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Performance Improvisation and Energy Conservation Using DSGC Protocol in Sensor Based Smart Grids

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ABSTRACT

In the data communication era, smart grid is visualized as decisive application for internet related applications and networking systems. To integrate the physical environment with the data communication applications, wireless sensors are required. In the wireless sensor based smart gird applications, load balancing and power quality measurements are predicted as major factors for better performance. In wireless network architecture involving smart grids, the deployment of the sensor nodes and the conservation of the residual energy are the two primary problems which attract research interest. Thereby analysis of the performance metrics based on the sensor node deployment and the energy conservation in the smart grids becomes important. In this paper, an efficient sensor grid deployment scheme (SGD) with a better coverage and improvised residual energy management (IREM) are proposed in the sensor based smart grid. The overall objective of the paper is to present an efficient protocol which improvises the performance of the data transmission of the nodes and conserves less energy during the transmission. A novel protocol called Dynamic Sensor Grid Coverage (DSGC) protocol is incorporated in the wireless sensor network architecture. The location of each sensor node is calculated by the weight, interference and residual energy of the particular grid. Improved Residual Energy Management (IREM) scheme is used to identify the consumption of energy by each grid in active as well as inactive states. IREM is used to find out a trade-off between the sensing power and the overall energy consumption of the grid. Residual energy and the detection probability are the metrics used for differentiating active and inactive states of the grid. By this combination, energy conserved in the sensor nodes is reduced considerably. Overlapping grid-cluster communication is also implemented to increase the efficient energy consumption. Simulation results show that Dynamic Sensor Grid Coverage protocol gives better packet delivery ratio, less packet loss and good energy conservation against the rapid mobile nature of the sensor nodes.

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INTRODUCTION

Current researches on sensor grid deployment networks consider only on stationary networks during the evaluation of the coverage protocols. In such network scenario, there will not be any movement in the sensor nodes after the deployment. But there are lot of applications where senor nodes are actively moving and have mobility nature. For example, monitoring purposes (Ali and Bilal, 2009) and moving target tracking mechanism. Topology changes and route failure in the sensor networks are challenging tasks which result in delay as well as packet loss. Some routing protocols (Heinzelman, *et al*., 2002; Karl and Willig, 2003; Chan *et al*., 2005) make a sensor to directly communicate with base station which leads to limited energy and scalability issues. Hierarchical based routing is used mostly for ad hoc networks (Heinzelman, *et al*., 2002; Huang, *et al*., 2006; Li, *et al*., 2006; Madani, *et al*., 2008; Tashtarian, *et al*., 2007; A Book, 2002; Liliana, *et al*., 2006) because of the energy efficiency and scalability of the nodes. Smart Grid Network architecture can be considered as a semi-auto controlled architecture in which the group of nodes communicate within themselves through cluster head and the cluster head which represents the group will communicate with the similar cluster head from the other groups. The data communication will be established in such a manner so that channel allocation and the energy resources are utilised effectively. The cluster head selection will be based on the residual energy of the nodes and the access selection criteria (Irfan, *et al*., 2013). Residual Energy Management Scheme (REM) considers residual energy as well as link quality of nodes that will make a good coverage for each region. REM is based on

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hierarchical clustering model in heterogeneous environment. In the proposed model, overlapping grid has set of clusters, sensors and mobile agents. Each cluster set has one leader called as Cluster Head (CH) (Thrun, *et al*., 2005; Ghosh, 2004; Berkeley, *et al*., 1998) and a set of member sensor nodes. Here Cluster Head and Member Nodes are in same energy level; but Mobile gateway agent (Thrun, *et al*., 2005; Gungor and Korkmaz, 2012; Min Chen, *et al*., 2006; Lingaraj and Aradhana, 2012) is a high energy resource. Member nodes send data to their corresponding CH. Cluster Head transfers data to corresponding Mobile gateway Agent. The execution of REM scheme is divided into rounds. Each round consists of four main processing areas; i) Cluster Head Selection in overlapping grid ii) Cluster Set Formation iii) Data Transmission iv) Mobile gateway Agent Placement and its Route planning.

Detection scheme is the important criteria in our proposed method. All interferences can be detected using integration of two filters i.e Bayesian filter (Jorge Hortelano, *et al*., 2010) and Particle filter (Ren, *et al*., 2012) are termed as Dam-Bayesian filter. It is used to reduce the interferences in the grid environment. This provides the better results in packet delivery and throughput compared to other routing protocols like Grid Based Robust Clustering GRC (Shahzad Ali and Sajjad Madani , 2011), Ad hoc On-Demand Distance Vector (AODV) Routing (Perkins, *et al*., 2003), Location Aided Routing (LAR) [5], and On Demand Multi path Distance Vector Routing in Ad Hoc Networks (AOMDV) (Marina and Das, 2001). In Particle Filter (Ren, *et al*., 2012), it is used mainly to calculate the pattern and sequence of the node parameter which is hidden and the parameter is based on RSS level, but the noisy environment is not considered. Bayesian Filters (Jorge Hortelano, *et al*., 2010) are used to estimate a uncertainty θ from newly observation. So integrating both the filters under sensor observation, all the interferences can be easily detected using following parameters, viz. fading, fault tolerance threshold, grid region effect, obstacle effect and time (Mostefa Bendjima and Mohamed Feham, 2012). These parameters can be equated to the summation of all weights and should be equal to unity using probabilistic distribution. Each node has its own grid position which consists of its own weights and mobility factor. In the process of overlapping grid-cluster communication, aggregated information data is sent from the cluster heads to their neighbouring counter parts. So if route failure occurs and if the particular information is lost, whole round information will be lost. In MAR (Karp and Kung, 2000), since most of the neighbour cluster heads are not in the nearest vicinity of each other, they could not send data between each other. Also there is no proper recovery mechanism existing in the system. Due to absence of proper recovery mechanisms, the results of MAR shows huge packet loss. (Smriti Srivastava, *et al*., 2012; Sheng Zhang, *et al*., 2012; Guoliang Xing, *et al*., 2007)

There are two methods available for the detection of packets. 1. Hop-by-hop 2. End-to end (Wang and Yang, 2007; Hasen Nicanfar, *et al*., 2014). Since the retransmission distance is lesser in Hop-by-hop recovery, it is energy efficient. Because of this nature, this method is implemented in our proposed work. Another advantage is that this method causes less end-to-end packet delay. So in case of loss of packets because of break in transmission path, the neighbour nodes to the destination node which will also receive the packets shall cooperate in the successful transmission.

The performance of WSN in the smart grid applications has been extensively studied based on the impact of noise level and the low power wireless links that work on IEEE 802.15.4 standard. Various adaptive exponential noise reduction schemes are in practice. By bringing performance metrics to a standardized value with minimum energy conservation parameters, the sensor grid architecture can be elaborated to achieve good results (Wei Ren, *et al*., 2011; Irfan, *et al*., 2013).

The protocol DSGC which is proposed in this paper is residual energy based grid protocol which is location based and distributed in nature. The protocol shows good results in terms of coverage when there is packet loss due to mobility of the sensor nodes. Also it effectively utilizes the location information when selecting the cluster heads and reduces packet loss. The recovery mechanism which is used during the inter-grid communication helps in achieving the results. The remaining sections of this paper are arranged as follows: section 2 explains the overall implementation and detection scheme of DSGC. Section 3 explains the cluster head selection. Section 4 explains the Residual energy management scheme. Section 5 presents the simulation and the result analysis. Section 6 concludes the paper.

MATERIALS AND METHODS

Distributed Sensor Grid Coverage Protocol Implementation:

In the wireless sensor network environment, with the wide transmission range between the source and the destination, the coverage of the sensor grid for data transmission is determined based on the transmission range and the ability of the intermediate sensors to detect the sink. After the establishment of the coverage area, the data transmission is channelized based on three parameters, packet size, burst time and idle time. Packet size is defined as the actual size of the packets for transmission. Burst time is the time at which the actual data packets are sent continuously to the destination. Idle time is the time difference between the two consecutive burst times.

Based on the implementation phases, DSGC is used for better coverage and residual energy management in the sensor grid architecture.

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Sensor Grid Architecture:

In Figure 1, the sensors are transmitting the data and the area ranges are marked as large circles. Each transmission range covers multiple regions. In the scenario shown in the figure 1, a cluster head wants to send data to base station which is located out of grid region. As shown in the figure, both the cluster head and the base station are not in the position where they can transmit data to each other. The transmission may occur if they are within the transmission range due to the mobility of the nodes. A detection strategy is required in case of occurrence of such situation. The existing detection mechanisms are based on the concept of Dam-Bayesian filter which uses the selection of aggregator mobile agent nodes. But in our proposed work, a node can be considered as aggregator mobile agent node only if it is within the data transmission range of two cluster heads. Aggregator nodes can cooperate and help in the data transmission to the Base station. An acknowledgement from the destination may also be considered, when one or more mobile aggregator agent nodes receive a message sent to neighbouring cluster head. In case of non reception of the acknowledgment, the packet may be considered as lost. Based on the timers set from the residual energy parameters, the robustness of the routing protocol can be calculated. The aggregator mobile agent node with low residual energy when compared to other aggregator mobile agent nodes expires first. In that case, it sends a copy of the data information to the other live nodes before expiry thereby increasing the robustness of the system with high speed mobility.

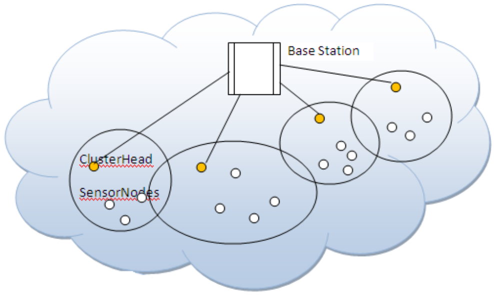

Fig. 1: Distributed Sensor grid mobile Grid Architecture.

Steps to Implement DSGC:

Dynamic Sensor Grid Coverage Protocol is implemented through the sensor grid deployment scheme with sensor nodes, mobile agents and cluster head. The detection scheme is incorporated and the interference and the minimal weight is calculated. Based on the weight age of the node deployment, the protocol framework is formed. Cluster head is chosen based on the residual energy of the individual nodes. The coverage scheme is incorporated based on the selection of cluster head, acknowledgement sending, grid cluster communication and overlapping of data. The performance analysis is done after routing planning and maintenance. The performance metrics used are packet delivery ratio, packet loss and energy conservation. The implementation steps for the

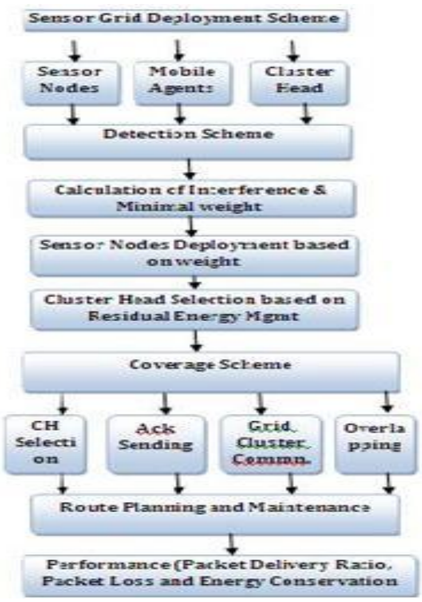

Fig. 2: DSGC Implementation Steps.

DSGC algorithm is shown in figure 2.

DSGC protocol consists of five phases.

1. Sensor Grid Deployment
2. Cluster Head selection based on IREM
3. Local Grid Cluster Formation
4. Overlapping Grid Cluster Communication
5. Aggregation process and Relocation

In the sensor deployment schemes, the nodes plotted in the architecture can be categorized based on three utilities: normal sensor nodes which are used for data transmissions, mobile agents which are the messagers for intermediate data gathering and forwarding and cluster head which are the zonal leaders in collecting the data received from the sensor nodes through the mobile agents and forwarding them to the destination. Based on the calculation of interference and the weight age of the nodes, the detection scheme is established. Cluster heads are selected based on the highest residual energy of the nodes during the data transmission. Routing planning and maintenance is done by means of grid cluster communication. Path message establishment is done by routing measures and the route request and route reply control messages. The performance metrics, viz. packet delivery ratio, packet loss and energy conservation are calculated as the final step in the dynamic sensor grid coverage protocol.

Sensor Grid Deployment Phase:

For the deployment of the sensor grid in the wireless sensor networks, we presume that the monitored coverage area has sensor nodes with knowledge about the location. For improving the coverage and uniformity, the sensor nodes have to move accordingly to find the best location. For identifying the exact location, grid identity is selected, The geographical identity of the area is separated into various grid and the information is passed to the base station in our architecture. Individual sensor grid is a cube with the narrow and uniform edges with adaptive size. The resolution of the grids is based on the size. With reduction in grid size, the resolution is better where as when the size increases, the computational complexity is reduced. The smallest location identification is estimated by the weight of each grid. Thus the deployment of the sensor nodes are based on the location identification, detection and the coverage schemes.

Cluster Head Selection Phase:

In the selection of cluster head, every node measures the weight based on its location region centre and residual energy. The weight is calculated by the following equation:

$$\text{Weight} = \text{Min(Weight)} * RE * RCN \quad (1)$$

Where 'RE' denotes the residual energy of sensor node and 'RCN' denotes the location based region center of the particular node. The location based region center is measured as follows. Let (x,y)be the location of a mobile node ' m ' where $1 < i < n$. Let (x_{min}, y_{min}) be the center point of the region and it has minimum detection probability in which ' mi ' is located. Then

$$RCN = | Xmin - x | + | Ymin - y | \quad (2)$$

Cluster Head Selection Procedure:

In the initialization phase, node weight is calculated based on the minimum weight observed so far in the environment, residual energy and the location of the node. The node is determined by the weight as whether it is a cluster head or a normal sensor. If it is a cluster head, the parameters viz. Node ID, weight, energy and the location details are updated in the repository. After calculating the weight, a node broadcasts a message (advertisement message) with the set parameters within the transmission range. Upon receiving cluster head announcement messages, a node that receives advertisement message checks to see whether it belongs to the same zone or not. The node which does not belong to the range, simply discards the message whereas the node of the same region checks whether its own computed weight s less compared to that received from the advertisement message. If the flag set for cluster head is "yes", it will redirect and the same node will behave as cluster head. It will mark down the advertising node as its cluster head and for the current round it will not broadcast its own advertise message. As this communication consumes very high energy as compared to sensing and computation in the sensor nodes (Mahlknecht and Madani, 2007) reducing the number of messages during formation of clusters leads to lower energy consumption. The cluster head selection algorithm is given below.

After final selection of cluster head, each cluster head sends a "Final Cluster Head Advertisement" message, so that all the nodes within its vicinity know about the final cluster head.

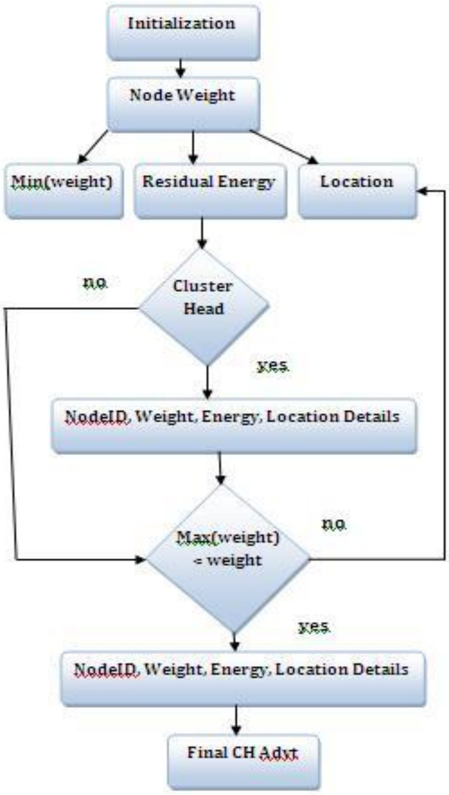

Fig. 3: Cluster Head Selection Algorithm.

Improved Residual Energy Management Scheme (IREM):
Local Grid -Cluster Communication:

Information transfer takes place during local grid-cluster communication when a sensor node communicates with its cluster head. Data aggregation takes place in the cluster head when each of the sensor nodes collects information from its neighbourhood that are associated with that cluster head. The energy spent during the transmission can be calculated.

Transmission energy (TE) estimation is expressed as,

$$TE(p,dt)= TE\text{-}elec(p)+TE\text{-}amp(p,dt) \quad (3)$$

$$TE(p,dt) = p.\beta.Eelec+p.PLfs.dt \quad \text{if } dt<dt0$$
or
$$TE(p,dt) = p.\beta.Eelec+p.PLmp.dt \quad \text{if } dt>=dt0 \quad (4)$$

Here, TE_{-elec} is the electronic energy consumption, TE_{-amp} is the amplifier energy consumption, β is spreading factor, PL_{fs} is path loss factor for free space, PL_{mp} is path loss factor for multipath fading. **β** is detection probability.

Reception energy (RE) estimation is expressed as

$$RE(p,dt)= TE\text{-}elec(p) = p.\beta.Eelec \quad (5)$$

Overlapping Grid-Cluster Communication:

The choice of a sensor node joining a cluster or not is decided by intra cluster communication cost. This cost value is decided by the proximity of the node or the angular degree of the node to its neighbor and also detection probability threshold β and interference threshold α. Each sensor node estimates CH_{prob} value for becoming a CH as follows :

$$CHprob=Cprob * Eresidual/Emax \quad (6)$$

This probability value should not beyond the threshold value P_{md}. P_{md} and E_{max} are inversely proportional to each other. This algorithm consists of constant number of iterations. Every node goes through this iteration until it finds a CH that it will be the node with least communication cost. At the end of iteration every node doubles the CH_{prob} value. Iteration will be terminated if CH_{prob} value reaches 1.Two types of CH status that a sensor node announces to its neighbors; i) Node becomes a tentative CH with CH_{prob} less than 1; ii) Node becomes permanently becomes a CH if its CH_{prob} reaches 1. At the end final CHs are considered as CHs, and tentative CH becomes regular nodes. In this the probability of two nodes within the transmission range of each other becomes CH is small.

Total energy consumed in each round could be calculated by the sum of energy consumed by cluster coordinator and regular nodes. Hence we get,

$$E = \sum_{i=1}^{NS} ECCHi + \sum_{i=1}^{NS} \sum_{j=1}^{|CSi|-1} ECMsi \quad (7)$$

Energy consumption is calculated by

$$ECC= Es+Ep+RE+EAg+TE \quad (8)$$

The total maximum and minimum energy consumption at each round respectively as,

$$Emax=NC.\ ECmax(CH)+ (NN-NC).\ ECmax(MN) \quad (9)$$

$$Emin=NC.\ ECmin(CH)+ (NN-NC).\ ECmin(MN) \quad (10)$$

Residual Energy Calculation:

The energy consumption of each sensor node and cluster head are obtained at the each round using the above equations. Residual energy is calculated by the difference between the initial energy and the consumed energy using this estimated value.

$$Eresidual = Einitial - Econsumption \quad (11)$$

Results:

The simulation experiments are tested using the versatile NS2 environment. To evaluate the Dam-Bayesian filter mechanisms with Dynamic Mobile Grid Coverage Protocol (DMGSC), the simulation environment was set up using the following table parameters and the graphs are drawn based on the results. The grid area is 1000*1000 and 100 sensors are used. The antenna model used is Two-ray ground antenna and of omni directional type.

Table 1: Simulation Environment.

Simulation parameters	Simulation values
WSN standard	IEEE 802.15.4
Number of sensor nodes	100
Base protocol	AODV
Algorithm	DSGC (Dynamic Sensor Grid Coverage Protocol)
System Bandwidth	2 Mbps
Protocol Layer	Cross Layer MAC
Antenna	Omni Directional
Simulation Environment	1000 * 1000
Channel Propagation	Wireless / Two ray ground

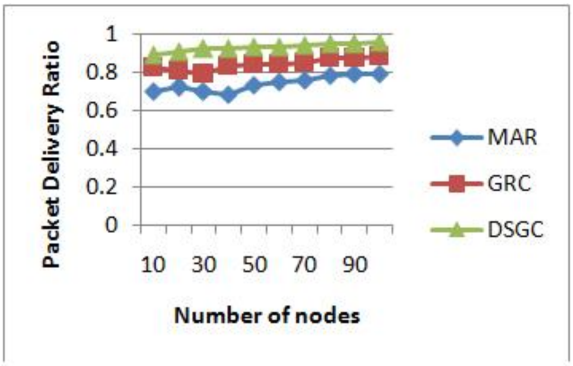

Fig. 4: Packet Delivery Ratio – Comparison between DSGC, GRC and MAR

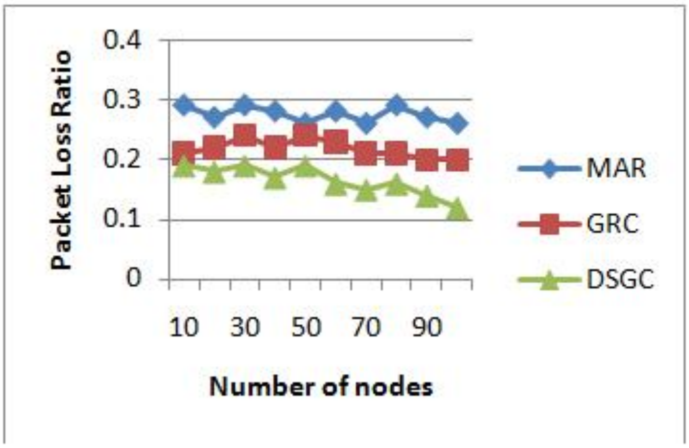

Fig. 5: Packet Loss Ratio – Comparison between DSGC, GRC and MAR.

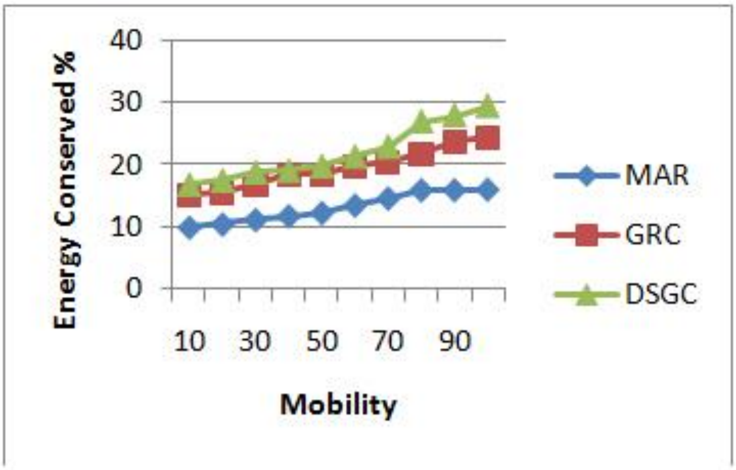

Fig. 6: Energy Conservation – Comparison between DSGC, GRC and MAR.

Discussion:

The above figures 4, 5 and 6 demonstrate the performance of the proposed algorithm DGSC in comparison with the existing algorithms MAR and GRC in terms of packet delivery ratio, packet loss ratio and energy conservation.

Packet Delivery ratio is defined as the rate in which the packets are delivered from the source to the sink in the sensor mobility environment. In the simulation analysis based on the Ns2 environment, the packet delivery ratio is measured over the number of nodes. With the increase in the number of nodes, the packet delivery ration is increased. Comparing the protocol DSGC with the existing algorithm, it is observed that the Packet Delivery Ratio for DSGC is better the existing protocols. Higher packet delivery ratio is the indicator of better throughput efficiency of the system.

Packet Loss Ratio is the loss rate of the packets during the transmission. Packet Loss Rate is measured as the difference between the number of packets transmitted from the source to the number of packets received in the sink over the total number of packets. This metric has to be as minimum as possible for the better system. Simulation analysis using the proposed protocol DSGC has minimum packet loss ratio while comparing with the existing protocols.

Energy conservation is measured in terms of the percentage of the energy conserved with the mobility parameter as index. For extending the life time of the nodes in the system, the amount of energy consumed by the nodes has to be reduced to minimum possible conserved has to be maximum as well. Simulation results show that considerable amount of energy is conserved by implementing DGSC in the simulated sensor grid environment when comparing with the other simulation protocols.

Conclusion:

In this paper, the wireless sensor based smart grid architecture is incorporated. An efficient protocol for improving the performance evaluation and the energy conservation is designed using the dynamic sensor grid architecture and residual energy management. The proposed protocol Dynamic Sensor Grid Coverage (DSGC) protocol for wireless sensor networks is implemented using smart grid applications. The important aspects of using this protocol are the coverage mechanism, detection mechanism, energy conservation and the usage of location information. These performance metrics, packet delivery ratio, packet loss ratio and the energy metrics, energy conserved are measured to be better while implemented using DSGC in the wireless sensor networks. Also, the protocol shows better flexibility in the high speed mobility environment. Because of the detection mechanism, the packet loss is minimized and the packet delivery ratio is enhanced. The analysis is tested for both static as well as moderate to high speed mobility environment and the proposed approach is suitable for all the environments. IREM algorithm ensures both optimality and reliability in WSN. By obtaining the optimal Cluster Head in each round, energy efficiency is maximized and hence network lifetime is maximized. Probabilistic detection guarantees are maintained over a region using the proposed protocol. Overlapping grid cluster is designed on a distributed detection model that considers data aggregation among multiple nodes. Cross Layer design with MAC implementation is proposed as future work in which better energy efficiency and robustness are expected in comparison with other mobility based protocols.

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