A Hybrid Scheduling Protocol for Target Coverage Based on Trust Evaluation for Wireless Sensor Networks

Pooja Chaturvedi, A. K. Daniel

Abstract— **Coverage is an intriguing problem in the domain of wireless sensor networks for supervising and tracking applications as an indicator of quality of service (QoS). Target coverage problem pertains to maximize the network lifetime while considering the resource scarcity. The paper proposes a hybrid scheduling protocol for target coverage for wireless sensor networks which determines the number of set covers for monitoring all the targets using the probabilistic coverage model, node contribution and trust values. The optimal observation probability is obtained for the parameter values of the sensing and communication characteristics of the nodes using Analytic Hierarchy Process (AHP) and probabilistic coverage model. The proposed protocol uses a node scheduling technique using Fuzzy Logic to activate the nodes to form the set covers. The proposed protocol is validated for a smaller network and is simulated for a real large network. The simulation results show that the performance of proposed protocol improves the network efficiency in terms of coverage, network lifetime and reliability in terms of trust factor. The comparison results show that the proposed protocol improves the performance in terms of the number of set covers, network lifetime and number of active nodes compared to disjoint set cover protocol. The simulation results show that the network lifetime and performance under constant performance is improved up to 200%.**

Index Terms— **AHP, Energy Efficiency, Network Lifetime, Target Coverage, Trust.**

I. Introduction

Wireless sensor networks have gained significant research attention in recent times due to their various applications ranging from national security, surveillance, military, healthcare and environmental monitoring. Wireless sensor network constitute of tiny, low cost, low powered sensors to perform sensing and data processing task in collaboration. Sensors accumulate information from a target region and transmit it to a central processor known as the base station (BS) [1] [2]. Sustaining an adequate sensing coverage level is an essential prerequisite in sensor networks because coverage ascertains the monitoring quality. The coverage problem is focused on the question "how well the sensor nodes observe the target region". Coverage denotes the measure of quality of service (QoS) of the sensing activity and is defined on the basis of the type of sensor node and its application. Apart from the coverage problem energy conservation is also a major issue in the field of wireless sensor networks because the nodes are energy constrained (battery powered Energy conservation approaches have been emphasized and thought about due to its substantial effect on the network lifetime. Network lifetime is defined as the duration for which the network is in operational state. The most efficient approach to enhance the network lifetime is to schedule the nodes in the active or sleep mode i.e. to keep the redundant nodes (in terms of coverage) in off mode. The following questions are answered while designing such a protocol: (1). Suggesting the rule under which the node should be kept in sleep mode. (2). Determining the time rotation in when the rules are to be executed. (3). Determining the duration for keeping the nodes in the sleep mode. (4). Such a protocol is designed to schedule the nodes in a manner so that connectivity of the network and the reliability and quality of data transmission is maintained as per the requirement of the application. Connectivity problem is concerned with the fact that there is a path from every node to the sink node. To achieve these objectives, an energy efficient node scheduling protocol for target coverage based on the trust model is proposed. A number of set covers are determined on the basis of probabilistic coverage model and trust concept and activated according to the schedule determined by the base station. The network lifetime is proportional to the number of set covers found i.e. larger the number of set covers, longer will be the network lifetime.

The organization of the paper is as follows; section 2 related work, section 3 proposed network model and design issues, section 4 proposed protocol, section 5 simulation results and analysis and section 6 conclusion.

II. Related Work

Wireless sensor networks constitute of resource constrained sensor nodes so the energy conservation is a major challenge, not only in the hardware and architectural level design, but also in the design of algorithm and network protocol at all layers of the network. Prolonging the network lifetime is a major challenge in the domain of wireless sensor networks. A sensor node can exist in any one of the four modes as: transmission, reception, processing, and idle/sleep. It has been found that the sensor node deplete maximum energy in communication and minimum energy in the idle/sleep mode. When a large number of nodes are deployed

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in a target region the energy problem can be curbed by keeping the redundant nodes in the sleep mode. The state of a sensor node is determined using the scheduling mechanism employed by the base station according to which the nodes are activated to perform the sensing task.

Maintaining the required confidence level for target monitoring is also a major challenge in the area of wireless sensor networks. Coverage problem in wireless sensor network pertains to the question, "how well and for how long the sensors are able to monitor the environmental phenomenon" [2]. Coverage is defined as a measure of quality of service of the sensing function and depends on the type and application of the sensor node. The coverage problem is classified into three types as: area coverage, barrier coverage and target coverage. Area coverage considers the fact that every point in the target region is monitored by at least one sensor node. Barrier coverage is concerned with the movement across a set of barriers and is often defined in terms of Minimum Exposure Path and Maximum Support Path. Target coverage problem is concerned with the continuous monitoring of a set of targets. The coverage problem emphasizes on the following two questions:

1. How to evaluate the coverage performance of the nodes deployed in a given monitoring region.
2. How to improve the coverage performance when wireless sensor networks cannot effectively satisfy the application requirements.

The Art Gallery Problem, Circle Covering Problem, Ocean Coverage and Robotics System Coverage Problem [3] [4] [5] are closely related problems to the coverage problem. The art gallery problem focuses on the determination of number and placement of the observers such that every point in the region is observed by at least one observer. It has been found that this problem can be solved in linear time for the 2-dimensional case and the minimum number of observers is $\lceil n/3 \rceil$. The above problem is NP-hard in the case of 3-dimensional. The circle covering problem is concerned with the determination of minimum radius of circles that can fully cover a plane. The ocean coverage problem is concerned with the monitoring of an ocean via the satellites. In robotics system three types of coverage problem have been studied as: blanket coverage, barrier coverage and sweep coverage. In blanket coverage, the goal is to achieve a static arrangement of sensors that maximize the total detection area. In barrier coverage the goal is to achieve a static arrangement of nodes that minimize the probability of undetected penetration through the barrier, whereas the sweep coverage is more or less equivalent to a moving barrier. The approaches to solve the coverage problem are categorized in three types as: Virtual Force Based Approach, Deployment Based Approach and Computational Geometry Based Approach [6]. In the virtual force based approach coverage is improved by the application of attraction/repulsion force on the sensor nodes. The nodes are repelled from each other if they are too close and attracted towards each other in the opposite case [7]. In the deployment based approach, the nodes are deployed in various grids as triangular, square and hexagonal. In this situation coverage is defined in terms of the ratio of the number of grids covered to the number of grids [8] [9]. The computational geometry based approach is concerned with the construction of geometrical constructs such as Voronoi Diagram and Delaunay Triangulation. These constructs are used to determine the best and worst case coverage [10].

The various approaches proposed for the target coverage in the literature are classified as: energy efficient target coverage, energy efficient and connected target coverage, target coverage under QoS constraint, target coverage with adjustable sensing range, centralized/distributed and disjoint/non disjoint approach. The various approaches for target coverage are as follows:

In [19], authors have addressed the problem of detecting and eliminating the redundancy in a sensor network by using the Voronoi Diagram and Multiplicative weighted Voronoi diagram. The authors have proved and achieved lower bound of solution to this problem and presented efficient distributed algorithm for computing and maintaining sensor failure or insertion of new sensor.

In [20], authors have proposed Greedy Iterative Energy-efficient Connected Coverage (GIECC) algorithm to address the problem of coverage, connectivity and energy efficiency in wireless sensor networks. The algorithm provides a suboptimal solution to the lifetime coverage and connectivity problem in polynomial time. This algorithm can easily be extended to operate in a distributed environment. The algorithm determines a number of disjoint set covers which can be activated periodically.

In [21], authors have proposed the linear programming formulation to find a minimum cost deployment of sensors to attain desired coverage of targets. An approximation algorithm in polynomial time is proposed for the grid coverage. Experimental results demonstrate the superiority of proposed algorithm over earlier algorithms for point coverage of grids.

In [22], authors have proposed the solution to the problem of selecting a minimum connected *K*-cover. It defines a set of sensors *M* such that each point in the sensor network is covered by at least *K* different sensors in *M* and the communication graph induced by *M* is connected. A random sensor whose sensing region intersects with the query region is chosen to be in *M*.

In [23], authors have proposed the Connected Set Cover (CSC) problem as finding a maximum number of set cover such that each sensor node to be activated is connected to the base station. A sensor can participate in multiple sensor sets, but the total energy spent in all sets is constrained by the initial energy. It is NP-complete problem and three solutions have been proposed: an integer programming based solution, a greedy approach, and a distributed and localized heuristic based.

In [24], authors have proposed a heuristic that selects mutually exclusive set of sensor nodes, where the members of each set completely cover the monitored area. The interval of activity is same for all the sets and only one set is active at any time. The experimental results demonstrate that by using only a subset of sensor nodes at each moment, a significant energy saving is achieved while preserving coverage.

In [25], authors have proposed an efficient method to extend the sensor network operational time by organizing the sensors into a maximal number of disjoint set covers which are activated successively. The current active set is responsible for monitoring all the targets and for transmitting the collected data and the remaining sets are in low energy/sleep mode.

In [26], authors have extended the work of disjoint set cover approach [38] and improved the network lifetime by removing the constraints of disjoint sensor set and equal operation time. The solution to the coverage problem is formulated as the maximum set cover problem. The two heuristics based on the integer linear programming and greedy optimization is proposed.

In [27], authors have addressed the maximal lifetime scheduling problem in *k-1* sensor surveillance system. The objective of this approach is to schedule the nodes such that the network lifetime is maximized, where the lifetime is defined as the time till all the targets are monitored. The proposed approach is based on the determination of sensor schedule by decomposing the work load matrix for each node. The work load represents the target a node can monitor.

In [28], authors have addressed the target coverage problem in wireless sensor networks with adjustable sensing range. The Adjustable Range Set Covers (AR-SC) approach has the objective to find a maximum number of set covers and the range associated with each sensor such that each sensor set covers all the targets. A sensor can participate in multiple sensor sets but sum of the energy spent in all sets is constrained by the initial energy.

In [29], authors have addressed the problem of optimal node placement for ensuring connected coverage in sensor networks. The authors have considered the two different practical scenarios. In the first scenario, a certain region (or a set of regions) is to be provided connected coverage, while in the second case, a given set of *n* points are to be covered and connected.

In [30], a *k*-(Connected) Coverage Set (*k-CCS/k-CS*) problem is formulated and a linear programming algorithm is developed, and two non-global solutions are described for them. Some theoretical analysis is also provided followed by simulation results.

In [31], authors have proposed a twofold solution for the coverage problem. The first solution is to deploy sensor node at optimal location such that the theoretically computed network lifetime is maximized. The second solution is to schedule these sensor nodes such that the network attains the maximum lifetime. Thus the overall objective is to identify optimal deployment location of the given sensor nodes with a pre specified sensing range and to schedule them such that the network lifetime is maximized with the required coverage level.

In [32], authors have proposed the coverage problem based on a more realistic model. The probabilistic sensing model is used in which the probability of detection by a sensor decays exponentially with respect to distance. The coverage problem is generalized to the probabilistic sensing model and an algorithm is proposed to calculate the minimum degree of coverage. The accuracy of the proposed algorithm is verified via simulation.

In [33], authors have proposed the maximum disjoint domination set based approach for the target coverage problem. In this approach nodes belonging to the maximal dominating set are responsible for monitoring the targets.

In [34], authors have proved that for a convex region, if the communication range is at least twice the sensing range, coverage implies connectivity. The authors have also considered the problem of density control. The authors have also proposed a fully distributed and localized protocol Optimal Geographic Density Control (OGDC) which can guarantee coverage and connectivity using minimum number of working nodes.

In [35], authors have proposed a probabilistic coverage protocol based on probabilistic sensing model. In this the maximum separation with the triangular vertex is obtained. The proposed protocol is a node scheduling approach in which the nearest node to the hexagonal vertex is activated in a distributed manner.

In [36], authors have proposed Coverage Configuration Protocol (CCP) which achieves different degree of coverage with respect to application. This flexibility allows the network to self-configure for a wide range of application and (possibly dynamic) environment. A geometric analysis of the relationship between coverage and connectivity is shown. This analysis yields key insights for treating coverage and connectivity within a unified framework. CCP is integrated with SPAN to provide both coverage and connectivity guarantee. The performance of the protocol guaranteed coverage and connectivity configuration through geometric calculation.

In [37], authors have proposed Probing Environment and Adaptive Sleeping (PEAS) protocol which forms a long-lived sensor network and maintain robust operation using a number of economical and short-lived sensor nodes. PEAS extend system functioning time by keeping only a set of sensors working and putting the rest into sleep mode. The sleeping period is self-adjusted dynamically to keep the sensors' wakeup rate roughly constant.

The issues identified from the literature review related to the target coverage problem are as follows:

1. Most of the research work is focused on the Boolean sensing model for the coverage in which the detection probability of an event is in 0/1 form which indicates that the signal strength beyond the sensing range decreases abruptly to 0. But in real world applications

the coverage probability decays gradually with respect to the increase in the distance. So to mitigate this, a more realistic probabilistic coverage model is considered which incorporates the sensing and communication characteristic in the detection of a target.

2. Considerable work has been done in the field of coverage, connectivity or combination of both but none of them have considered the quality metrics in the data transmitted to the base station.

3. The active nodes are assumed to be one hop away from the base station in most of the works, which is not always true for a large network.

4. Most approaches deal with the determination of the set covers in the beginning of the network operation. This approach is not efficient as the sensor nodes are often deployed in hostile environment and left unattended for long time where the network condition may deteriorate and perish over time.

To eradicate these drawbacks, we have proposed a node scheduling protocol in which the set covers are computed dynamically before sensing the data from the environment and environmental uncertainty is considered using the trust concept. The unreliable nodes are filtered out by using the trust factors based on the Direct Trust, Recommendation Trust and Indirect Trust. The recommendation trust of the recommender nodes' is considered by using reliability and familiarity of the recommender nodes. The nodes in communication from long time will have the higher reliability and familiarity. In calculation of the direct trust values Data Trust, Communication Trust and Energy Trust are considered for deriving the optimal number of nodes to be incorporated in the set covers.

III. PROPOSED NETWORK MODEL AND DESIGN ISSUES

For a network of n sensor nodes $S=\{s_{1,}s_2..s_n\}$ and m target nodes $T=\{t_1,t_2..t_m\}$, the goal of target coverage problem is to determine a number of set covers which can monitor all the targets with the objective of maximizing the network lifetime. The set cover thus obtained have the minimal number of nodes and it can operate till the energy of the sensor node.

Consider the network as shown in Fig.1. The set of sensor nodes is $S=\{s_1,s_2,s_3\}$ and set of targets is $T=\{t_1,t_2,t_3,t_4\}$ in which the nodes can monitor the targets as: $s_1=\{t_1,t_2\},s_2=\{t_3,t_4\},s_3=\{t_2,t_3\}$.

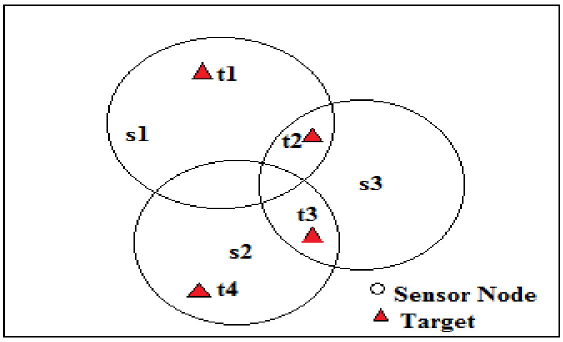


Fig. 1. Example of the sensor target relationship in a network

Suppose each node can monitor the targets for 0.1 time unit, then if all the nodes are activated at once then the network lifetime will be 0.1 time unit. But if the nodes are scheduled in various set covers as:

$$C_1=\{s_1,s_2,s_3\},C_2=\{s_1,s_2\}$$

Suppose the monitoring time of each set cover is 0.3and 0.2 then the network lifetime is extended to 0.5 time units.

For a sensor network consisting of n sensor nodes $S=\{s_1,s_2..s_n\}$ and m targets $T=\{t_1,t_2..t_m\}$, the target coverage problem is defined as an integer linear programming problem with the objective to minimize the function = $\sum_{j=1}^{n} x_{ij}$ subject to the constraints:

$$\begin{Bmatrix} x_j\times\sum_{j=1}^{n}P_{ij}^{obs}>0 & \forall\ T_i\in T \\ P_{cvr}(i)\geq CL & \forall T_i\in T \\ x_j\in(0,1) & \forall\ S_j\in S \end{Bmatrix}$$

The objective is to minimize the number of sensor nodes in active state. *CL* represents the desired coverage level for the targets. x_{ij} is a Boolean variable which is set to *1* if the sensor node S_j is able to observe the target T_i and *0* otherwise. $P_{cvr}(i)$ represents the probability that the target region is covered by any sensor node. P_{ij}^{obs} represents the probability that the target is monitored by a sensor node and is calculated as:

$$P_{ij}^{obs}=Cov(i,j)\times STL \tag{1}$$

where *STL* represents the trust level of the sensor node.

A. Assumptions

The following assumptions are considered for the proposed protocol:

1. The sensor network consists of n nodes which are deployed randomly and uniformly in the rectangular field of the dimensions $m\times n$. It is assumed that the

base station is sufficiently far away from the target region.

2. The nodes of the network can exist in any one of the modes (ρ) as: active, observer and sleep depending on the coverage probability. The node which has the coverage probability lower than the threshold 0.3 is kept in the sleep mode. The node which has the coverage probability between 0.3 and 0.5 is considered as the observer node and is used to calculate the trust level of the nodes. The node having coverage probability higher than 0.5 is kept in active mode and participates in the reception and transmission of the data.

$$\rho = \begin{cases} active; & if\ \mathrm{cov}(i,j) \geq 0.5 \\ observer; & if\ 0.3 \leq \mathrm{cov}(i,j) < 0.5 \\ sleep; & if\ \mathrm{cov}(i,j) < 0.3 \end{cases}$$

3. The coverage and sensing model of each sensor node is considered as circle of radius *r*.

4. A heterogeneous network consisting of normal and advanced nodes deployed in the regions R_1 and R_2 respectively as shown in Fig. 2 is considered. The advanced nodes having higher energy than the normal nodes are deployed near the base station and can communicate directly with the base station, whereas the normal nodes use multi hop communication.

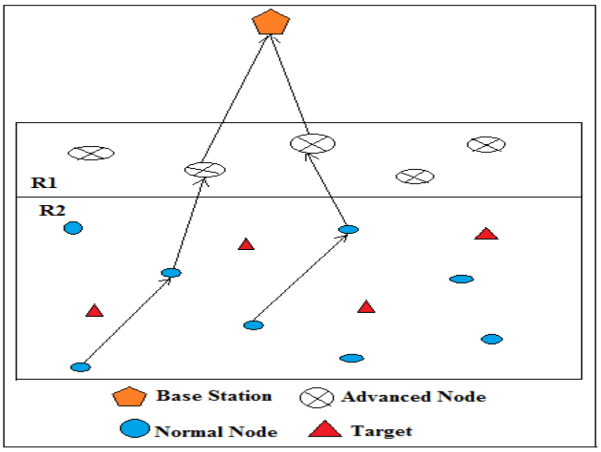


Fig. 2. Network Model

5. Sensor node can alternate between active/sleep mode according to their appearance in the *cover*.

B. Proposed Probabilistic Coverage Model

The proposed protocol is based on the probabilistic coverage model, in which the probability of detection of an event decreases exponentially with the increase in the distance between the sensor node and the target. The coverage probability is defined as follows:

$$Cov(i,j) = \begin{cases} 0 & if\ r_s + r_e \leq d(S_j,T_i) \\ e^{-\lambda\alpha^{\beta}} & if\ r_s - r_e < d(S_j,T_i) < r_s + r_e \\ 1 & if\ r_s - r_e \geq d(S_j,T_i) \end{cases}$$

where *cov(i, j)* represents the coverage probability of the target *i* with respect to the node *j*, $d(S_j,T_i)$ represents the distance between the sensor node S_j and the target T_i, r_s represents the sensing range and r_e is the detection error range, α, β and λ are hardware specific parameters which represents the characteristics of the sensing and computing unit. These parameters depend on the sensor type and application. The parameter α is defined as:

$$\alpha = d(S_i,T_j) - (r_s - r_e)$$

C. Proposed Trust Model

The proposed trust model is based on various factors as direct trust, recommendation trust and indirect trust. The network considered for the trust calculation is shown in the Fig.3.

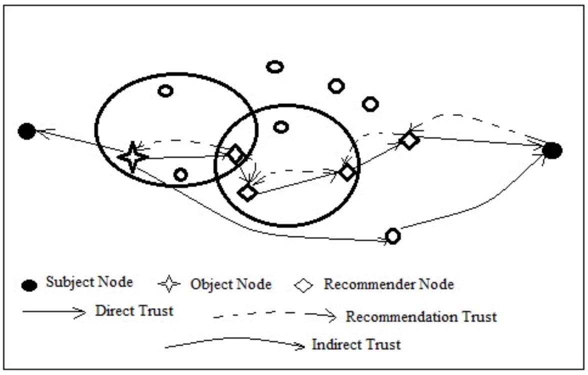


Fig. 3. Network for Trust Calculation

The node which determines the trust value of the other node is known as the subject node and the node for which the trust value is calculated is known as the object node. The hierarchical structure for the various trust factors is shown in the Fig.4. The trust value of a sensor node consists of three trust factors direct trust, recommendation trust and indirect trust. The direct trust value of a node is determined as the weightage average of the data trust, communication trust and energy trust. The three possible cases in the trust calculation are as follows [9]:

1. If the subject node and the object node can directly communicate with each other and the number of communications is higher than a predefined threshold then the direct trust is considered

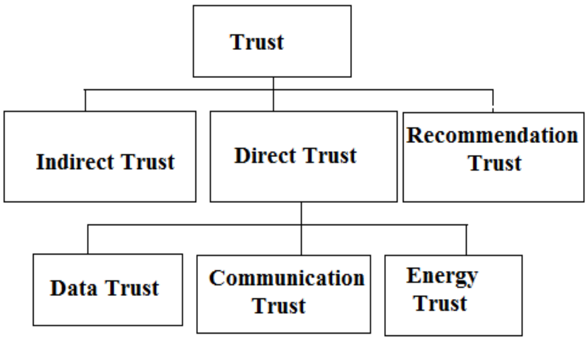


Fig.4. Hierarchical Structure for Trust Factors

2. If the subject node and object node are reachable via the common neighbors and the number of communication is less than the specified threshold then the recommendation trust is considered.

3. If there is neither the direct communication nor the common neighbors between the subject node and the object node and the number of communication is less than the specified threshold and then the indirect trust is calculated. The indirect trust is calculated using the recommendation chain of the intermediate nodes which are optimal in terms of energy and hop count.

i. Data Trust

The data trust (T_D) is calculated as the number of the correct data packets received at the base station:

$$T_D = (1 - \frac{N_{err}}{N}) \times 100\% \quad (2)$$

where N_{err} is the number of incorrect data packets and N is the total number of data packets transmitted. The incorrect data packets are identified by the variation in the readings of the nearby nodes.

ii. Communication Trust

Communication trust (T_C) of the sensor node depends on the previous behavior of the nodes and it reflects the uncertainty of the network. In the proposed protocol subjective logic framework is used in which the trust is defined as a 3-triplet value: {*b*, *d*, *u*}, where *b*, *d* and *u* denotes the belief, disbelief and uncertainty of the nodes. $b, d, u \in [0,1]$ and $b+d+u=1$, *s* and *f* represents the successful and the failed communication of a node. The Communication Trust is calculated as:

$$T_C = \frac{2b+u}{2} \quad (3)$$

where Belief $b = \frac{s}{s+f+1}$ and Uncertainty $u = \frac{1}{s+f+1}$

iii. Energy Trust

Energy conservation is a major issue in the field of the wireless sensor networks so energy trust (T_E) is considered on the basis of energy consumption rate p_{ene}. The Energy Trust is calculated as:

$$T_E = \begin{cases} 1 - p_{ene}, & \text{if } E_{res} \geq \theta \\ else & 0 \end{cases} \quad (4)$$

where E_{res} is the Residual Energy of the node. Energy consumption rate p_{ene} is calculated as:

$$p_{ene} = \frac{IE - RE}{r}$$

where *IE* and *RE* represents the initial and residual energy of the nodes and *r* is the round number.

iv. Direct Trust

Direct Trust (T_{Direct}) is calculated as the weighted average of the Data, Communication and Energy Trust as follows:

$$T_{Direct} = w_1 T_D + w_2 T_C + w_3 T_E \quad (5)$$

where w_1, w_2 and w_3 are the weight values for the Data, Communication and Energy trust respectively and $w_1 \in [0,1], w_2 \in [0,1]$ and $w_3 \in [0,1]$ & $w_1 + w_2 + w_3 = 1$.

v. Recommendation Familiarity

Recommendation Familiarity (T_F) represents the duration for which the recommender node is the neighbor of the object node. The longer the recommender node is the neighbor of the object node, higher will be its trust value.

$$T_F = \frac{n}{N} \times reg^{\frac{1}{n}} \quad (6)$$

where *n* represents the number of successful communication between the recommender *R* and object node *Y* and *N* represents the number of successful communication by the recommender node *R*. *reg* is the regulatory factor for the number of communication and $reg \in [0,1]$.

vi. Recommendation Reliability

Recommendation Reliability (T_R) is calculated to remove the false trust values from the several trust values and is defined as:

$$T_R = 1 - \left| T_R^Y - T_{avg}^Y \right| \quad (7)$$

where T_R^Y is the recommendation value of object node Y calculated by recommender node R and T_{avg}^Y is the average value of all the recommendations.

vii. Recommendation Trust

When direct communication between two nodes is not possible, then the recommendation trust is calculated on the basis of the recommender node. There is a possibility of false recommendation from the recommender node, so to avoid this recommendation familiarity and reliability is calculated. Recommendation Trust $(T_{\mathrm{Re}com})$ is calculated as:

$$T_{\mathrm{Re}com} = \frac{\sum_{i=1}^{n} 0.5 + (T_R^Y - 0.5) \times T_F \times T_R}{n_0} \quad (8)$$

where n_0 is the number of recommender.

viii. Indirect Trust

When the subject and object node are not directly reachable but have several intermediate nodes between them. In this case a recommendation chain of the nodes, which comprise of the optimal path based on the distance and energy is determined. Indirect trust $(T_{ID\,R}^{\;Y})$ is calculated as:

$$T_{ID\,R}^{\;Y} = \begin{Bmatrix} T_R \times T_R^Y & \text{if } T_R^Y < 0.5 \\ 0.5 + (T_R - 0.5) \times T_R^Y, & \text{else} \end{Bmatrix} \quad (9)$$

$$T_{ID\,R+1}^{\;Y} = \begin{Bmatrix} T_{R+1} \times T_{ID\,R}^{\;Y}, & \text{if } T_{ID\,R}^{\;Y} < 0.5 \\ 0.5 + (T_{R+1} - 0.5) \times T_{ID\,R}^{\;Y}, & \text{else} \end{Bmatrix} \quad (10)$$

The trust values are updated as follows:

$$T(i+1)_{new} = w_i T(i) + w_{i+1} T(i+1) \quad (11)$$

where $T(i+1)_{new}$ represents the trust value in the next cycle, *T(i)* and *T(i+1)* represents the trust value at *ith* and *(i+1) th* time slot, w_i and w_{i+1} represents the aging factor.

D. Fuzzy Inference Model

Fuzzy inference provides a formal methodology to represent, manipulate and implement heuristic knowledge for decision making. The major components of the fuzzy inference are shown in Fig.5. The rule base consist of IF –THEN rules. The inference engine determines the relevant rules for obtaining the output for a given set of input. The fuzzification module transforms the input so that they can be interpreted and evaluated according to the rules. Defuzzification module converts the fuzzy output into the crisp value.

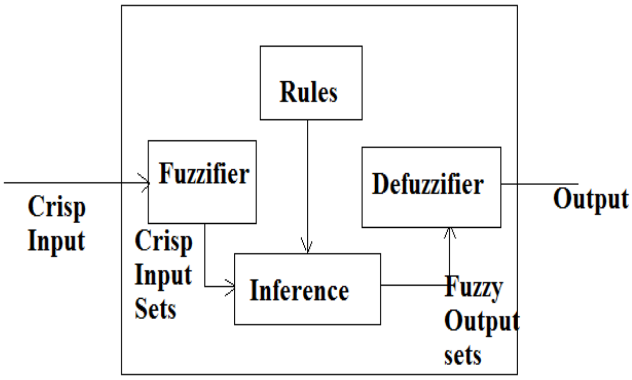
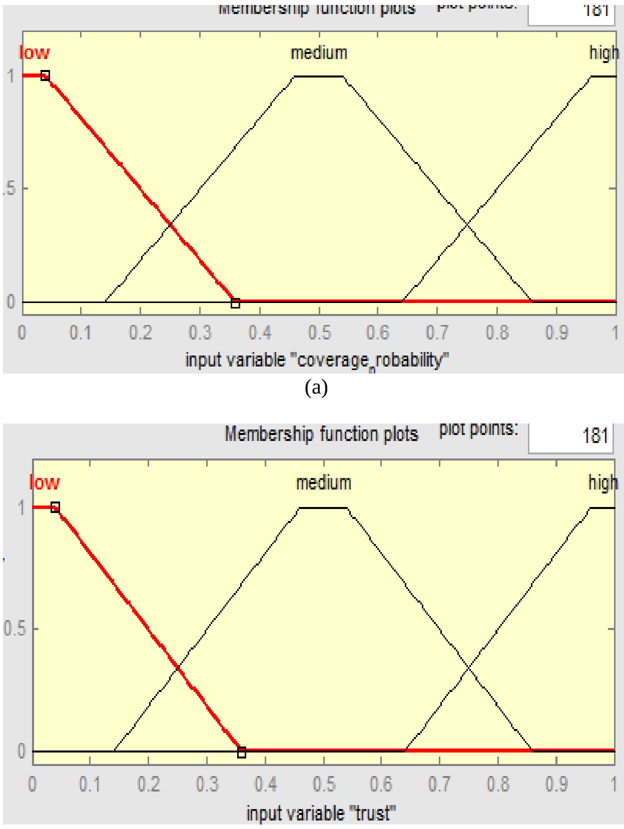


Fig. 5. Fuzzy Inference Process

Fuzzy logic is used to determine the set of nodes to be included in the *cover*. The two input variables coverage probability and trust value and an output variable observation probability are considered. The trapezoidal membership functions are considered for the input variables are shown in Fig.6 a and Fig. 6 b. and for the output variable is shown in Fig. 6c.The values for the input variables are considered as: low, medium and high and the value for the output variable is considered as: very low, low, average, good and very good. Mamdani fuzzy inference mechanism is used for determining the node status to be included in the *cover* or not.



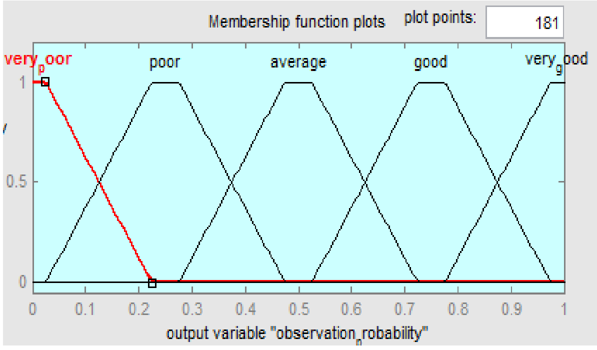
(a)

(b)

Fig. 6. Membership function for the input variable a) coverage probability b) trust

A. Rule Set for Activating the Nodes

The 9 rules obtained for the observation probability of the nodes are as shown in Table I.



(c)

Fig. 6 c. Membership functions for the output variable observation probability

TABLE I. RULE BASE FOR THE OBSERVATION PROBABILITY

Coverage Probability	Trust	Observation Probability
Low	Low	Very Poor
Low	Medium	Poor
Low	High	Average
Medium	Low	Average
Medium	Medium	Average
Medium	High	Average
High	Low	Average
High	Medium	Good
High	High	Very Good

IV. PROPOSED PROTOCOL

The sensor nodes regularly send the opinion about their neighbor in terms of coverage probability and trust values to the base station. This enables the base station to have a comprehensive view of status of the nodes. The observation probability of each target with respect to each node is computed. Thereafter, the base station utilizes a greedy heuristic scheme to build the set cover as described in Table II. The base station informs the sensor nodes belonging to the *cover* to remain active and monitor the nearby target for the next time interval. The proposed protocol function in rounds and each round consist of following three phase as shown in Fig. 7:

1. The first phase is the setup phase in which the base station gathers the trust information about every node and determines the activation schedule based on the contribution, coverage probability and the trust values. The contribution of a node is defined as the number of targets it can monitor.

2. The second phase is the sensing phase in which the node sense the environmental parameter according to the schedule determined by the base station.

3. The third phase is data transmission phase in which the sensed data is transmitted to the base station using either single hop communication or multi hop communication.

A. Pseudo Code for the Calculation of Set Cover

The proposed protocol works in rounds and each round consist of three phase as setup phase, sensing phase and transmission phase.

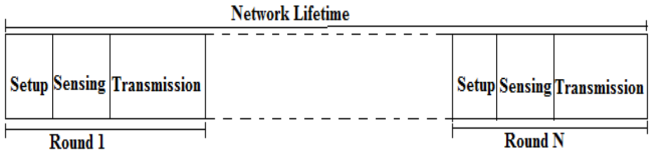


Fig 7. Organization of Network Activities

TABLE II. PSEUDO CODE FOR THE CALCULATION OF THE SET COVER

In the set up phase the base station determines the schedule

Input

set of n sensor nodes=*{S}*, set of m target nodes=*{T}*, $\forall t_j \in T, \forall s_i \in S$ where i=*{1,2…n}* and j=*{1,2…m}*

Terms

RCL= required trust level for every target

STL= trust level of the sensor node

B_i =lifetime of the sensor node i

cov(i ,j) = coverage probability of the node i detecting the target j

P_{ij}^{obs} = observation probability of sensor node i for the target j

contr(i)= contribution of the node and is defined as the number of targets it can monitor

TAR= set of targets monitored

cover= cover set which can monitor all the targets and *count*= number of set covers.

Algorithm

1. Initialize $B_i = 1 \forall s_i \in S, i = \{1,2,..n\}$
2. *TAR={}*
3. Initialize *count*=0
4. Compute *cov(i, j)* $\forall s_i \in S, \forall t_j \in T$
5. Calculate *STL* $\forall s_i \in S$
6. Compute observation probability as follows:

$P_{ij}^{obs} = \text{cov}(i, j) \times STL$

7. Arrange the observation probability in decreasing order.
8. Sort the nodes according to the contribution of the nodes.
9. While *TAR= {T}*!! $P_{ij}^{obs} > RCL$
10. Find *(i, j)*=arg max(P_{ij}^{obs})
11. $TAR = TAR \cup j$
12. cover=cover $\cup i$
13. $\forall k$ such that $P_{ik}^{obs} > RCL \| \text{cover}(k) = \{\}$
14. $TAR = TAR \cup k$
15. If $P_{nj}^{obs} < P_{ij}^{obs}$ discard that node.
16. *S=S-i*
17. *count=count+1*
18. $updateB_i = B_i - e_i$
19. goto step 10
20. return *cover*

of the nodes according to which the nodes will be activated on the basis of observation probability. The observation probability for every target with respect to every node is calculated on the basis of probabilistic coverage model and trust model. The observation probabilities are stored in a matrix. The number of set cover is initialized to zero; set cover is initialized as empty and the set of targets monitored *TAR* is initialized as empty. For the calculation of the set cover the node with the maximum observation probability is selected. The target being monitored by this node is determined and if its coverage probability is greater than the required coverage threshold, it is marked as monitored and added to the *TAR*. A node can monitor more than one target with the desired coverage probability, so all the targets are marked as covered and added to *TAR*. The node is added to the set cover and removed from the set of sensor nodes. The above process is repeated until all the targets are covered or till there is no target which can be monitored with the required coverage threshold. The output of the algorithm is the number of set covers obtained.

B. Flow Chart of the proposed Algorithm

The flow chart of the algorithm is shown in the Fig.8.

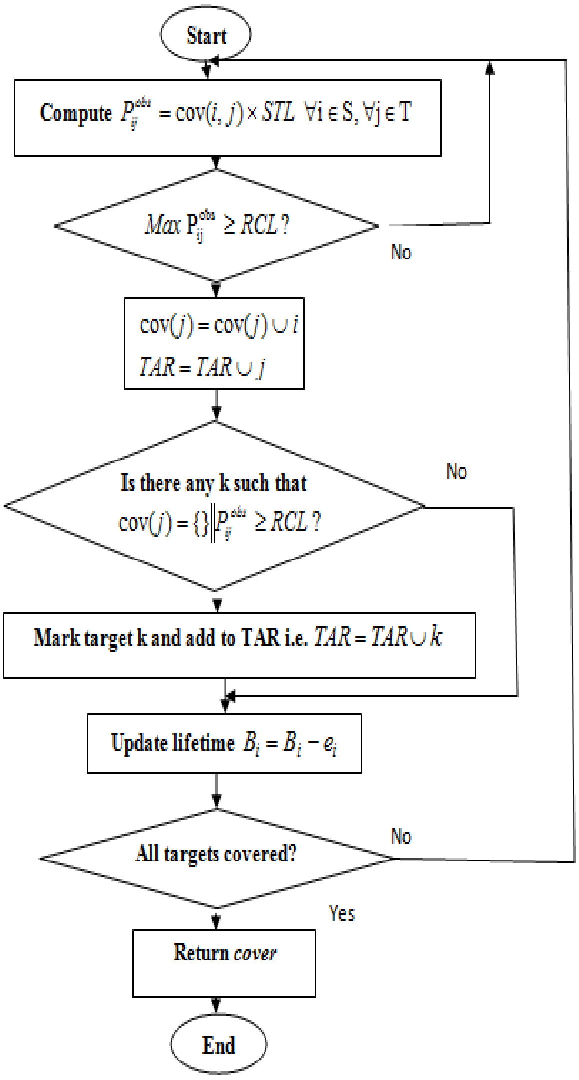


Fig. 8. Flow chart for the set cover algorithm

C. Validation of the Pseudo Code

Consider a network of 6 nodes and 3 targets randomly deployed in a region of 50*50 dimensions. The observation probability matrix for the network is obtained as:

$$P_{ij}^{obs} = \begin{bmatrix} 0.4 & 0.4 & 0 \\ 0.19 & 0.19 & 0 \\ 0.35 & 0 & 0 \\ 0.29 & 0.29 & 0.29 \\ 0.67 & 0 & 0 \\ 0 & 0 & 0.5 \end{bmatrix}$$

Initially the set of the targets monitored is empty and is represented as *TAR= {}*.

The required coverage level is assumed to be 0.4. The maximum observation probability is 0.67 for the node 5 and it can monitor the target 1, so the values of *cover* and *TAR* are updated as:

Cover= {5}
TAR= {1}

Since the node 5 can't monitor any other target so the values of the set of nodes, *count* and the sensor's energy level are updated according to the steps 15, 16 and 17. The above steps are repeated until all the targets are monitored by at least one sensor node. The values of the cover and *TAR* are computed as follows:

Step2. *Cover= {5, 6}*
TAR= {1, 3}

Step3. *Cover= {1, 5, 6}*
TAR= {1, 2, 3}

The protocol ends here as all the targets are monitored. The network efficiency is improved as all the targets can be monitored by using only 3 nodes. By continuing the process the network lifetime can be improved by determining the maximum number of set covers which consist of optimal number of nodes.

V. SIMULATION RESULTS AND ANALYSIS

The various simulations have been carried out using *C* language and *MATLAB* tool to obtain the optimal values of the parameters λ, β and the coverage probability. The simulation results show that the coverage probability decreases exponentially with the distance between the node and the target.

It is observed that the coverage probability is optimal for the parameter values $\lambda = 0.1$ and $\beta = 0.1$. A network of 10 nodes and 5 targets is considered for which the operational distance range is 8.06*m* to 24.35*m* and the coverage probability is maximum 0.89 units at a given signal strength.

A. Simulation for Weight Assignment for Trust Factors for Proposed Model

Analytical Hierarchy Process (AHP) is used to determine the weightage of the various trust factors. It uses a multi-criteria decision making approach to derive scaled ratios using the pair wise comparison of the attributes [11]. AHP consists of following steps:

i. Construct a hierarchical structure model of the factors which affect the decision making.

ii. Construct a basic judgment matrix based on the pairwise comparison of the attributes.

iii. Calculate the weight matrix of decision factors.

iv. Make a consistency test for the judgment matrix.

The precedence order of trust factors are as follows:

Direct Trust > Recommendation Trust > Indirect Trust.

Therefore direct trust has the highest priority and indirect trust has the lowest priority.

The precedence order for the direct trust factors are as follows:

Communication Trust > Energy Trust > Data Trust.

Therefore it implies that the communication trust has highest priority and data trust has lowest priority.

The judgment matrix for the direct, recommendation and indirect trust is as follows:

$$[C] = \begin{bmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 1/7 \\ 1/3 & 7 & 1 \end{bmatrix}$$

The element of the matrix represents the comparison value of direct, trust recommendation trust and indirect trust.

The weight matrix for the trust factors using AHP is as follows:

$$\begin{bmatrix} w_1 \\ w_2 \\ w_3 \end{bmatrix} = \begin{bmatrix} 0.59 \\ 0.33 \\ 0.08 \end{bmatrix}$$

The direct trust, recommendation trust and indirect trust have weights 0.59, 0.33 and 0.08 respectively.

The direct trust factors communication trust, energy trust and data trust has following judgment matrix using AHP.

$$[D] = \begin{bmatrix} 1 & 1/5 & 1/7 \\ 5 & 1 & 1/3 \\ 7 & 3 & 1 \end{bmatrix}$$

The element of the matrix represents the comparison value of the communication, energy and data trust factors.

The weight matrix for direct trust factors using AHP is as follows:

$$\begin{bmatrix} w_D \\ w_E \\ w_C \end{bmatrix} = \begin{bmatrix} 0.06 \\ 0.29 \\ 0.65 \end{bmatrix}$$

The data trust, energy trust and communication trust factors have weight values 0.06, 0.29 and 0.65 respectively.

B. Simulation and Validation of the Proposed Protocol for a Smaller Network

A network of 40 nodes and 15 targets is deployed in a region of dimensions 120*120. The base station is located at the center. The standard energy model is considered for the transmission, sensing and receiving the data values. The other simulation parameters are shown in Table III.

TABLE III. SIMULATION PARAMETERS

Parameter	Value
Area of the Region	120*120sq. m.
Number of Nodes	20-50
Sensing Range	15m
Detection Error Range	10m
Initial Energy of normal node	0.5J
Energy Factor α, β	1,2
Initial energy of normal node	1.0J
Initial energy of advanced node	1.5J
Energy consumed in the electronics circuit to transmit or receive the signal (E_{elec})	50 nJ/bit
Energy consumed by the amplifier to transmit at a short distance (E_{fs})	10pJ/bit/ m^2
Energy consumed by the amplifier to transmit at a longer distance (E_{amp})	0.0013pJ/bit/ m^4
Data Aggregation Energy (E_{DA})	5nJ/bit/report
Packet Size (L)	500 byte
Regulatory factor (R)	0.5
Required coverage level for every target	0.5

The initial deployment of the nodes is shown in the Fig. 10.a. The various set covers obtained for the considered network are shown in the Fig.10 b to Fig.10 h.

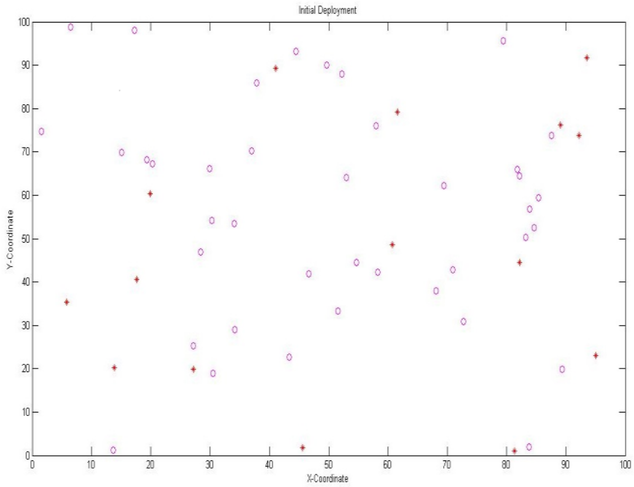


Fig.10 a. Initial network deployment

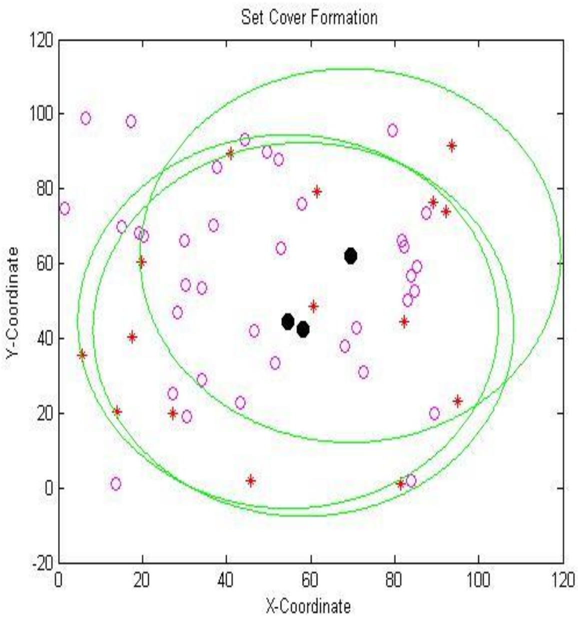


Fig. 10 b.

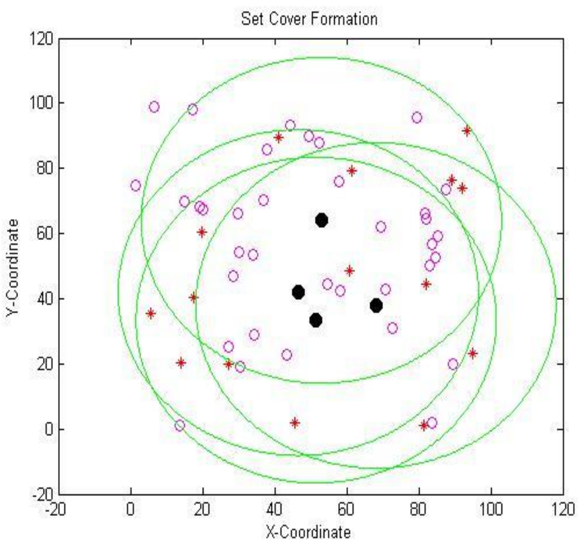


Fig. 10 c.

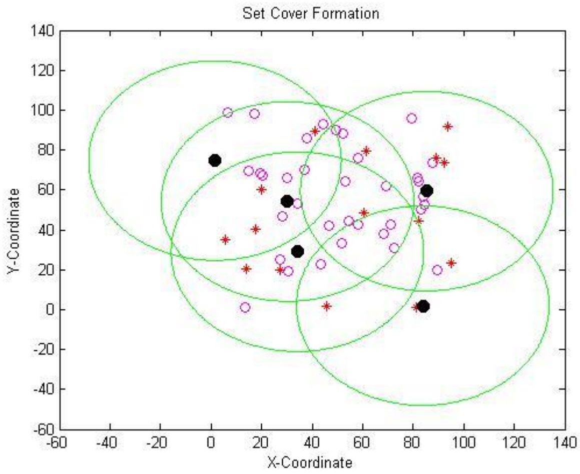


Fig. 10 d.

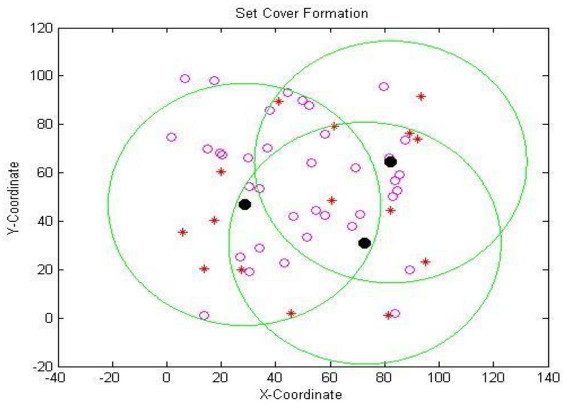


Fig. 10 e.

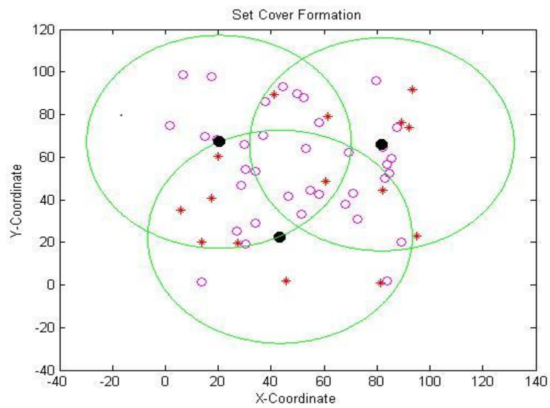


Fig. 10 f.

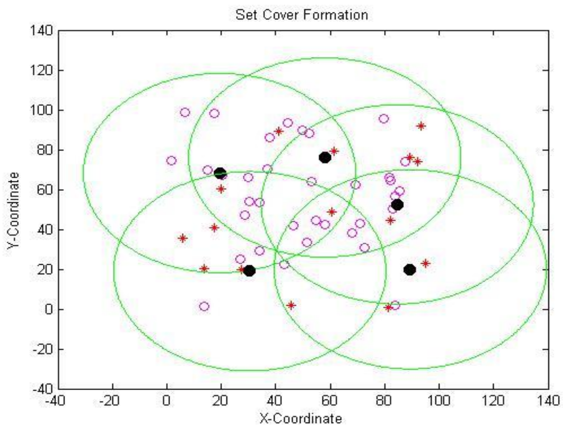


Fig. 10 g.

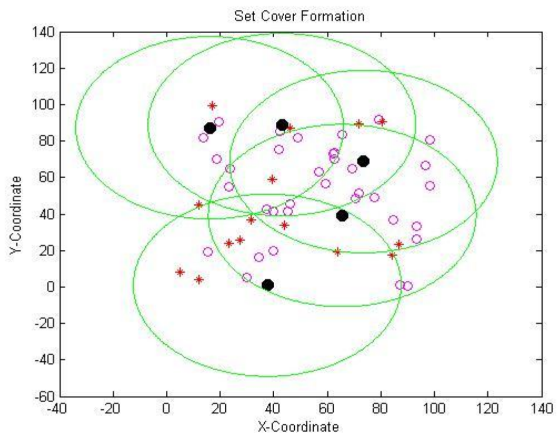


Fig. 10 h.

Fig.10. Set covers obtained for the considered network

The 25 set covers are obtained for the given network as shown in Table IV.

TABLE IV. SET COVERS DETERMINED

Set Cover	Node Set	Set Cover	Node Set
C1	{4,7,10}	C14	{5,14,15,29,30}
C2	{5,7,10}	C15	{5,6,15,29,30}
C3	{7,10,28}	C16	{5,8,15,29,30}
C4	{7,10,30}	C17	{5,15,23,29,30}
C5	{7,10,33}	C18	{5,15,23,30,34}
C6	{1,5,6,15,30}	C19	{5,6,15,30,34}
C7	{1,5,8,15,30}	C20	{5,8,15,30,34}
C8	{1,5,14,15,30}	C21	{5,14,15,30,34}
C9	{1,5,15,23,30}	C22	{5,6,15,30,37}
C10	{5,8,9,15,30}	C23	{5,8,15,30,37}
C11	{5,6,8,9,15,30}	C24	{5,14,15,30,37}
C12	{5,9,14,15,30}	C25	{5,15,23,30,37}
C13	{5,9,15,23,30}		

The proposed protocol improve the network lifetime by determining the maximum number of set covers consisting of optimal number of nodes. The optimal number of nodes is 6 for the given network. The simulation result shows that the following nodes have the maximum contribution through the set covers:

{1,4,5,6,7,8,9,10,15,15,23,28,29,30,33,34,37}

The improvement factor in terms of active nodes in the set covers and toal number of nodes is upto double.

The performance of the proposed protocol in terms of the maximum observation probability vs. target is shown in the Fig. 11 a. The results show that the observation probability is maximum for the parameter values $\lambda = 0.1$ and $\beta = 0.1$. The contribution of the nodes is shown in Fig. 11 b. The node contribution determines the number of targets monitored by a node. The result shows that the node 5 has the highest contribution and it can monitor 9 targets. The minimum contributing nodes for target coverage are as follows: {12,21,24,25,26,32,39}. The different residual energy level of the nodes in different set covers are shown in the Table V. The set covers are activated periodically as long as all the targets are monitored.

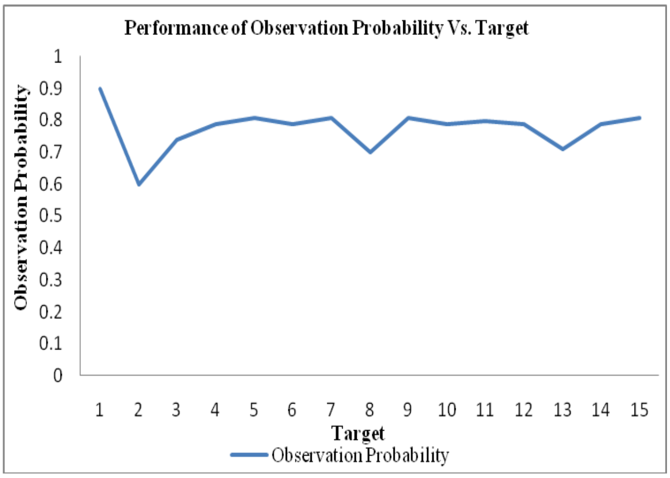


Fig. 11 a.

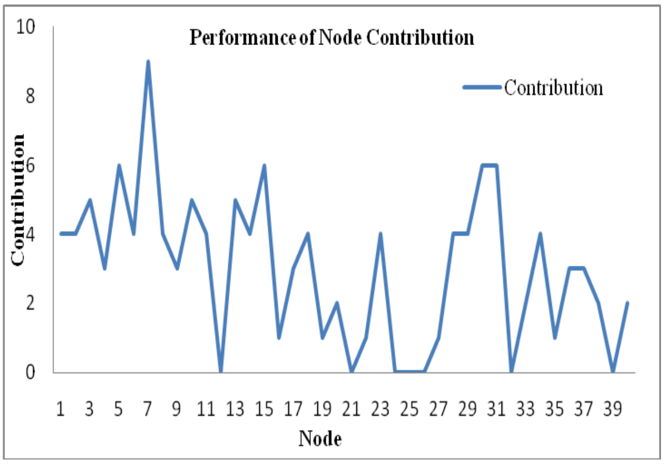


Fig. 11 b.

Fig.11 Performance of the proposed protocol:a. Observation probability vs. target b. Contribution of the node

On the basis of node contribution a leader node is selected in each set cover for transmitting the aggregated sensed data from other nodes to the base station while other nodes in the set cover performs the sensing and transmitting to the leader node. The result show that some nodes are included in all the set covers and are always monitoring the targets, therefore these nodes are considered as the critical nodes and may be replaced by higher energy nodes so it generates the heterogeneity in the system.

It is observed that after activation of all the set covers the residual energy of the nodes (5,15, 30} is decreased at a higher rate because these nodes are critical nodes for the given network. The energy levels of the critical nodes is shown in the Fig 12. It is observed that after the activation of all the set covers the residual energy of node 5 is lowest among the critical node set.

The energy level of normal nodes in the set covers is shown in the Fig 13. The average energy depends on the number of set covers in which the node belongs. It is observed from the result that the average energy of the nodes decreases as the netwrok remains active. The performance of the average energy level in each set cover is shown in the Fig.14.

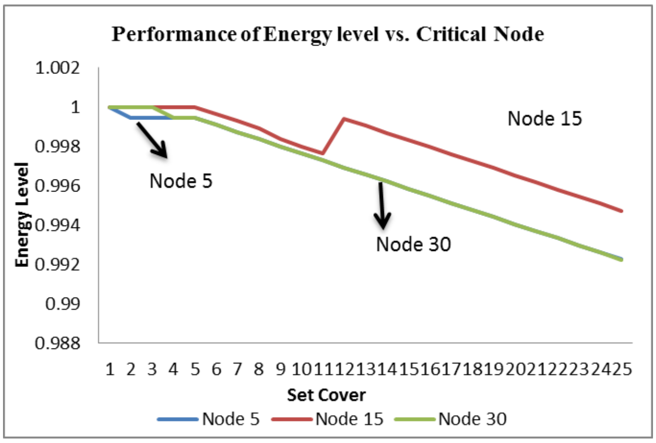


Fig.12. Energy level of the critical nodes

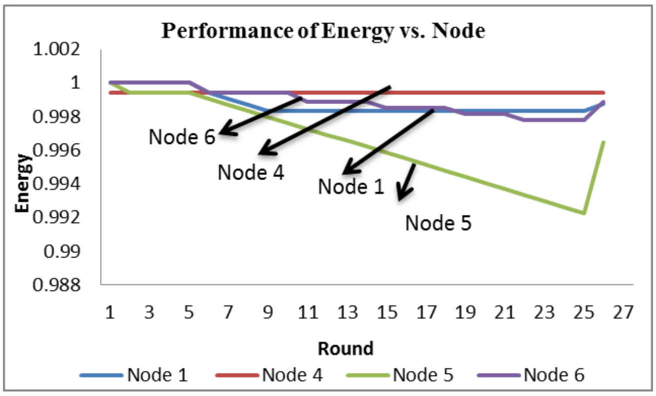


Fig.13. Energy levels of the normal nodes

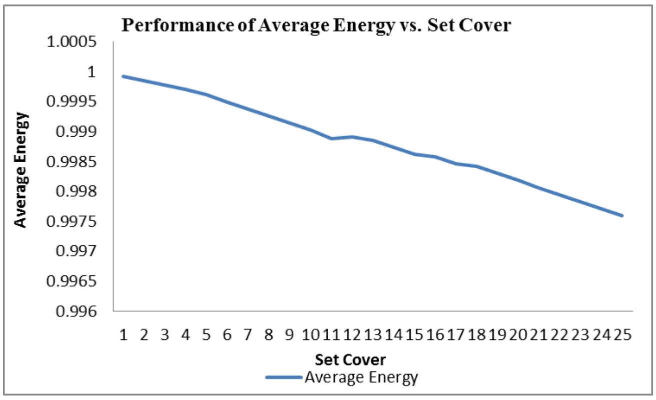


Fig.14. Average energy vs. Set Cover

The average energy of the nodes after the completion of 25 set covers in one round is shown in Fig.15. It is observed that the nodes 5 and 30 have the least average energy because it belongs to all the set covers.

The residual energy of each node in the set cover after execution of all set covers is shown in the Fig.16. The results show that the node 5 has the minimum residual energy, hence the network lifetime is restricted by the remaining energy level of the nodes 5,15 and 30 (critical nodes). The maximum number of rounds for which the network is operational is 1771.

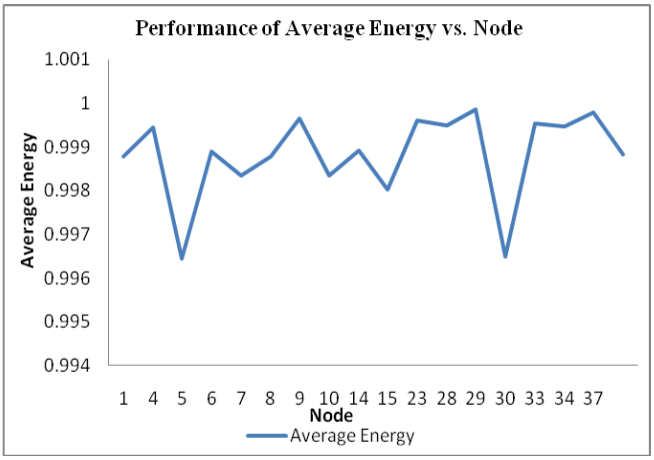


Fig.15. Average energy vs. Node

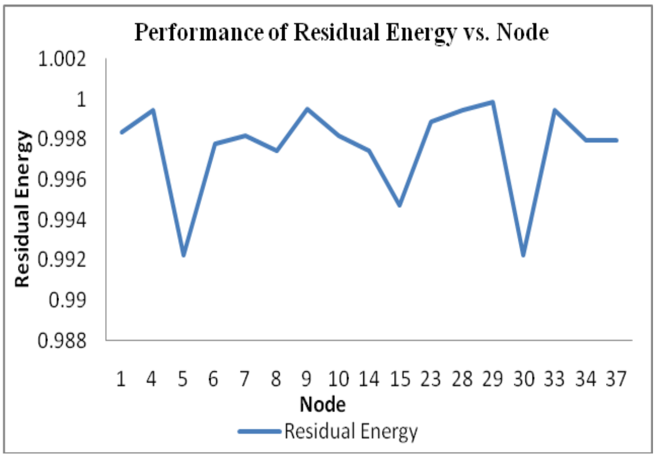


Fig.16. Residual energy of the nodes

The number of set covers in which a node contributes is shown in the Table VI.

TABLE VI. NUMBER OF SET COVERS VS. NODE

Node	No. of Set Covers
1	20
4	25
5	24
6	20
7	25
8	19
9	16
10	25
14	18
15	20
23	17
28	23
29	12
30	22
33	21
34	17
37	21

The number of rounds for which the nodes are in the active state are shown in the Fig. 17.

It is observed that the number of successful transmission decreases with the increase in the distance among the nodes. At the distance *55m* the given network performance starts failing. The number of successful message transmissions is shown in the Fig.18. The performance of the proposed protocol is evaluated in terms of number of active nodes, set covers and the network lifetime as shown in the Fig 19 a to Fig 19 f. The number of sensor nodes are varied from 20 to 50.

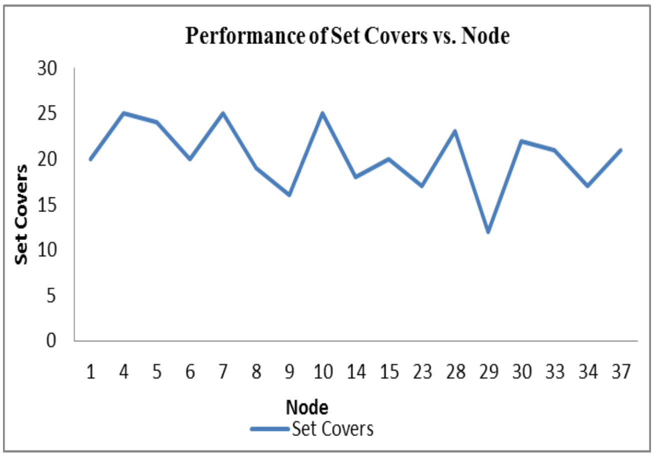


Fig.17. Number of set covers vs. node

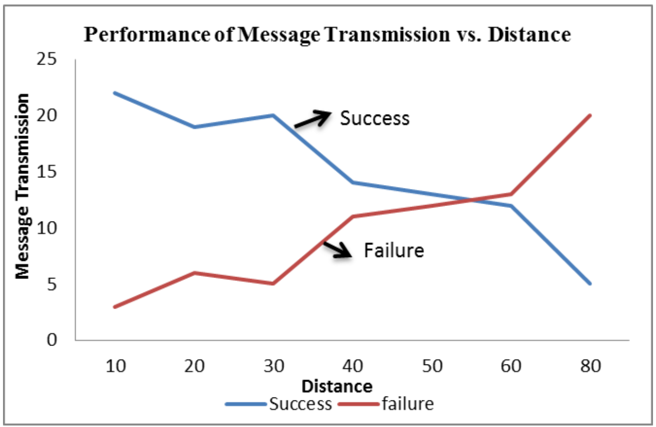


Fig.18. Message Transmissions vs. Distance

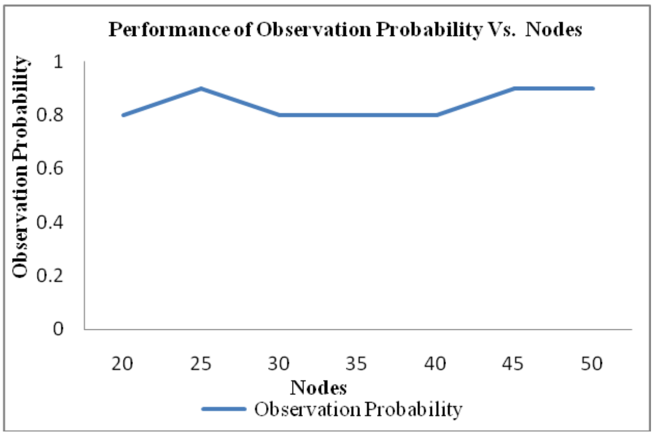
Fig. 19 a shows the maximum observation probability achieved with respect to number of sensor nodes. The results show that the proposed protocol achieves optimal observation probability up to 0.8 in almost all cases. Fig. 19 b shows that the maximum observation probability achieved by varying the number of the targets. It is observed that the observation probability is optimal in almost all cases. The number of active nodes increases linearly with the number of nodes as shown in the Fig. 19 c. The network lifetime obtained with respect to increase in the number of nodes is shown in Fig. 19 d. The network lifetime increases linearly with the increase in the number of sensor nodes. The number of optimal nodes to be deployed with respect to the varying number of targets is shown in Fig. 19 e. It is observed that the coverage probability is optimal with respect to the distance as shown in Fig. 19 f.

C. Simulation Results for a Real Network

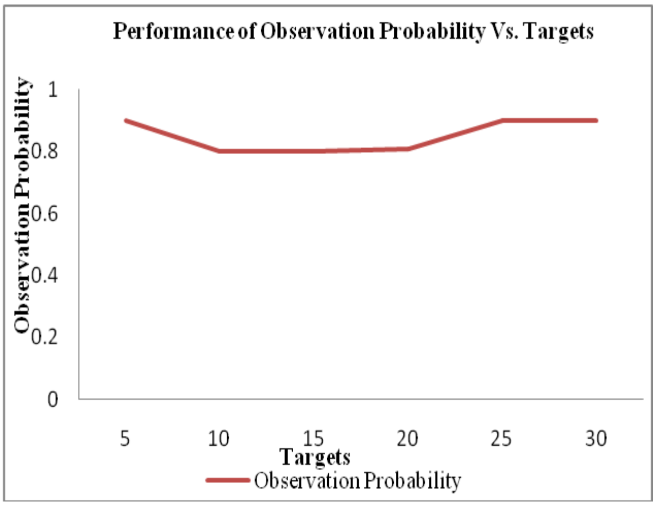
The performance of the proposed protocol is analyzed by varying the number of nodes from 20 to 2000 and the number of targets from 5 to 1000. The number of set covers is obtained for each case as shown in Fig. 20 a and Fig. 20 b. It is observed that the number of set covers is increased exponentially with respect to the number of nodes and the targets.

The performance of the proposed protocol is compared with disjoint set cover (DSC) protocol as shown in Fig. 21 a, 21 b and 21 c. In DSC protocol the set cover are disjoint i.e. a sensor node cannot participate in more than one set cover.

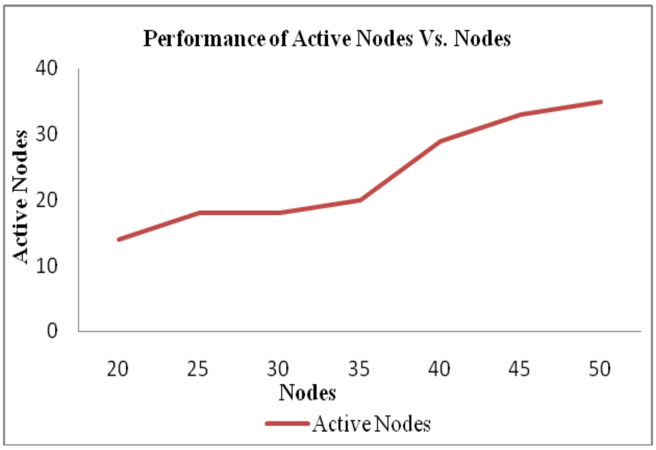
Fig. 21 a shows that the number of set covers is more in proposed protocol with respect to DSC so the network lifetime is improved. Fig. 21 b shows the comparison of active nodes obtained in both the approaches on increasing the sensor nodes. The results show that the number of active nodes is less in the proposed approach than DSC so the energy consumption is reduced and the network lifetime is increased as shown in the Fig. 21 c.



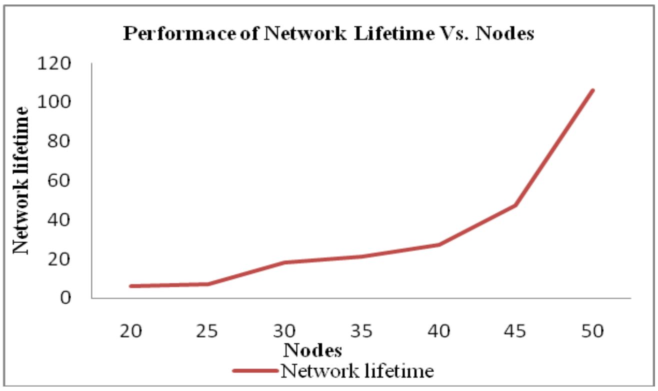
a.



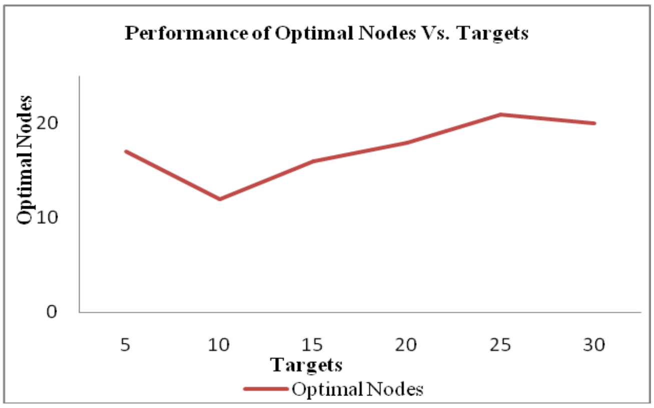
b.



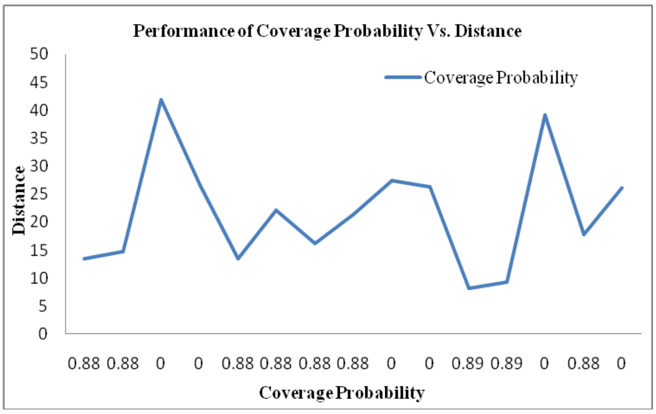
c.



d.

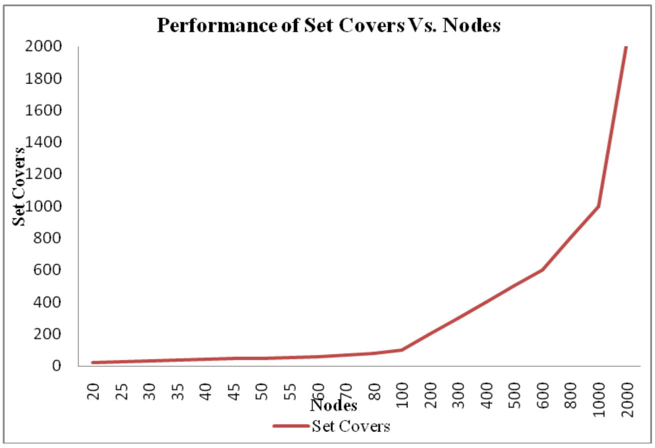


e.

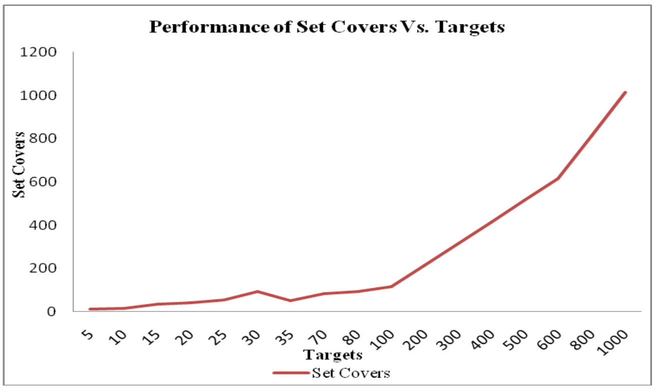


f.

Fig.19. Performance of Proposed Protocol: a. Observation Probability vs. Nodes, b. Observation Probability vs. Targets, c. Active Nodes vs. Nodes, d. Network Lifetime vs. Nodes, e. Targets vs. Optimal Nodes, f. Coverage Probability vs. Distance



a.



b.

Fig. 20. Performance of the proposed protocol a. Set covers vs. nodes. b. Set covers vs. targets

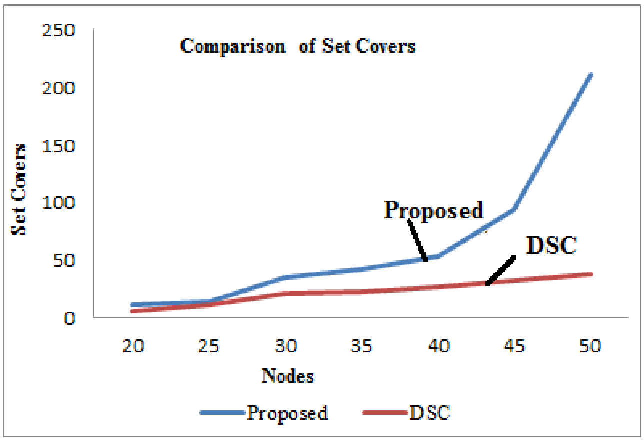


Fig. 21 a.

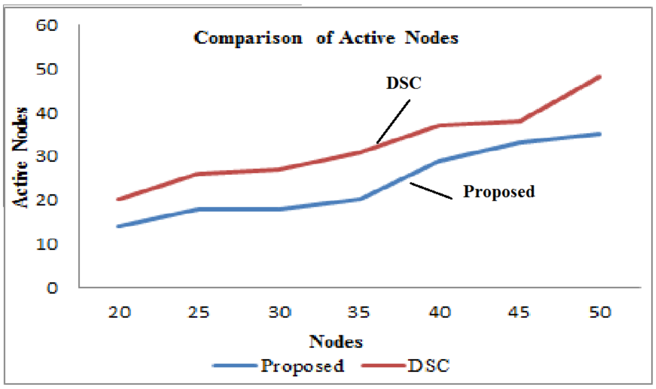


Fig. 21 b.

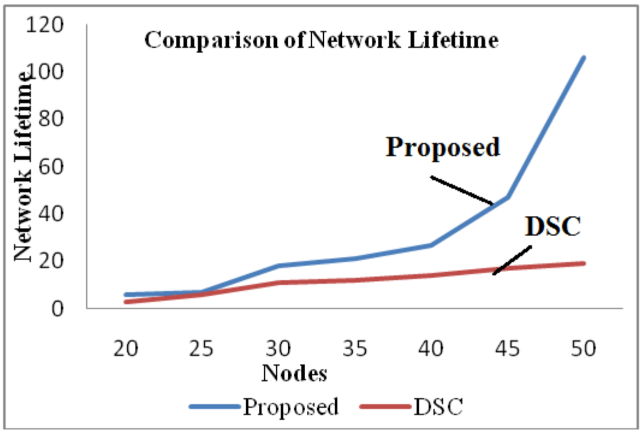


Fig. 21 c.

Fig. 21. Comparison of Proposed Protocol with Disjoint Set Cover Approach: a. Set Covers vs. Nodes, b. Active Nodes vs. Nodes, c. Network Lifetime vs. Nodes

VI. CONCLUSION

The proposed protocol is a hybrid scheduling protocol for target coverage based on trust evaluation for wireless sensor networks through determining the number of set covers for monitoring all the targets using the probabilistic coverage model, node contribution and trust values. The optimal observation probability is obtained for the parameter values of the sensing and communication characteristics λ and β as 0.1. The weight level of the various trust factors is determined using the AHP. The simulation results show that the performance of proposed protocol improves the network efficiency in terms of coverage, network lifetime and reliability in terms of trust factor. The comparison results show that the proposed protocol improves the performance in terms of the number of set covers, network lifetime and number of active nodes compared to disjoint set cover protocol.

TABLE V. ENERGY LEVELS OF THE NODES WITH RESPECT TO SET COVERS OBTAINED

Round /Node	1	4	5	6	7	8	9	10	14	15	23	28	29	30	33	34	37
1	1	0.999	1	1	0.999	1	1	0.999	1	1	1	1	1	1	1	1	1
2	1	0.999	0.999	1	0.999	1	1	0.999	1	1	1	1	1	1	1	1	1
3	1	0.999	0.999	1	0.998	1	1	0.998	1	1	1	0.999	1	1	1	1	1
4	1	0.999	0.999	1	0.998	1	1	0.998	1	1	1	0.999	1	0.999	1	1	1
5	1	0.999	0.999	1	0.998	1	1	0.998	1	1	1	0.999	1	0.999	0.999	1	1
6	0.999	0.999	0.999	0.999	0.998	1	1	0.998	1	0.999	1	0.999	1	0.999	0.999	1	1
7	0.999	0.999	0.998	0.999	0.998	0.999	1	0.998	1	0.999	1	0.999	1	0.998	0.999	1	1
8	0.998	0.999	0.998	0.999	0.998	0.999	1	0.998	0.999	0.998	1	0.999	1	0.998	0.999	1	1
9	0.998	0.999	0.998	0.999	0.998	0.999	1	0.998	0.999	0.998	0.999	0.999	1	0.998	0.999	1	1
10	0.998	0.999	0.997	0.999	0.998	0.999	0.999	0.998	0.999	0.998	0.999	0.999	1	0.997	0.999	1	1
11	0.998	0.999	0.997	0.998	0.998	0.998	0.999	0.998	0.999	0.997	0.999	0.999	1	0.997	0.999	1	1
12	0.998	0.999	0.996	0.998	0.998	0.998	0.998	0.998	0.999	0.999	0.999	0.999	1	0.996	0.999	1	1
13	0.998	0.999	0.996	0.998	0.998	0.998	0.999	0.998	0.999	0.999	0.999	0.999	1	0.996	0.999	1	1
14	0.998	0.999	0.996	0.998	0.998	0.998	0.999	0.998	0.998	0.998	0.999	0.999	0.999	0.996	0.999	1	1
15	0.998	0.999	0.995	0.998	0.998	0.998	0.999	0.998	0.998	0.998	0.999	0.999	0.998	0.995	0.999	1	1
16	0.998	0.999	0.995	0.998	0.998	0.998	0.999	0.998	0.998	0.997	0.999	0.999	0.999	0.995	0.999	1	1
17	0.998	0.999	0.995	0.998	0.998	0.998	0.999	0.998	0.998	0.997	0.999	0.999	0.999	0.995	0.999	1	1
18	0.998	0.999	0.994	0.998	0.998	0.998	0.999	0.998	0.998	0.997	0.999	0.999	0.999	0.994	0.999	0.999	1
19	0.998	0.999	0.994	0.998	0.998	0.998	0.999	0.998	0.998	0.996	0.999	0.999	0.999	0.994	0.999	0.998	1
20	0.998	0.999	0.994	0.998	0.998	0.997	0.999	0.998	0.998	0.996	0.999	0.999	0.999	0.994	0.999	0.998	1
21	0.998	0.999	0.993	0.998	0.998	0.997	0.999	0.998	0.997	0.996	0.999	0.999	0.999	0.993	0.999	0.997	1
22	0.998	0.999	0.993	0.997	0.998	0.997	0.999	0.998	0.997	0.995	0.999	0.999	0.999	0.993	0.999	0.997	0.999
23	0.998	0.999	0.992	0.997	0.998	0.997	0.999	0.998	0.997	0.995	0.999	0.999	0.999	0.992	0.999	0.997	0.998
24	0.998	0.999	0.992	0.997	0.998	0.997	0.999	0.998	0.997	0.995	0.999	0.999	0.999	0.992	0.999	0.997	0.998
25	0.998	0.999	0.992	0.997	0.998	0.997	0.999	0.998	0.997	0.994	0.998	0.999	0.999	0.992	0.999	0.997	0.997

REFERENCES

[1] I. F. Akyildiz, W Su, Y. Sankarasubramaniam and E. Cayirci, "Wireless Sensor Networks: A Survey," Computer Networks, Vol. 38, No. 4, 2002, pp. 393-422.

[2] J. Yick, B. Mukherjee, D. Ghoshal, Wireless Sensor Networks Survey, Computer Networks 52 (2008) 2292–2330.

[3] J. O'Rourke, Art Gallery Theorems and Algorithms, Oxford University Press, Oxford, 1987.

[4] W.W. Gregg, W.E. Esaias, G.C. Feldman, R. Frouin, S.B. Hooker, C.R. McClain, R.H. Woodward, Coverage opportunities for global ocean color in a multimission era, IEEE Transactions on Geosience and Remote Sensing 5 (1998) 1620–1627.

[5] D.W. Gage, Command control for many-robot systems, Proceedings of the Nineteenth Annual AUVS Technical Symposium 1992; 22–24.

[6] Anurag Dagar, Vinod Saroha, "An Efficient Coverage Scheme for Wireless Sensor Network", Volume 3, Issue 4, April 2013 ISSN: 2277 128X, International Journal of Advanced Research in Computer Science and Software Engineering.

[7] My T. Thai Feng Wang Ding-Zhu Du, Coverage Problems in Wireless Sensor Networks: Designs and Analysis, International Journal of Sensor Networks, Vol. 3,Issue 3, May 2008, pp. 191-200.

[8] Zahra Taghikhaki, Nirvana Meratnia, Paul J.M. Havinga, "A Trust-based Probabilistic Coverage Algorithm for Wireless Sensor Networks", 2013 International Workshop on Communications and Sensor Networks (ComSense-2013), Procedia, Computer Science 21 (2013), 455 – 464.

[9] Jinfang Jiang, Guangjie Han, Feng Wang, Lei Shu, Mohsen Guizani, "An Efficient Distributed Trust Model for Wireless Sensor Networks", IEEE Transactions on Parallel and Distributed Systems, 2014.

[10] Hyo Sang Lim, Yang Sae Moon, Elisa Bertino, Provenance based Trustworthiness Assessment in Sensor Networks, DMSN'10, September 13, 2010, Singapore.

[11] Saaty, T. L., 1990, How to make a decision. The Analytical Hierarchy Process. European Journal of Operational Research, 48, 9–26.

[12] Heinzelman, W. R., Chandrakasan, A. & Balakrishnan, H. (2000). Energy-efficient communication protocol for wireless microsensor networks, HICSS '00: Proceedings of the 33rd Hawaii International Conference on System Sciences-Volume 8, IEEE Computer Society,Washington, DC, USA, p. 8020.

[13] Pooja Chaturvedi, A. K. Daniel, "Recovery of Holes Problem in Wireless Sensor Networks", IEEE 4th International Conference on Information Communication & Embedded Systems (ICICES-2014), ISBN No. 978-1-4799-3835-3, DOI: 10.1109/ICICES.2014.7034172 (Indexed in IEEE Xplore Digital Library), 2014.

[14] Pooja Chaturvedi, A. K. Daniel, "An Energy Efficient Node Scheduling Protocol for Target Coverage in Wireless Sensor Networks" in the 5th International Conference on Communication System and Network Technologies (CSNT-2015), April 2015.

[15] Pooja Chaturvedi, A. K. Daniel "Trust Based Node Scheduling Protocol for Target Coverage in Wireless Sensor Networks", 3rd International Conference on Emerging Research in Computing, Information, Communication & Applications (ERCICA-2015), Bangalore, Springer India 2015, N.R. Shetty et al. (eds.), Emerging Research in Computing, Information, Communication and Applications, DOI 10.1007/978-81-322-2550-8_16.

[16] Pooja Chaturvedi, A. K. Daniel, "Trust Based Target Coverage Protocol for Wireless Sensor Networks Using Fuzzy Logic", in the 12th International Conference on Distributed Computing & Internet Technology (ICDCIT-2016), organized by KIIT University, Bhubaneswar, Odisha, India, during the period 15th Jan 2016-18th Jan 2016.

[17] Pooja Chaturvedi, A. K. Daniel, "Lifetime Optimization for Target Coverage in Wireless Sensor Networks" in 8th Annual ACM India Conference Compute 2015, organized by Academy of Business & Engineering Sciences Engineering College (ABESEC), Ghaziabad during the period 29th Oct 2015-31st Oct 2015.

[18] Pooja Chaturvedi, A. K. Daniel, "Trust Based Energy Efficient Coverage Preserving Protocol for Wireless Sensor Networks", in the International Conference on Green Computing & Internet of Things (ICGCIOT-2015), organized by Galgotia's College of Engineering & Technology, Greater Noida during the period 8th Oct 2015-10th Oct 2015.

[19] BOGDAN CA˘RBUNAR, ANANTH GRAMA, and JAN VITEK, Redundancy and Coverage Detection in Sensor Networks, ACM Transactions on Sensor Networks, Vol. 2, No. 1, February 2006, Pages 94–128.

[20] N. Jaggi, and A. A. Abouzeid, Energy-Efficient Connected Coverage in Wireless Sensor Networks, Proc. 4th Asian International Mobile Computing Conference (AMOC), pp. 77-86, January 2006 .

[21] Xiaochun Xu and Sartaj Sahni, Approximation Algorithms For Wireless Sensor Deployment, April 21, 2006.

[22] Z. Zhou, S. Das and H. Gupta. Connected k-coverage problem in sensor networks. In Proc. of International Conference on Computer Communications and Networks (ICCCN'04), Chicago, IL, October 2004, pp. 373–378.

[23] Wang, J.; Zhong, N. Efficient point coverage in wireless sensor networks. J. Comb. Optim. 2006, 11, 291–304

[24] MIHAssELA CARDEI, DING-ZHU DU, Improving Wireless Sensor Network Lifetime through Power Aware Organization, Wireless Networks 11, 333–340, 2005.

[25] Cardei, I, Cardei M. (2008) "Energy-efficient connected-coverage in wireless sensor networks", IJSNET, Vol 3. Issue No 3.

[26] M. Cardei, M. T. Thai, and Y. Li. Energy-efficient target coverage in wireless sensor network. Proc. Infocom'05, May 2005.

[27] M. Cardei, D. Z. Du, "Improving Wireless Sensor Network Lifetime through Power Aware Organization", Wireless Networks 11, 333–340, 2005.

[28] M. Cardei, J. Wu, M. Lu, and M. Pervaiz, "Maximum network lifetime in wireless sensor networks with adjustable sensing ranges," in Proc. of the IEEE Intl. Conf. on Wireless and Mobile Computing, Networking and Communications (WiMob), August 2005.

[29] Shuhui Yang,Fei Dai, Mihaela Cardei, Jie Wu, Floyd Patterson, On Connected Multiple Point Coverage in Wireless Sensor Networks International Journal of Wireless Information Networks, Vol. 13, No. 4, October 2006.

[30] S. Mini, Siba K. Udgata, and Samrat L. Sabat , Sensor Deployment and Scheduling for Target Coverage Problem in Wireless Sensor Networks, IEEE SENSORS JOURNAL, VOL. 14, NO. 3, MARCH 2014

[31] S. Slijepcevic, M. Potkonjak, Power efficient organization of wireless sensor networks, Proceedings of IEEE International Conference on Communications 2 (2001) 472–476.

[32] Zaixin Lu, Wei Wayne Li, Miao Pan, Member, Maximum lifetime scheduling for target coverage and data collection in wireless sensor networks, 10.1109/TVT.2014.2322356, IEEE Transactions on Vehicular Technology.

[33] Honghai Zhang and Jennifer C. Hou, Maintaining Sensing Coverage and Connectivity in Large Sensor Networks, Ad Hoc & Sensor Wireless Networks, Vol. 1, pp. 89–124, 2005.

[34] M. Hefeeda and H. Ahmadi, "Probabilistic coverage in wireless sensor networks," Simon Fraser University, TR 2006-21, Tech. Rep., Updated March 2007.

[35] GUOLIANG XING, XIAORUI WANG, YUANFANG ZHANG, CHENYANG LU, ROBERT PLESS, and CHRISTOPHER GILL, Integrated Coverage and Connectivity Configuration for Energy Conservation in Sensor Networks, ACM Transactions on Sensor Networks, Vol. 1, No. 1, August 2005, Pages 36–72.

[36] Fan Ye, Gary Zhong, Songwu Lu, Lixia Zhang, PEAS: A Robust Energy Conserving Protocol for Long-lived Sensor Networks Proceedings of the 10 th IEEE International Conference on Network Protocols (ICNP'02)1092-1648/02 $17.00 , 2002.

[37] M. Cardei, My. T. Thai, Y. Li. Weili Wu, Energy Efficient Target Coverage in Wireless Sensor Networks, infocom 20005, 1976-1984.

[38] Hai Liu, Pengjun Wan, Xiaohua Jia, Maximal lifetime scheduling for K to 1 sensor–target surveillance networks, Computer Networks 50 (2006) 2839–2854.

[39] Cardei M, Wu J, Lu M, Pervaiz M. Maximum network lifetime in wireless sensor networks with adjustable sensing ranges. In: IEEE international conference on wireless and mobile computing, networking and communications, August 2005 (WiMob'2005), vol. 3; 2005b. p. 438–45.

[40] K. Kar and S. Banerjee, "Node Placement for Connected Coverage in Sensor Networks," Proc. of WiOpt 2003: Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks, March 2003

[41] Hung-Lung Wang, Wei-Ho Chung, The Generalized k-Coverage under Probabilistic Sensing Model in Sensor Networks, IEEE Wireless Communication and Networking Conference,Mobile and Wireless Networks, 2012.

[42] M. Cardei, D. MacCallum, X. Cheng, M. Min, X. Jia, D. Li, and D.-Z. Du, "Wireless Sensor Networks with Energy Efficient Organization", Journal of Interconnection Networks, Vol 3, No 3-4, pp 213-229, Dec 2002.

[43] Ionut Cardei and Mihaela Cardei, Energy-Efficient Connected-Coverage in Wireless Sensor Networks, International Journal of Sensor Networks, Vol.3, Issue 3, May 2008, pp201-210.
[44] 26 M. Cardei, D. Z. Du, "Improving Wireless Sensor Network Lifetime through Power Aware Organization", Wireless Networks 11, 333–340, 2005.
[45] 27 M. Cardei, J. Wu, M. Lu, and M. Pervaiz, "Maximum network lifetime in wireless sensor networks with adjustable sensing ranges," in Proc. of the IEEE Intl. Conf. on Wireless and Mobile Computing, Networking and Communications (WiMob), August 2005.
[46] YI ZOU and KRISHNENDU CHAKRABARTY, Sensor Deployment and Target Localization in Distributed Sensor Networks, ACM Transactions on Embedded Computing Systems, Vol. 3, No. 1, February 2004, Pages 61–91.
[47] Cheng, M., Ruan, L. and Wu, W. (2005) "Achieving Minimum Coverage Breach under Bandwidth Constraints in Wireless Sensor Networks", IEEE INFOCOM'05.
[48] Guiling Wang, Guohong Cao, Member, Thomas F. La Porta, Movement-Assisted Sensor Deployment, IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 6, NO. 6, JUNE 2006.
[49] Mihaela Cardei, Jie Wu, Energy-efficient coverage problems in wireless ad-hoc sensor networks, Computer Communications, pp1-8, 2005.
[50] Howard, A., Mataric, M.J, and Sukhatme, "Mobile Sensor Network Deployment using Potential Fields: A Distributed, Scalable Solution to the Area Coverage Problem", in Proc. Of the 6th International Symposium on Distributed Autonomous Robotics Systems, Fukuoka, Japan June 25-27, 2002 pp. 299-308.
[51] Shen X., Chen J., Wang Zhi, Sun Y. "Grid Scan: A Simple and Effective Approach for Coverage Issue in Wireless Sensor Networks", in Proc. Of IEEE International Communications Conference, Vol. 8, pp. 3480-3484, June 2006. Dagar et al., International Journal of Advanced Research in Computer Science and Software Engineering 3(4), April - 2013, pp. 557-563.
[52] Sanjay Shakkottai, R. Srikant, Ness Shroff, "Unreliable Sensor Grids: Coverage, Connectivity and Diameter", in Proc. of Twenty-Second Annual Joint Conference of the IEEE Computer and Communications Societies, Austin TX, USA, Vol. 2 ,pp. 1073-1083,March 30-April 3,2003.
[53] Aurenhammer, F. "Computational Geometry – Some Easy Questions and their Recent Solutions", Journal of Universal Computer Science, vol.7, no. 5, 2001.
[54] Wang, G., Cao, G. and Porta, T.L "A Bidding Protocol for Deploying Mobile Sensors Network Protocols", in Proc. of 11th IEEE International Conference on Network Protocols, pp.315 – 324,2003.

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