Optimised Energy Distributed Algorithm for Connected Coverage in Wireless Sensor Network (OEDCC)

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ABSTRACT

Recent technological developments in Micro-Electro-Mechanical Systems (MEMS) technology, wireless communications and electronics have led to the emergence of large-scale wireless sensor networks (WSNs).One of the key research questions of the wireless sensor networks is issues of having coverage while keeping connectivity. Most of the related researches have concerned coverage, connectivity and energy conservation independently or required sensing/transmission range restrictions. The quality of service (QoS) of a wireless sensor network depends to a large extent on the sensing coverage, and its lifetime is determined by its energy consumption. In this paper we present energy efficient, scalable and collision free priority based multiple MAC layer protocol for wireless sensor networks. The approach proposes time-based arbitration of medium access to control signal interference among the transmission of sensors and the authors aim to prolong the network lifetime by redundant sensor nodes with ensured connectivity and coverage simultaneously, without any accurate location information was addressed. We evaluate the distributed algorithm using NS2 simulator and show that our algorithm results in significant reduction of energy consumption, with strong connectivity and coverage.

Keywords: *Sensor, Coverage, Energy, Connectivity. Wireless Sensor Networks*

INTRODUCTION

Wireless sensor networks have attracting a lot of attention in the recent times. For a sensor network to operate successfully, sensor nodes must maintain both sensing coverage and network connectivity. Such environments may consist of many inexpensive sensor nodes, each capable of collecting, storing, and processing all environmental information and communicating/ transceiving with neighboring sensor nodes through wireless links. This issue has been studied in [1] & [2], both of which reach a similar conclusion that coverage can imply connectivity as long as sensors' communication ranges are no less than twice their sensing ranges. To function satisfactorily, a sensor network must also provide satisfactory network connectivity so that sensor nodes can communicate for data fusion and reporting to base stations. Connectivity affects the achievable throughput of communication in a wireless sensor network. None of the above coverage

maintenance algorithms addresses the problem of maintaining network connectivity. On the other hand, several other algorithms (e.g., ASCENT [3], SPAN [4], AFECA [5], and GAF [6]) concentrates to maintain network connectivity, but do not ensures sensing coverage. Unfortunately, satisfying either coverage or connectivity alone is not sufficient for a wireless sensor network to provide sufficient service. Without establishing sufficient connectivity, sensor nodes may not be able to coordinate and communicate effectively or transmit data back to base stations (BS).

Sensing Coverage and Network connectivity is an important component considered in most of the functions of sensor networks including clustering, synchronization, query and information discovery and deployment. Different applications may have different degrees of sensing coverage and network connectivity expectations.

Coverage can be defined as the region around the sensor node to monitor efficiently, and can be used to receive and transmit the data accurately. Wireless sensor network is power constraint network with limited power and also with limited computational, data transmitting strength. This densely mode type of deployment is the essential with sensor motes, because during the information transfer to the base station /sink network can't depend on few paths within sensor networks, If it is not in densely mode than the probability is there to break the link from the sink if any sensor node in between just dye or almost nearer to complete drain of this battery. Therefore the chances are there to formulate independent cluster or separate smaller parts of sensor network without having access to the sink.

Network Connectivity with sensor is different in nature from wireless ad hoc network, the reason for it is the dense deployment of sensor nodes, and therefore a good number of neighbor sensor nodes are available around the given node. Secondly, the broadcasting of data's for attempting the network connection initially in all directions. Losing of network connectivity is common in sensor network, since of power constraints, and intern connection losing activity affect routing activity.

It has been predicted to have a greater range of applications related to military, environment, health care, home, security and other important areas. Many researchers are presently working hard towards the improvement of the technologies needed for different layers of the sensor networks.

RELATED WORK

In this paper [7], the authors proposed to develop an energy efficient distributed algorithm for the connected sensor cover design to minimize the energy utilization with a lesser communication overhead. Instead of treating sensing coverage and network connectivity as two separate sub issues, the proposed protocol attempts to integrate them in a single algorithm. Each and every sensor node has a priority assigned to it in the proposed distributed algorithm. Depending on their balance energy and battery capacity, the priorities are assigned. Normally the sensor nodes with high residual energy and capacity of the battery are assigned to be higher priorities. To minimize the probability for selecting the lesser priority sensor nodes, the connected sensor covers are selected with higher priority nodes. To minimize the energy, the low priority sensor nodes that are not required in the sensing coverage can go to a sleep mode. The authors evaluated the distributed algorithm using NS2 simulators and showed that their approach results in greater reduction of energy, with strong network connectivity and sensing coverage.

In [8], without depending on this strong assumption, author proposed the issue from a different perspective and developed necessary and sufficient conditions for guaranteeing sensing coverage and connectivity of a sensor network. Therefore, the results significantly generalize the results in [9] [10]. This work is also an extension of their earlier research work [11] which addresses how to calculate the level of sensing coverage of a given sensor network, but does not consider the network connectivity issue. Their work is the first work allowing an arbitrary relationship between sensing ranges and network communication distances of motes. Authors presented a decentralized method for determining, or even adjusting, the levels of sensing coverage and connectivity of a given network. Adjusting the degree of coverage and network connectivity is very much essential when sensors are overly deployed, and they approached this issue by putting sensor nodes to sleep mode and tuning their transmission powers. This protocol results in enhances network lifetime.

In [12], authors proposed a hybrid approach to solve the sensing Coverage and network Connectivity problem in WSNs. This issue can be modeled as a Mathematical Programming problem, but it requires a hard computational work and since the WSNs may be very dynamic, any slow management decision may leads to serious problems. In this presentation, the issue was decomposed into two sub-problems and solved by a hybrid approach, which consists of two phases: a local search based on two classical graph algorithms and a genetic algorithm (GA). Their protocol could run along with WSN management architecture which is similar to the one which is proposed in [13].Their results showed that their algorithm does well in some particular scenarios, and runs fast over all of them, including the largest ones. It is an important observation since WSNs may be very dynamic, and the manager should act fastly to the sudden changes, otherwise serious problems such as death of sensor nodes or loses in the degree of QoS (Quality of Service) can occur. Simulations have been developed in the software NS2 to validate the results.

In [14], authors presented the joint problem of determining sensor, relay and base station placements and finding bandwidth-constrained power-efficient routes while guaranteeing expected degree of coverage, network connectivity. The practicality, effectiveness and performance of proposed algorithm have been studied through simulations. Their techniques of identifying strategic placements of sensor nodes are very useful when a modest number of motes are to be deployed and terrain information is available. For example, in many indoor applications such as involving factories or industrial units or airports where floor plans are available, their approaches are readily applicable. They recognized that ILP formulations are NP-hard to solve. Since placement problems of nodes are off-line problems, more computational energy with required duration of time can be devoted for their solutions. Hence, modest size of issues can be solved to the best and good feasible solutions can be obtained for given region of larger size of problems using techniques such as Lagrangian Relaxation [15]. Moreover, the solutions of ILP formulations can be very useful in benchmarking a better approximation algorithm or a heuristic.

Himanshu Gupta et al [16] have presented similar approach to reduce the communication cost of a query is to self-organize the sensor network and in response to a query, into a network topology that involves only a minimum number of subset of the sensors required to process the query. The query is then performed using only the limited number sensors in the constructed topology. Authors have developed the notion of a connected sensor cover and developed a centralized approximation protocol that develops a routing topology involving a near-optimal connected sensor cover. Also, they constructed a distributed self-organization version of the approximation protocol, and presented several optimizations to minimize the communication overhead of the protocol, but does not ensure anything on the size of the connected sensor cover constructed.

In [17], authors presented the design and analysis of protocols that can dynamically configure a sensor network which results the guaranteed coverage and connectivity. This work differs from existing sensing connectivity or network coverage maintenance algorithms in several ways: 1) Authors presented a Coverage Configuration Protocol (CCP) that can provide desired levels of sensing coverage expected by applications. This flexibility allows the network to self-configure for a variety of applications and possibly dynamic environments. 2) They also provided a geometric analysis of the relationship between sensing coverage and network connectivity. This analysis results key insights for treating coverage and connectivity in a combined framework: this is in sharp contrast to many existing approaches that address the two problems in isolation. 3) Lastly, they integrated CCP with SPAN to provide both coverage and connectivity guarantees.

Zhang and Hou [18] described a protocol for selecting covering sensors in synchronized network. In each round, a sensor node initiates the decision process, which then propagates to the entire network. New sensors are selected so that the priority is given to sensor nodes situated closer to vertices in a regular hexagonal tiling. The need for a sensor to initiate the process may result in problems while applying it, including increased latency. Secondly, the problem is that the original sensing coverage area is not preserved, as resulted by experiments.

In this paper [19], the author presented an energy efficient distributed connected coverage (EEDCC) algorithm and a set of dynamic coverage maintenance (DCM) algorithms.. EEDCC aims to minimize the energy consumption with a lesser communication overhead. The DCM algorithms aid in the tracking of changes in wireless sensor network topology thereby addressing the problems related to dynamic coverage and loss recovery. These protocols would assist in the dynamic maintenance of the coverage either by migrating sensor motes or by changing the radii accordingly.

PROBLEM DEFINITION

Now we will define the connected sensor cover problem discussed in this paper. We start with a few definitions.

Definition 1: Covered. A node v, a point $p \varepsilon C(v)$, means that p is covered by v.

Definition 2: Total number of nodes in the network is defined as N^*

Definition 3: The minimum number of on-duty nodes is denoted as $N = (1\text{-}Q)\, N^*$.

Definition 4: Sleeping ratio. Denoted as Q, it is the ratio of sleeping nodes number to total nodes number in the network. Sleeping ratio is as a measure of saving energy. The higher sleeping ratio is, the better saving energy for networks is.

Definition 5: Network Lifetime. The network lifetime is defined as the elapsed time since the launch of the sensor networks till the instant that the sink node fails to receive from q_i, k type i source sensors for any target r_k.

Definition 6: If a communication path (multiple hops) exists between any two nodes in the network. Then the network is connected. If between any two nodes there exists k independent paths (which are not interested with each other), then the network is k degree connected.

Definition 7: If any node in network is among the communication range of one active node, then we call the network is covered.

Definition 8: The number of nodes which are directly connected to one node 'U', namely the number of neighbor nodes, called as node degree, represented by d(u).If d(u)=0,then the node has no neighbor nodes, we call it as a isolated node.

Definition 9: (neighbor). For any two sensors A and B, if the distance between them is less than or equal to the communication radius R, then sensor A and B are neighbors.

Connected Sensor Coverage Problem. Given a sensor network maintains the following values: network and a query over the sensor network, the connected sensor coverage problem is to find the optimum connected sensor coverage.

OPTIMISED ENERGY DISTRIBUTED ALGORITHM FOR CONNECTED COVERAGE (OEDCC)

Criteria for the Algorithm

For selecting a connected sensor cover of near-optimal size, it is planned to have greedy algorithm.

We consider a wireless sensor network with large amount of sensor nodes that are deployed randomly over a 2-dimensional convex monitoring region M. The senor nodes are placed in higher tight density in order to provide better degree of coverage requirement and more robust ensured connectivity.
S is assumed to be the set of sensors, $S = \{s_1, s_2 \ldots s_n\}$, in monitoring region M. It is also assumed that there are 'n' tiny sensor nodes and randomly deployed in the region of interest (ROI) with location at coordinate (x_i, y_i) with a sensing range of R_s, a communication range R_c, Each sensor node s_i has a residual current energy E_i, where i = 1...n.

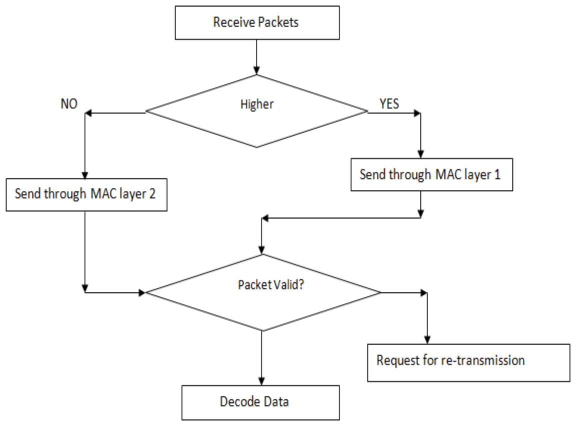
Given a set of stationary targets T = {t1,t2,t3,……….tn} and a set V = {V1,V2,……..Vn} of sensors, the target monitoring problem asks for generating a large family of subsets of sensors V1……….Vs called *monitoring sets*, such that each Vi monitors all targets The idea is that only one such set is active for any certain period of time and after that time period another set becomes active and so on, thus providing continuous monitoring. However, the objective of this problem is to maximize z = s/k, where k=max uϵV {I: u ϵV_i}
Without loss of generality, the index variables listed below are used for the corresponding work, if no otherwise mentioned.

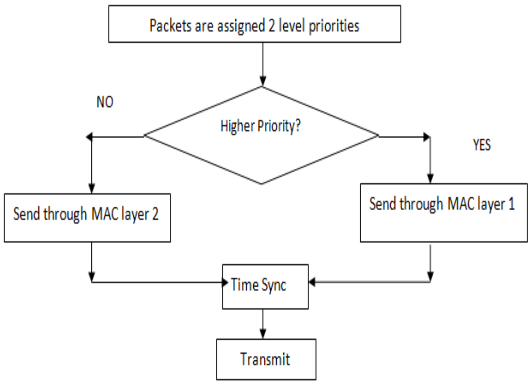
- m:m^{th} monitoring region ,where $1 \le m \le M$
- n: n^{th} sensor ,where $1 \le n \le N$
- E_i: Residual Energy in i^{th} node
- set of sensors, $S = \{s_1, s_2 \ldots s_n\}$, $\forall E_i > 0$

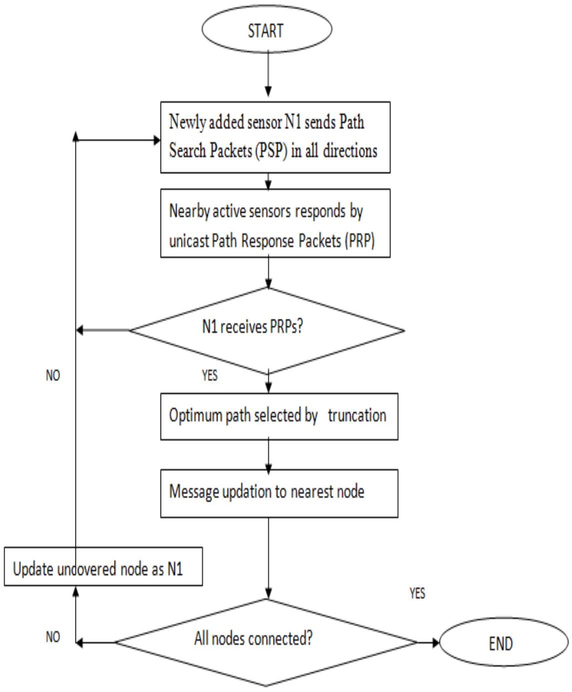
The following sequence of transmission phases is contained in each stage of the distributed algorithm.

1. For each set of nodes find current vertex.
2. Find the set of its neighbors.
3. If valid PSPs are received for PRPs sent,

- Calculate distance between new node and active nodes.
- Find the node which has minimum distance with the new node.
- Connect the two nodes.
- Add the new node to set or connect the closed new vertex such that it has the minimum distance with the current vertex.
- Continue from step 1 throughout the process







ENERGY REDUCTION

1. STANDBY: The duration of this state by a node is determined by a timer. When the standby timer of a node expires, the corresponding node turns on its receiving radio and enters audible state.

2. AUDIBLE: When a packet is received, the node checks it. If the packet is destined for the receiving node then the node changes its state to transceiving state.

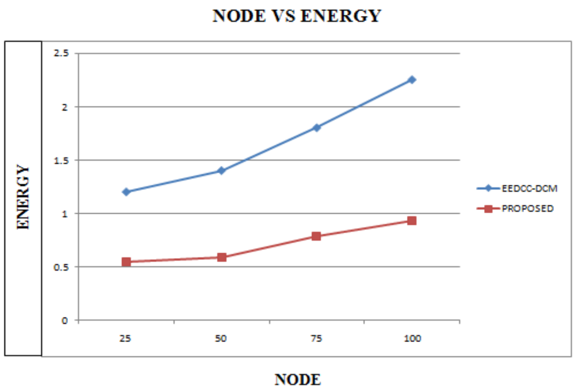
3. TRANSCEIVING: When a request for connection is received by a node, an algorithm is executed to remain in transceiving state. If not in that state then a countdown timer is started. If not invoked within timer expiration, the node enters standby state.

SIMULATION PARAMETERS

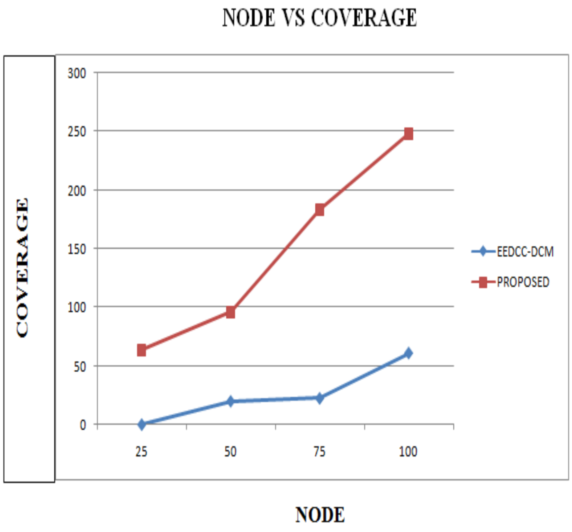
We evaluate our proposed Optimized Energy Distributed Algorithm for Connected Coverage (OEDCC) using NS2 simulator [9]. We use a bounded region of 1000 x 1000 square meters, in which we place sensor nodes using a uniform distribution. We assign the energy levels of the sensor nodes such that the transmission range and the sensing range of the nodes are all 250 meters. We use the Distributed Coordination Function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. In our experimentation and simulation, sensor nodes of sizes 50, 100 and 150 are deployed in a 1000 m x 1000 m rectangular area for 50 seconds of simulation time. The simulated traffic is Constant Bit Rate (CBR). To measure the performance of different protocols under different ratios of communication range/sensing range, we changed the communication range by 250,300,350 and 400m, in the network interface. All experimental results presented in this section are averages of ten runs on different randomly chosen scenarios.

The following table 1 summarizes the simulation parameters used

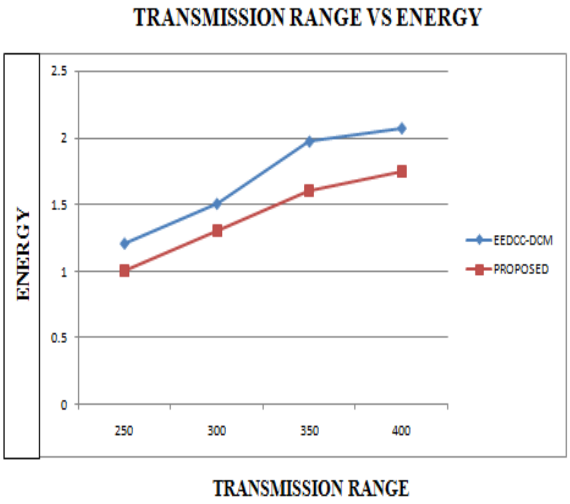
No. of Nodes	50,100,150 and 200
Area Size	1000 X 1000
MAC Protocol	802.11
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Transmit Power	0.360W
Receiving Power	0.395W
Idle Power	0.335W
Transmission Range	250,300,350 and 400
Routing Protocol	AODV



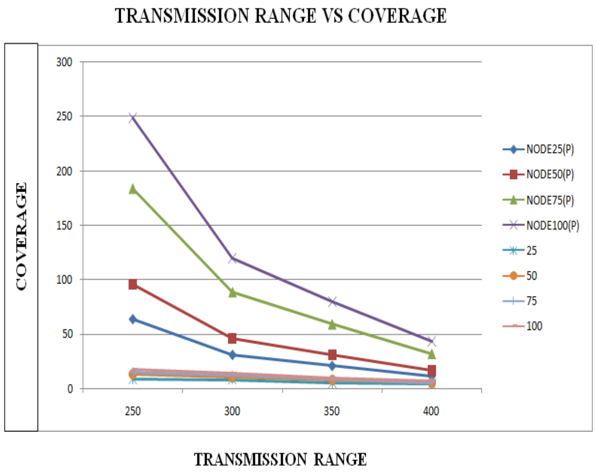
Experiment 1: In experiment 1, we vary the no. of nodes as 25, 50, 75 and 100 and measure the average energy consumption. From Fig.2, we can see that, our proposed Optimized Energy Distributed Algorithm for Connected Coverage (OEDCC) consumes less energy when compared with the existing scheme. The transmission range is fixed as 250m.



Experiment 2: In experiment 2, we measure the connected sensor coverage in terms of active nodes. Fig.3 shows the results of coverage nodes, for network sizes of 25, 50, 75 and 100.



Experiment 3: In this experiment, we vary the transmission range as 250,300,350 and 400, and measure the average energy consumption. We keep the no. of nodes as 100. From Fig. 4, we observe that, the energy is significantly reduced in our distributed algorithm, when compared with CCP-SPAN and EEDOC-DCM.



Experiment 4: In this experiment, the results of coverage in terms of active nodes are measured. Fig.5 shows the coverage results for different network sizes, when the transmission range is varied from 250 to 400

CONCLUSION & FUTURE WORK

In this paper work, we presented Optimized Energy Distributed Algorithm for Connected Coverage (OEDCC) protocols', a randomized algorithm which is run locally at a sensor node to govern its operation. In this paper we present energy efficient, scalable and collision free priority based multiple MAC layer protocol for wireless sensor networks. The approach proposes time-based arbitration of medium access to control signal interference among the transmission of sensors.

We presented recent energy-efficient connected coverage issues proposed in literature, their formulations and assumptions as well as solutions proposed. Sensor coverage, connectivity and energy are the three important elements for QoS in applications with WSNs. This proposed Optimized Energy Distributed Algorithm for Connected Coverage (OEDCC) protocol' is simulated using NS2 and compared against energy efficient distributed connected coverage (EEDCC) algorithm and a set of dynamic coverage maintenance (DCM) algorithms proposed in[19] and showed that our presented results in significant reduction of energy, with strongly connected coverage. Most recent works on the sensor connected coverage problem are still limited to theoretical study. In future, more and more research work will be concentrated on distributed and localized solutions for practical deployment.

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