Potential measure to enhance lifespan of power plant monitoring system in era of IoT

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***Abstract*—Power plant systems are particularly valuable to the country as well to the society development breaches due to the highly require related to every person life through the use of power in the various form. With the growing interest of the Internet of Thing (IoT), optimal placement of sensor in the area of large scale is a big issue to save node energy thereafter enhancing network lifetime. One of the main reasons to consume the network energy drastically by activating all the participate nodes unnecessary due to lack of energy making policy. The simulation data was collected through internet and extensive work has done based on maintenance and construction protocol. Gaussian node energy distribution model was proposed for monitoring plant. For result analysis two types of performance matrices were measured data.**

***Index Terms*—power plant monitoring, maintenance protocol, IoT**

I. Introduction

"Smart Grid" is a modern concept which refers to the conversion of the mainstream or typical electric power grid to a modern power grid [1]. Power is the heart of a country that is the prerequisite to becoming a develop country. Since, the whole system monitoring is too expensive, therefore, to scale down the system cost, the specific part of power system must be monitoring. Besides, the entire technical person such as engineering and also the customers should acknowledge about modernized power system which use the advance monitoring tool [2]. Any unit of power plant suddenly may shut down due to catastrophic event like flooding, earthquakes and others. The purpose of power plant monitoring system contains safety monitoring, risk analysis, health monitoring of various devices, fault detection and cost reduction [3].

For large scale area network, to collect sensing data, topology plays an important role to determine the network lifetime. Therefore, to place sensor node optimally in the area of monitoring infrastructure is a challenging work. To do so, topology construction and maintenance are two potential algorithm to grow the network size largely. Topology construction protocol create the monitoring network in the deployment area. After created network topology, the maintenance protocol has been used to recreate new connected topology when existing one is no longer optimum further [4].

Recently proposed Rampal power station, Bangladesh will generate more than 38 million tons of ash during 60 years of operations [5]. 90 percent of electric load generation capacity will be generated by this plant. The approximate budget to develop this power station is 2 billion dollar and finally raised it up to 5 [6] billion dollar with considering dredging of river [7]. Therefore, to develop power efficient monitoring system is a vital concern.

II. Wireless Sensor network

Wireless sensor networks have become an efficient technology to monitor health damage, detect events (e.g., fire protection and natural events like flood), track objects and others. Wireless sensor networks usually consist of three basic elements: sensor coverage area, communication system and computing and analysis section. Most sensor applications operate with very low battery power which determines the overall system lifetime [8]. Fig. 1 shows the general architecture of WSN network.

On-board microprocessors can be used for digital signal processing, self-diagnostics, self-identification and self-adaptation functions. Lynch and Loh (2006) described a number of papers on smart WSNs for infrastructure health monitoring conducted [9].

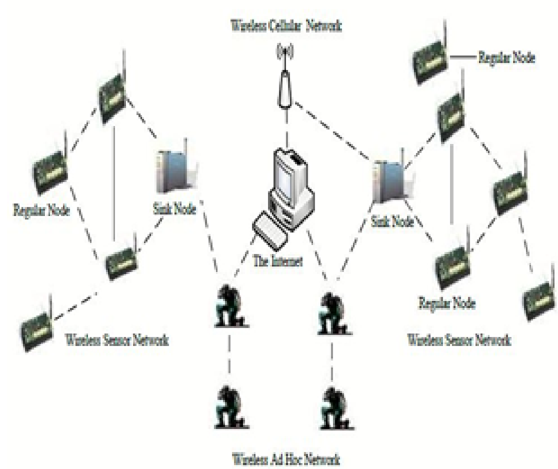

Fig. 1. General architecture of WSN.

Fig. 2. Rampal power plant.

III. Literature review

In recent years, WSN technology has been used to overcome the above problems. Technical challenges of WSN network are time synchronization, scalability and coverage area for large-scale infrastructure monitoring [8]. Still, there are various issues related to networking among those lifetime of network is the limited sensor coverage area with tiny sensor node power. Theory of geometric random graph approach has been used to develop optimum topology sensor. Topology construction protocols have been used in order to generate the topology network. The lifetime is a major concern of the sensor network because it determines entire system aliveness [10].

Author Dawei et al. (2013) has been developed an real time monitoring system for power plant to solve the work load issue for control purpose. In this system, online monitoring is used for main equipment of power plant such as gas turbine, steam turbine, generator and etc. It also able to measure several physical phenomena such vibration, temperature and others [11]. On the other hand, Lin et al. (2004) has been taken as a novel technology for monitoring nuclear power plant. In this system various component of reactor and other environment has been measured using proposed model [12].

Monitoring and preventing massive power plant damages is a major concern. Power plant damage monitoring seeks to detect infrastructure health damage and is a mechanism to access system performance. These measures are based on different types of sensors that are connected to different kinds of sensor network topologies. These sensors are located in diverse locations to cover the entire service location. Many challenging issues continue to prevent the development of an optimal monitoring system. Fig. 2 shows the Rampal power station [13].

Wireless Intelligent Sensor and Actuator Network (WISAN) were proposed as an alternative solution that support a large number of sensors nodes. The lifetime of the overall monitoring system should be increased to scale down the system cost as well as limited maintenance will be required. Although, many researchers have applied WSN for monitoring system, until now very little attention has been paid on lifetime issues using Gaussian distribution model [14].

Moreover, the benefit of the topology construction algorithm is widely accepted, the problem of this complex system is that it cannot produces accurate results if the procedure is not performed carefully. Another problem of the topology construction protocol is that, if the design is not energy efficient, this protocol consumes equal or greater energy compare to save energy. Therefore, an efficient design of topology construction protocol is an important factor to save node energy .

IV. Research methodology

This section presents the lifetime evaluation model of dense using *A3*, *EECDS* topology construction, and *SGTTRot,DGETRec,DGTTRec* and *HGTTRecRot* topology maintenance and Gaussian based node energy distribution model. The TGRG approach is used to develop both analytic and simulation model. The evaluation models and parameters definition are also presented.

A. Dense topology sensor network

In the dense network, Topology construction protocol works on two layers, data link layer and network layer [8]. The data link layer allows nodes to find their neighbor and establish the corresponding links, and the network layer is responsible for packet forwarding. it is assumed that there exists a data link layer that deals with packet losses and retransmissions. The maximum value of delay variable is considered $0.2s$ which has negligible effect in the developed dense network. Thus, the effect of interference in MAC protocol of the network is also negligible.

Fig. 3 shows an example of fully connected dense topology sensor networks. Since all the nodes are directly connected with each other, the network is fully connected.

Fig. 4 represents the functional block diagram of dense topology sensor networks. To start the formation of dense topology sensor networks, the other parameters block defines first those related with S-D inter-query time; TM protocol variable and others. The deployment generator block defines all parameter related to the deployment area. The *CTR* of the dense networks is added with deployment area. After created

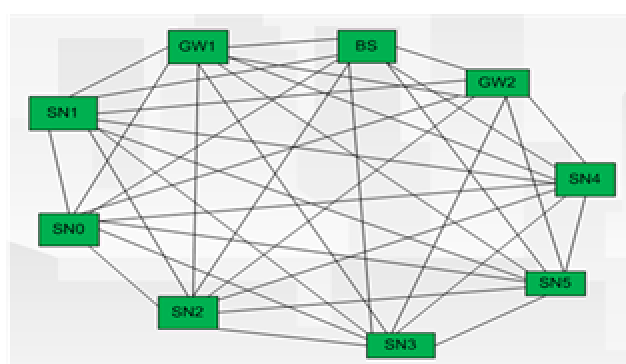

Fig. 3. Dense topology network.

deployment area, it transfer in the Atarraya platform [15]. After that,simulate the scenario with require parameters.

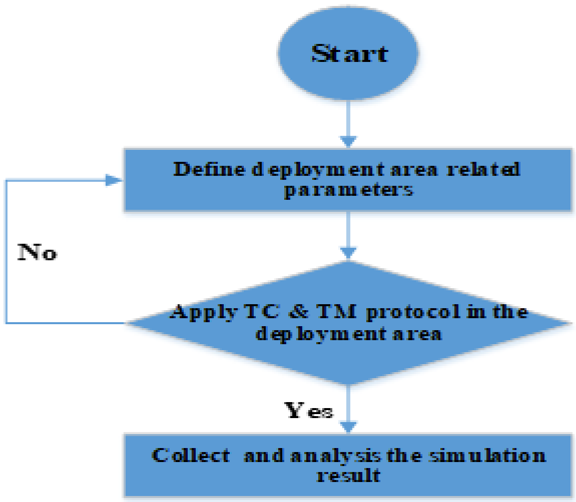

Fig. 4. Functional block diagram of dense network.

Geometric random graph of WSNs is represented as *G = (V, E, R)*, in which *V* is the set of nodes, *E* is the set of links and R is the transmission range of nodes. In general, two kinds of geometric random graph such as critical transmission range *(CTR)* and range assignment approaches are frequently used in WSN. In any network, finding the minimal transmission range and better coverage area, *CTR* approach would be a better choice. The Penrose formula " (1)" is used to determine *CTR* value for a dense topology sensor networks as follows [10].

$$CTR(k) = \sqrt{\frac{ln(k) + f(k)}{k * \pi}} \tag{1}$$

Where k is the total number of nodes and $f(k)$ is the function of k. An increasing value of k leads to an increasing value of function $f(k)$. If $\lim_{k \to +\infty}$, then, $f(k) = +\infty$.

B. Node energy model

The energy of a node that perform an action in order to execute network activity. In this study, the energy model is used to design node energy consumption based on (2) and (3), introduced by Heinzelman in [10]. The model is based on receiving and transmitting of node data.

$$E_T = E_e + E_a + R_c * \pi \tag{2}$$
$$E_R = E_e \tag{3}$$

Where, E_T is the required transmit signal energy to transmit 1 bit and E_R is the receiver energy to receive the same number of bit like E_T. The energy of the electronics component of the radio signal is denoted by E_e and amplifier radio energy is represented by E_a. The second terms present the square area of the transmission range that is achieved by radio signal. Due to simplicity of the energy model, it is frequently used in the WSNs network. It is supposed that, at ideal condition there is no energy consumption happened. The energy model parameter values are summarized in *Table I*.

TABLE I
MAPPING VALUE OF NODE ENERGY

Initial node energy	1Joule
E_e	*50nJ/bits*
E_a	*10pJ/bits/m*^{2}

C. Simulation setup of dense topology network

Table II shows the simulation setup of Rampal based monitoring system. Atarraya simulator is used to develop the network model [14]. The 100 number of nodes is used that defines the scalability. The minimum number of active node assist in deciding protocols energy efficient. A compact number of sensor nodes usually use for shorter area monitoring whereas higher number for large area monitoring. Initial *CTR* defines the initial value of the monitoring network. The *CTR* step defines the increasing value from the initial CTR. The area side of monitoring network defines the deployment area of the network. The above Equation (1) is presented for 2-dimensional dense topology networks using a uniform distribution law.

TABLE II
MAPPING VALUE OF NODE ENERGY

Parameters	**Design value**
Number of nodes	100
Communication radius	100m
Sensing radius	20m
Deployment area	600m * 600m center at (300m * 300m)
Distribution model	Gaussian
TM protocols	*SGTTRot,DGETRec,DGTTRec,HGTTRecRot*
Routine protocol	Simple forwarding
Aggregation protocol	simple S and D

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D. Cost analysis of the proposed system

We have used Mica Z mote which is the third generation product devices from Crossbow technology. We choose this version due to low power energy consumption. Although each sensor node is capable to transmit the data over 100m, for strong communication network we have deployed 100 nodes in the 600m*600m deployment area. Since, each sensor cost is approximately 99 dollar [15], the estimated total cost of this project will be 9900 dollar. It will cover 3.24km area among the total coverage area 8km approximately. Therefore, the proposed monitoring system will become cheaper compare to its budget.

V. RESULT ANALYSIS

This section presents the evaluation result of the case study considered in this work for the dense topology sensor networks. The two types of case studies has evaluated to define the monitoring system's lifetime: one is the number of active nodes and another is reachable nodes from sink.

A. A3 Construction protocol

The aim of this case study is to compare the computational result of *A3* construction protocols using *DGETRec, DGTTRec, SGTTRot* and *HGTTRecRot* maintenance algorithms.

1) Case Study 1: Number of active nodes: Over whole transmission period, from Fig. 5, it is seen that *DGETRot* consume higher amount of node energy means providing the poor network performance compare to all others maintenance protocols. Since, the *SGTTRot* maintenance protocol draw the lower amount of active node means prove itself as an optimum maintenance protocol. In the main time, *HGTTRecRot* and *DGTTRec* consume moderate amount of energy. Therefore, It concludes that, the *DGTTRec* protocol provides the better performance in case of *A3* construction protocol.

2) Case Study 2: Number of reachable nodes: The main object of this test is to provide the comparison result of four different well know topology maintenance protocols using *A3* maintenance protocol. Fig. 6 shows the extensive simulation results of dense network for the number of reachable nodes from sink. Result exhibit that, the *DGETRec* protocol draw the better performance, while *DGTTRec* degrade the system performance and *SGTTRec* maintenance protocol consume the medium amount of network energy. In case of *HGTTRecRot*, the result is slightly worst compare to *DGETRec*.

B. EECDS Construction protocol

This section present the simulation result of *EECDS* protocol using four kinds of topology maintenance protocols and same kinds of performance metrics.

1) Case Study 1: Number of active nodes: This case study shows the simulation result of active node using considered topology stopology construction protocol in case of *EECDS* construction protocol.

Fig. 7 shows the amount of active node using considered topology maintenance and *EECDS* construction protocol. Comparison result shows that, the number of reachable node

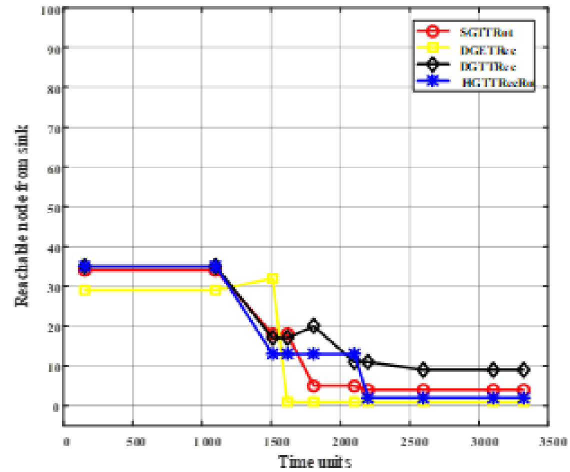

Fig. 6. Number of reachable node from sink using *A3* Construction

for *HGTTRecRot* draw the optimum performance compare to others, because it has ability to turn off maximum number of nodes. On the other hand, it can save node energy and maximize the lifetime of network.

2) Case Study 2: Number of reachable nodes: Fig. 8 shows the performance of the reachable node from sink using considered maintenance and *EECDS* construction protocol. In case of *EECDS*, the *DGETRec* draw the higher amount of reachable node compare to others over whole lifespan of the monitoring network.

C. Comparative Study

From Fig. 5 and Fig. 7, the comparison result shows that, the *DGETREC-A3* mode exhibit the better result in case of active node. On the other hand, result from Fig. 6 and Fig. 8 show that, the *EECDS-DGETRec* mode provide the optimum performance in case of reachable node.

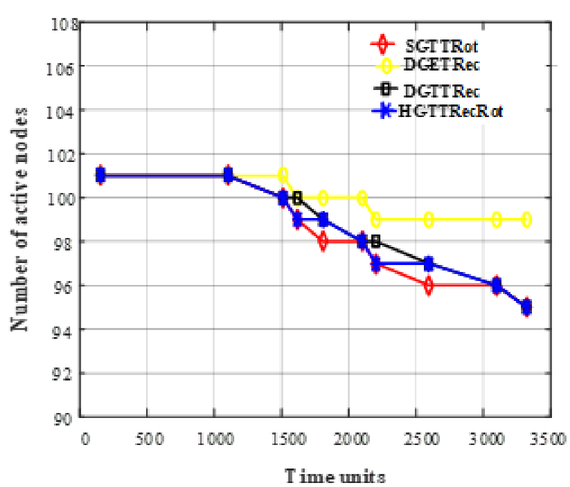

Fig. 5. Network lifetime for a number of active nodes using *A3*

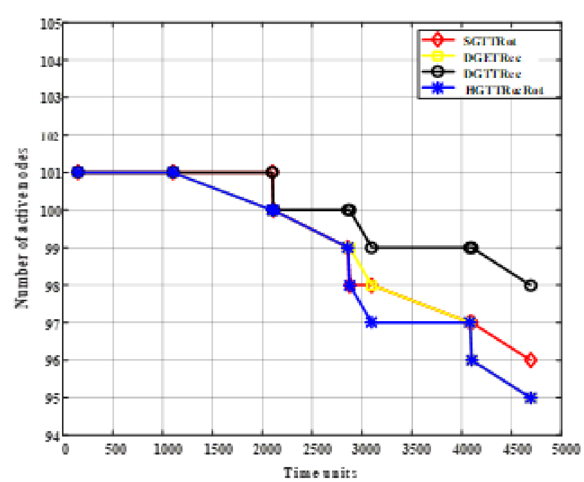

Fig. 7. Number of active nodes using *EECDS* Construction

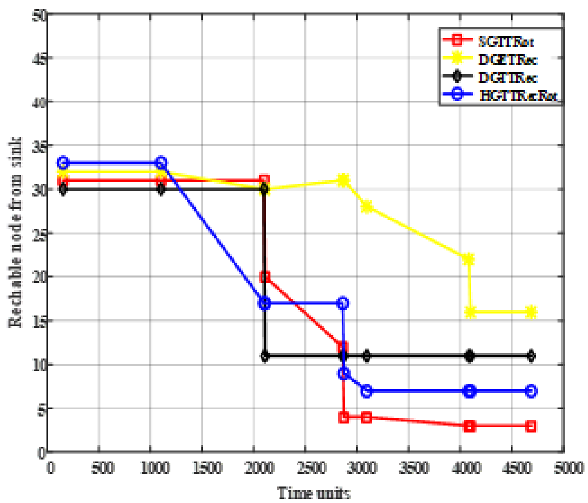

Fig. 8. Number of reachable nodes from sink using *EECDS* Construction

VI. Conclusion

In this article we have proposed the dense topology sensor network for overseeing Rampal based power plant in the era of IoT. In dense topology, we have integrated the topology maintenance protocol with construction protocol. Optimal placement of sensor node also been solved in the large scale monitoring network. We have tested the proposed maintenance protocol with construction using Rampal power plant data. In the active number of nodes, result shows that *DGETRec-A3* shows the better result. On the other hand, *EECDS-DGETRec* mode claim the optimum result in case of reachable node for monitoring purpose.

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