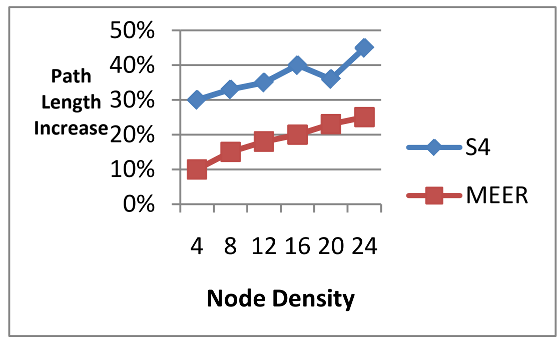

Figure 9: case 2

The result in figure 10 show that the total energy consumed for transmission of data is higher with S4 protocol compared to that of our MEER protocol.

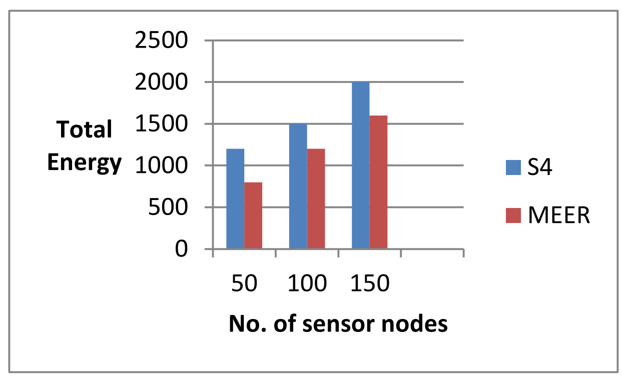

Figure 10: case 1

The results in table 2 show that percentage increase in energy is more for S4 rather than that of MEER protocol.

Table 2: Energy consumption of the routes

Case	Hop communication	Energy consumption of S4	Energy consumption of MEER
1	Multi hop	30%	20%
2	Multi hop	40%	25%

The average hop length increase in table 3 is obtained by taking double the number of sensor nodes each time the length is estimated.

Table 3: Average hop length increase in the routes

Case	Average hop length increase in S4	Average hop length increase in MEER
1	25%	18%
2	29%	20%

The results in table 3 shows the percentage increase in hop length for different routes as obtained for S4 and MEER protocol simulations. Hence, MEER has minimum number of hops included between source and sink compared to that of S4 protocol.

5. CONCLUSION:

In this paper, we have proposed an energy efficient routing protocol which prolongs the lifetime of sensor networks. In this protocol, we have chosen the routes such that they include minimum number of hops and at the same time, the total energy spent in transmission is reduced. Simulation results show that the average hop length increase as well as the total energy consumed is significantly lesser compared to that of S4 protocol. In summary, with MEER protocol, the battery power utilization in the network is done efficiently with all the routes. Hence, we conclude that sensor networks employing MEER protocol can have longer lifespans.

6. ACKNOWLEDGMENTS
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8.AUTHORS PROFILE

Prasad Reddy P.V.G.D is currently the Rector (Pro-vice chancellor) of Andhra University. He completed his Ph.D. in the year 1993. He has 24 years of teaching and research experience which includes more than 10 years of administrative experience with Andhra University at various senior capacities. He has so far successfully guided 12 Ph.D.'s, 18 M.Phil.'s and 259 M.Tech Projects in the field of Computer Engineering, and has to his credit, more than 104 research papers, which include 42 publications in international journals of repute, 2 patents filed and he has presented 19 publications in international conferences across the world.

Sandhya Devi G is currently a full time research scholar in CSSE department of Andhra University. She has 2 years of teaching experience. Her research area is wireless adhoc sensor networks.

Suvarna Kumar G is currently working as the Senior Assistant Professor in CSE Department of MVGR College of Engineering. His Research area is Speech and video processing. He published 6 international journals and attended 2 conferences in Singapore. He has 9 years teachingexperience, 2 years R &D and 1 year industrial experience. He is a member of ACM, National Science Congress, IAENG and IACSIT.