

An Energy Aware Dispatch Scheme WSNs

Siddhartha Chauhan, Kumar S. Pandey, and Prateek Chandra

Abstract—One of the key research issues in wireless sensor networks (WSNs) is how to efficiently deploy sensors to cover an area. In this paper, we present a Fishnet Based Dispatch Scheme (FiBDS) with energy aware mobility and interest based sensing angle. We propose two algorithms, one is FiBDS centralized algorithm and another is FiBDS distributed algorithm. The centralized algorithm is designed specifically for the non-time critical applications, commonly known as non real-time applications while the distributed algorithm is designed specifically for the time critical applications, commonly known as real-time applications. The proposed dispatch scheme works in a phase-selection manner. In this in each phase a specific constraint is dealt with according to the specified priority and then moved onto the next phase and at the end of each only the best suited nodes for the phase are chosen. Simulation results are presented to verify their effectiveness.

Keywords—Dispatch Scheme, Energy Aware Mobility, Interest based Sensing, Wireless Sensor Networks (WSNs).

I. INTRODUCTION

WIRELESS sensor networks (WSNs) are based on physically small-sized sensor nodes exchanging mainly environment-related information with each other. WSNs have a very wide application area including home control, military applications, environmental monitoring etc. Sensors typically have very limited power, memory and processing resources. Therefore interactions between sensors are limited to short distances and low data-rates. In the recent years, with the rapid progress in embedded micro-sensing MEMS and wireless communication technologies, *wireless sensor networks (WSNs)* have been studied intensively for various applications such as environment monitoring, smart home, and surveillance. A WSN usually consists of numerous wireless devices deployed in a region of interest, each able to collect and process environmental information and communicate with neighboring Scheme (FiBDS) with energy aware mobility and interest based sensing angle. We propose two algorithms, one is FiBDS devices. Sensor deployment is an essential issue in WSN because it not only determines the cost to construct the network but also affects how well a region is monitored by sensors. In this paper, we present Fishnet Based Dispatch centralized algorithm and FiBDS distributed algorithm. The centralized algorithm is designed specifically for the non-time

critical applications, commonly known as non real-time applications while the distributed algorithm is designed specifically for the time critical applications, commonly known as real-time applications. The proposed dispatch scheme works in a phase-selection manner. In this each phase a specific constraint is dealt with according to the specified priority and then moved onto the next phase and at the end of each only the best suited nodes for the phase are chosen. The rest of the paper is organized as follows: Section II reviews related work, Section III introduces the proposed dispatch scheme, Section IV presents the simulation results and graphs and Section V concludes the paper.

II. RELATED WORK

An enormous amount of work has been done in such a small time in the field of Wireless Sensor Networks which, according to some, is still considered a nascent field of research in the Computer Science and Engineering. Many constraints are there in a wireless sensor network which limits its Omni-applicable property. Some of the latest research work for the rectification of these constraints has been studied in this chapter. Basically this section includes the set of research work which focuses the problem set defined by the base paper as well as the proposed scheme.

Coverage is one of the main research interests in wireless sensor networks (WSN); it is used to determine the quality of service (QoS) of the networks. Therefore, [1] aims to review the common strategies use in solving coverage problem in WSN. Shih-Lin-Wu, et al. [2] proposed a binary model in which the sensing range of a sensor is modeled by a disk. In [3], the author investigates the coverage issues in wireless sensor networks based on probabilistic coverage and propose a distributed Probabilistic Coverage Algorithm (PCA) to evaluate the degree of confidence in detection probability provided by a randomly deployed sensor network. Wang et al. [4] proposed that when the transmission range R_t of sensors is not smaller than twice the sensing range R_s ($R_t \geq 2R_s$), then if the sensor network is k -covered it implies that the sensor network is k -connected, where k -connected means that the network will remain connected after removing any arbitrary $k-1$ sensors from the network. In [5], the author discusses the issue of full connection probability and network efficiency using a minimum number of nodes in wireless sensor networks is addressed. In [6], the author investigates the network characteristics through a number of simulations. Using various input parameters, they try to approximate four realistic scenarios: a football pitch, a forest, a building and a tunnel. Author in [7], presents cooperative transmission to connect

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previously disconnected parts of a network thus overcoming the separation problem of multi-hop networks. In [8], the author discusses the connectivity issue of WSNs for sandstorm monitoring. Sensing coverage is a fundamental problem in wireless sensor networks. It reflects how well the environment is monitored, and serves as a basis for applications such as physical phenomenon or target detection, classification and tracking. Due to the diversity of the sensor network applications, the concept of sensing coverage is subject to a wide range of interpretations [8], [9]. Omni-directional sensors have no notion of direction involved in their measurements. Omni directional sensor nodes will consume power proportional to $[r]^2$ [10]. In [11], the author proposed a new method for selection of data transmission route that is able to solve this problem. This method is based on learning automata that selects the route with regard to energy parameters and the distance to sink. In [12], the author gives an overview of the different routing strategies used in wireless sensor networks and gives a brief working model of energy efficient routing protocols in WSN. The energy conservation techniques and algorithms for computing the optimal transmitting ranges in order to generate a network with desired properties while reducing sensors energy consumption are discussed and compared through simulations in [13]. Authors in [14], proposes an adaptive algorithm, based on the recently developed theory of adaptive compressive sensing, to collect information from WSNs in an energy efficient manner. In [15] author proposes a approach which significantly reduces the total and average distance traveled by mobile nodes while maintaining the same level of coverage. The approach only increases the message complexity.

III. PROPOSED DISPATCH SCHEMES

In this section a Fishnet Based Dispatch Scheme (FiBDS) has been proposed, with energy aware mobility and interest based sensing angle. First, the description about the system architecture and the functionalities of the hardware is given and then about algorithms and their explanations.

The system architecture of the proposed algorithm has been depicted in the Fig. 1. The entire nodes perform the sensing task in a twofold manner. First, a sensor nodes' dual string connects sink to the sensor nodes performing the sensing task. The distance between two adjacent nodes is the communication radio range, r_c . In the figure, an area of Interest, I is covered using directional sensor nodes using a Fishnet based dispatch Scheme (FiBDS). In this Scheme, we place a string of sensor nodes to between the area of interest, I and the sink node. This string of sensor nodes mostly transmits or receives the data but does not sense it. This pair of sensor nodes will act as a connecting string between the sink and the sensing nodes functioning in the area of Interest, I . Thus this pattern of the string actually enhances the coverage range of the network system.

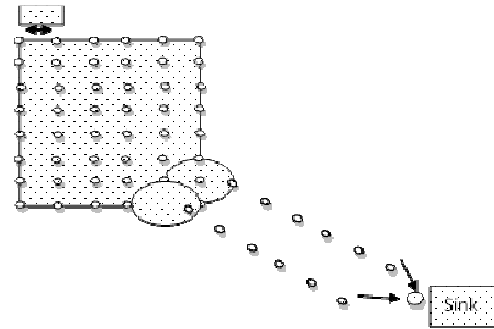


Fig. 1 Fishnet Based Dispatch Scheme (FiBDS)

The proposed dispatch scheme works in a phase-selection manner. In this in each phase a specific constraint is dealt with according to the specified priority and then moved onto the next phase and at the end of each only the best suited nodes for the phase are chosen.

A. Dispatch Scheme for Non-Time Critical Applications (Centralized Algorithm)

This algorithm is designed specifically for the non-time critical applications, commonly known as non real-time applications. This algorithm tries to resolve most of the anomalies due to which loss of energy takes place in a sensor network having mobile sensor nodes. The various phases along with their respective explanations are listed below.

1. Location Verification Phase

In this phase the various locations are checked so that there is an existence of the sensor network dual-string to connect the area of interest, I , to the sink so that the data transmission to sink can be performed efficiently. This string basically acts as a connection to send the sensed data to the sink for the processing and for the network maintenance information passing in both the directions.

2. Computation Phase

In this phase various computations related jobs are done in order to get the optimization done. These results are computed so as to get transmitted to the sink node where entire management task is to be done. The sink node selects the optimal node according to the priority of the parameters.

3. Energy Computation Phase

In this phase various energy consumptions are done. For example e_{ij}^{move} , the movement energy consumed to move from the sensor initial location (x_j, y_j) to the sensing location, (x_i, y_i) is computed in order to get the energy consumption of respective node to move to the desired location (s).

4. Angle and Duration Computation Phase

In this phase the **DSN_ANGLE_COMPUTATION (L_i, A)** algorithm is used by the sensor nodes to compute the sensing angle required at the specified location. Using the result of this computation and the knowledge about the reserve energy,

$e_i^{reserve}$, the duration of node is computed for the desired location.

5. Updation Phase

In this phase the results of the computation of the previous stage is fed to the sink using the sensor node string connecting the area of interest, I , and the sink node where it is then processed for further actions.

6. Selection Phase

In this phase, the sink node selects the optimal node according to the set priority of the parameter optimization. The result of this phase is then broadcasted so that the concerned sensor nodes may act accordingly.

7. Termination Phase

In this phase, the nodes which are not selected will end up in terminated state while other chosen one will move till they reach the desired location where they will eventually end in terminated state and start sensing job.

Non-Time Critical Algorithm (Centralized Algorithm)

1. The sink node will broadcast a set of locations L to sensor nodes, where following must hold true:

Let (x_j, y_j) be the coordinates of location L_j and (x_k, y_k) be the coordinates of L_k , then, there must exist

$$d_{(j,sink)} \leq d_{(j-1,sink)} + r_c \quad \text{and}$$

$$d_{(k,sink)} \leq d_{(k-1,sink)} + r_c$$

where

$$d_{(a,b)} \rightarrow d_{ab}, \text{ Euclidian distance between nodes } a \text{ and } b.$$

where

$$d_{ab} = \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2}$$

where

$x_a \rightarrow$ x coordinate of the a node.

$y_a \rightarrow$ y coordinate of the a node.

$x_b \rightarrow$ x coordinate of the b node.

$y_b \rightarrow$ y coordinate of the b node.

$j \in (sink, L)$

and $k \in (sink, L)$

and $(j \cap k) = \{sink\}$

$$L_j = (x_j, y_j, z_j, duration_j, delay_j)$$

where

$x_j \rightarrow$ x coordinate of L_j location.

$y_j \rightarrow$ y coordinate of L_j location.

$n_j \rightarrow$ number of nodes required to cover L_j location.

$duration_j \rightarrow$ sensing time required at L_j location.

2. Select L_j from L , set of locations and select sensor $s_i, (x_i, y_i)$.

3. Each sensor will construct OCC Table from L such that:

a. $e_{ij}^{move} = e_{ij}^{move} * d_{ij}$

and

$$e_{ij}^{left} = e_i^{reserve} - e_{ij}^{move}$$

if

$$e_{ij}^{left} \leq 0$$

then continue else goto (b).

remove (x_i, y_i) from L for location L_j goto step 2.

where

$e_{ij}^{move} \rightarrow$ movement energy consumed by i^{th} sensor node for moving to L_j location.

$e_{ij}^{move} \rightarrow$ movement energy consumption of i^{th} sensor node for a unit distance.

$e_{ij}^{left} \rightarrow$ energy left in i^{th} sensor node after moving to L_j location.

$e_i^{reserve} \rightarrow$ reserve (or pool) energy of i^{th} sensor node.

b. Sensor nodes will calculate $duration_{ij}$ as follows:

$$duration_{ij} = \left(\frac{e_{ij}^{left}}{\left(\frac{e_j^{angle}}{e_i^{angle}} \right) * e_i^{sensing_energy}} \right) - duration_j$$

where

$duration_{ij} \rightarrow$ relative duration of node i at location L_j .

$e_j^{angle} \rightarrow$ It is the angle of sensing required at L_j .

$e_i^{angle} \rightarrow$ It is the angle of sensing coverage of a directional sensor.

$e_i^{sensing_energy} \rightarrow$ It is the energy consumption of one sensor of the directional sensor node per unit time.

4. Sensor node updates the one hop node according to following rule:

Let there be a node (x_k, y_k) one hop from (x_i, y_i) , then, check

$$d_{(i, sink)} \stackrel{?}{\geq} d_{(k, sink)}$$

a. If multiple entries qualify then select,

$$\min(d_{(i,sink)} \geq d_{(k,sink)})$$

b. If no entry qualifies then select,

$$\min(d_{(k,sink)}), \text{ neighbor.}$$

5. The sink selects the optimal node for the coverage such that:

$$duration_{ij} \geq 0$$

$$busy_{s_i} \neq true$$

where

$busy_{s_i} \rightarrow$ state of sensor (true \leftarrow busy, false \leftarrow free).

a. if multiple entries qualify then select,

$$\min(e_{ij}^{move})$$

which is the minimum movement energy consumed by a sensor node i to move at location L_j .

i. if multiple entries qualify then select,

$$\max(e_{ij}^{left})$$

where

$\max(e_{ij}^{left}) \rightarrow$ maximum energy left in i^{th} node after moving to L_j location.

location.

$$busy_{s_i} \leftarrow true$$

b. if no entry qualifies then select,

$$\max(duration_{ij})$$

$$busy_{s_i} \leftarrow true$$

$$duration_j \leftarrow duration_j - duration_{ij}$$

goto step 5.

where

$\max(duration_{ij}) \rightarrow$ maximum duration of a sensor

node i at location L_j .

6. Set all nodes to the terminated state.

B. Dispatch Scheme for Time Critical Applications (Distributed Algorithm)

This algorithm is designed specifically for the time critical applications, commonly known as real-time applications. This algorithm tries to resolve most of the anomalies in a real time environment, due to which loss of energy takes place in a sensor network having mobile sensor nodes. It has various phases which cohesively work in order to achieve effective real-time task of energy conservation along with other parameter optimization for enhanced and prolonged performance.

Time Critical FiBDS Algorithm (Distributed Algorithm)

1. The sink node will broadcast a set of locations L to sensor nodes, where following must hold true:

Let (x_j, y_j) be the coordinates of location L_j and (x_k, y_k) be the coordinates of L_k , then, there must exist

$$d_{(j,\text{sink})} \leq d_{(j-1,\text{sink})} + r_c \quad \text{and}$$

$$d_{(k,\text{sink})} \leq d_{(k-1,\text{sink})} + r_c$$

where

$d_{(a,b)} \rightarrow d_{ab}$, Euclidian distance between nodes a and b .

where

$$d_{ab} = \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2}$$

where

$x_a \rightarrow x$ coordinate of the a node.

$y_a \rightarrow y$ coordinate of the a node.

$x_b \rightarrow x$ coordinate of the b node.

$y_b \rightarrow y$ coordinate of the b node.

$j \in (\text{sink}, L)$

and $k \in (\text{sink}, L)$

and $j \cap k = \{\text{sink}\}$

$$L_j = (x_j, y_j, z_j, \text{duration}_j, \text{delay}_j) \quad \dots (1)$$

where

$x_j \rightarrow x$ coordinate of L_j location.

$y_j \rightarrow y$ coordinate of L_j location.

$n_j \rightarrow$ number of nodes required to cover L_j location.

$\text{duration}_j \rightarrow$ sensing time required at L_j location.

$\text{delay}_j \rightarrow$ maximum permissible delay for a node to reach at L_j location.

2. Select location L_j from L .

3. Select sensor node s_i , (x_i, y_i) , where

$\text{busy}_{s_i} \neq \text{true}$

Where

$\text{busy}_{s_i} \rightarrow$ state of sensor ($\text{true} \leftarrow \text{busy}$, $\text{false} \leftarrow \text{free}$).

4. Each sensor will construct OCC Table from L such that:

$$a. e_{ij}^{\text{move}} = e_{ij}^{\text{move}} * d_{ij}$$

and

$$e_{ij}^{\text{left}} = e_i^{\text{reserve}} - e_{ij}^{\text{move}}$$

if

$$e_{ij}^{\text{left}} \leq 0$$

then continue else goto (b).

remove (x_i, y_i) from L for location L_j goto step 2.

where

$e_{ij}^{\text{move}} \rightarrow$ movement energy consumed by i^{th} sensor node for moving to L_j location.

$e_i^{\text{move}} \rightarrow$ movement energy consumption of i^{th} sensor node for a unit distance.

$e_{ij}^{\text{left}} \rightarrow$ energy left in i^{th} sensor node after moving to L_j location.

$e_i^{\text{reserve}} \rightarrow$ reserve (or pool) energy of i^{th} sensor node.

b. Sensor nodes calculate delay_{ij} for the locations in L , as follows:

$$\text{delay}_{ij} = (d_{ij} / s_i^{\text{move}})$$

where

$\text{delay}_{ij} \rightarrow$ time duration taken by i^{th} sensor to move at location L_j .

$s_i^{\text{move}} \rightarrow$ movement speed of the i^{th} sensor node.

c. Sensor Nodes update the one hop neighbor regarding delay_{ij} , duration_{ij} and e_{ij}^{left} and starts moving.

5. Selection will be made according to following criteria:

$$\text{delay}_i \leq \text{delay}_j$$

$$\text{duration}_{ij} \geq 0$$

where,

$$\text{duration}_{ij} = \left(\frac{e_{ij}^{\text{left}}}{\left(\frac{e_j^{\text{angle}}}{e_i^{\text{angle}}} \right) * e_i^{\text{sensing_energy}}} \right) - \text{duration}_j$$

where

$\text{duration}_{ij} \rightarrow$ relative duration of node i at location L_j .

$e_j^{\text{angle}} \rightarrow$ It is the angle of sensing required at L_j .

$e_i^{\text{angle}} \rightarrow$ It is the angle of sensing coverage of a directional sensor.

$e_i^{\text{sensing_energy}} \rightarrow$ It is the energy consumption of one sensor of the directional sensor node per unit time.

i. if multiple entries qualify then select,

$$\min(e_{ij}^{\text{move}})$$

where

$\min(e_{ij}^{\text{move}}) \rightarrow$ minimum movement energy consumed by a sensor node i to move at location L_j .

if multiple entries qualify then select,

$$\max(e_{ij}^{\text{left}})$$

where

$\max(e_{ij}^{\text{left}}) \rightarrow$ maximum energy left in i^{th} node after moving to L_j location.

$$\text{busy}_{s_i} \leftarrow \text{true}$$

ii. if no entry qualifies then select,

$$\max(\text{duration}_{ij})$$

where

$\max(\text{duration}_{ij}) \rightarrow$ maximum duration of a sensor node i at location L_j .

$$\text{delay}_j \leftarrow \text{delay}_j + \text{duration}_{ij}$$

$$\text{busy}_{s_i} \leftarrow \text{true}$$

goto step 3.

b. if no entry qualifies then select,

$\min(\text{delay}_{ij})$

where

$\min(\text{delay}_{ij}) \rightarrow$ minimum delay for any i^{th} sensor node to reach L_j location.

i. If multiple entries qualify, then select:

$\text{duration}_{ij} \geq 0$

I. if multiple entries qualify then select,

$\min(e_{ij}^{\text{move}})$

A. if multiple entries qualify then select,

$\max(e_{ij}^{\text{left}})$

$\text{busy}_{s_i} \leftarrow \text{true}$

II. if no entry qualifies then select,

$\max(\text{duration}_{ij})$

$\text{busy}_{s_i} \leftarrow \text{true}$

$\text{delay}_j \leftarrow \text{delay}_j + \text{duration}_{ij}$

$\text{duration}_j \leftarrow \text{duration}_j - \text{duration}_{ij}$

goto step 3.

6. Set all nodes to the terminated state.

IV. RESULTS AND FIGURES

Omnet++ an open source simulator used for evaluating the performance of various protocols namely CBDS, greedy, centralized and our proposed Fishnet Based Dispatch Scheme (FiBDS).

A. Simulation Parameters

The simulation parameters such as transmitter delay, awake period, distance between sensors nodes, energy used for various functioning etc. are given in Table I.

TABLE I
SIMULATION PARAMETER AND THEIR VALUES

Parameter	Value
Simulation Field Area (A)	600 m x 600 m square region
Area of Interest (I)	300 m x 300 m square region
Movement speed of each sensor (s_i^{move})	1 m/s
Movement energy cost of sensor node i (e_i^{move})	randomly selected [0.8 J, 1.2 J] per meter
Timers ($T_{\text{update_OCC}}$ and $T_{\text{broadcast}}$)	5 s
Initial reserve energy of each sensor node (e_i^{reserve})	6400 mWh
Angle of sensing coverage of a directional sensor (e_i^{angle})	90° (degrees)
Unit Energy consumption by a sensor node ($e_i^{\text{sensing_energy}}$)	Randomly selected [0.2 J, 0.4 J] per second
Percentage of Energy deficient nodes	5, 10, 15, 20, 25 (at various instances)
Communication range (r_c in meters)	34.7, 24.1, 19.3, 16.7, 14.9, 13.4, 12.5
Sensing range (r_s in meters)	20.0, 13.9, 11.1, 9.62, 8.6, 7.71, 7.16
Number of locations (L_j)	100-700
Number of sensor nodes (s_j) for $k=3$ where k is coverage level	300, 600, 900, 1200, 1500, 1800, 2100

The following figures present the simulation results of our proposed FiBDS protocol compared with other protocols. Simulation is carried out on different parameters in order to get more realistic results. We have simulated our proposed

protocol for 600m X 600m square region, where area of interest is 300m X 300m square region.

Fig. 2 shows that FiBDS has better performance as compared to CBDS and centralized algorithms in case of total moving energy on sensor nodes. Fig. 3 shows that in case of avg moving distance FiBDS has the lowest avg moving distance in all compared methods. Fig. 4 shows that FiBDS consumes less total energy as compared to CBDS. In case of FiBDS distributed algorithm Fig. 5 shows that when compared to greedy, CBDS, and centralized algorithms it has the lowest total moving energy for sensor nodes.

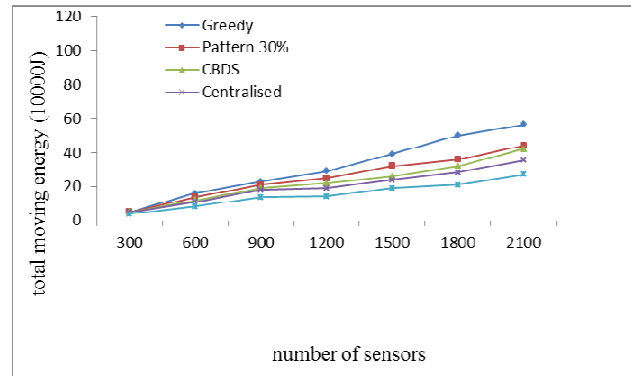


Fig. 2 FiBDS Centralized Algorithm (Number of sensor nodes vs. total moving energy (J))

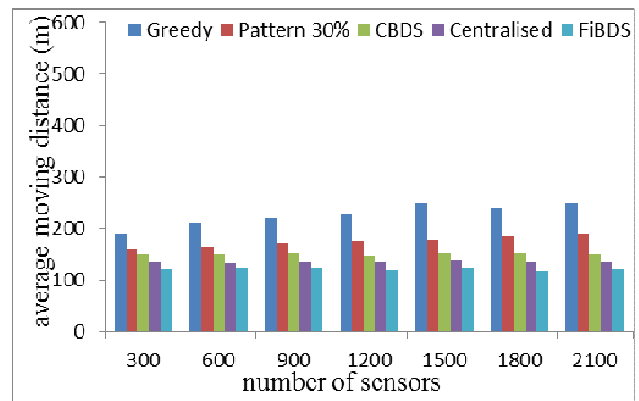


Fig. 3 FiBDS Centralized Algorithm (Number of sensor nodes vs. average moving distance (m))

Fig. 6 shows that FiBDS distributed algorithm has the lowest total moving distance when compared with greedy, CBDS and centralized algorithms. Fig. 7 shows the graph for no. of sensor nodes vs total sensing energy. It shows that FiBDS uses less amount of total sensing energy as compared to CBDS.

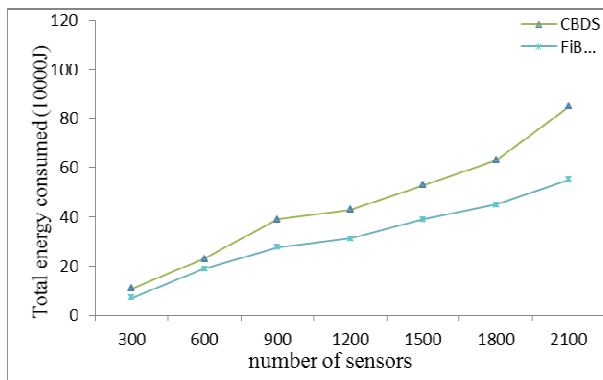


Fig. 4 FiBDS Centralized Algorithm (Number of Sensors vs. Total energy consumed (J))

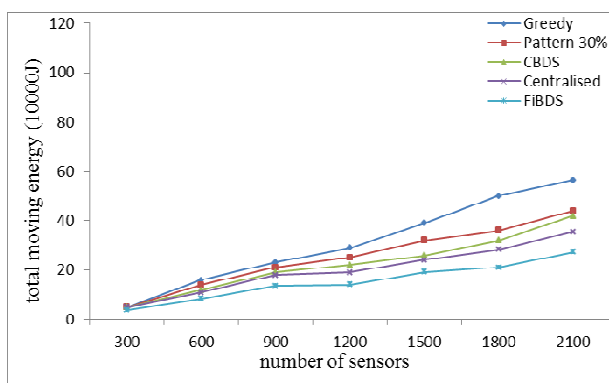


Fig. 5 FiBDS Distributed Algorithm (Number of Sensors vs. total moving energy (J))

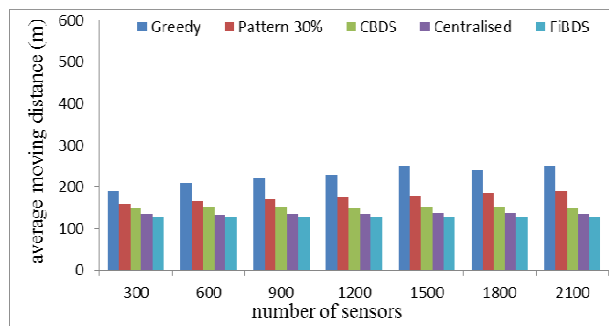


Fig. 6 FiBDS Distributed Algorithm (Number of Sensors vs. average moving distance (m))

V. CONCLUSION

WSNs are designed for specific applications. Applications include, but are not limited to, environmental monitoring, industrial machine monitoring, surveillance systems and military target tracking. Each application differs in features and requirements. Some applications are time critical and some nodes are non- time critical. This paper proposes that by computing duration, delay and energy efficiency in competition based dispatch scheme of “Distributed deployment schemes for Mobile Wireless Sensor Networks to

ensure multilevel coverage” a model can be made that is more optimized than present dispatch scheme of the network for non-real time systems. While in the paper optimization is made only on distance between the nodes and uncovered location is considered. Minimum distance node is considered to cover the location but its energy is not calculated that’s why new dispatch scheme comes out to be more energy efficient. Here, it can be concluded that as the number of sensors having energy less than required to move to the opted location increases the efficiency of the FiBDS proved itself to be more beneficial than CBDS. Further this work could be extended to meet the requirements of variable sensor movement speed and variable energy consumption.

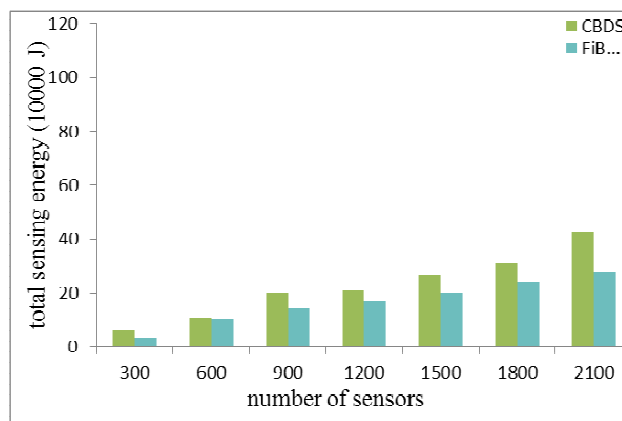


Fig. 7 FiBDS Distributed Algorithm (Number of Sensors vs. total sensing energy (J))

REFERENCES

- [1] Nor Azlina Ab. Aziz, Kamarulzaman Ab. Aziz, Wan Zakiah Wan Ismail, “Coverag Strategies for Wireless Sensor Networks,” in *World Academy of Science, Engineering and Technology* 50, 2009.
- [2] Shih-Lin-Wu, Yu-Chee Tseng, “Ad hoc networking, Personal Area, Local area and Sensory area network”, 2011.
- [3] Nadeem Ahmed, Salil S. Kanhere, Sanjay Jha, “Probabilistic Coverage in Wireless Sensor Networks”, Proceedings of the IEEE Conference on Local Computer Networks 30th Anniversary (LCN’05)
- [4] A. E. F. Clementi, P. Penna, R. Silvestri, “Hardness results for the power range assignment problem in packet radio networks,” in *2nd International Workshop on Approximation Algorithms for Combinatorial Optimization Problems (RANDOM /APPROX ’99)*, pp. 197–208, 1999.
- [5] Tomáš Mácha, Peter Stančík, Vit Novotný, “Connectivity in a wireless sensor network,” in *IJCSNS International Journal of Computer Science and Network Security*, vol. 8, no. 12, Dec. 2008.
- [6] L. Subramanian, R. H. Katz, “An Architecture for Building Self-Configurable Systems,” Department of Electrical Engineering and Computer Sciences, University of California–Berkeley. <http://www.eecs.berkeley.edu/>.
- [7] Pu Wang, Zhi Sun, Mehmet C. Vuran, Mznah A. Al-Rodhaan, Abdullah M. Al-Dhelaan, Ian F. Akyildiz, “On network connectivity of wireless sensor networks for sandstorm monitoring,” *Computer Networks* 55, pp. 1150–1157, 2011.
- [8] Jing Ai, Al-hussein, A. Abouzeid, “Coverage by directional sensors in randomly deployed wireless sensor networks” *Springer*, Oct. 2005.
- [9] Yi Wang, Guohong Cao, “Minimizing Service Delay in Directional Sensor Networks,” Department of Computer Science and Engineering The Pennsylvania State University, Pennsylvania.

- [10] ou-Chiun Wang, Yu-Chee Tseng, "Distributed Deployment Schemes for Mobile Wireless Sensor Networks to Ensure Multi Level Coverage, in *IEEE Transactions on Parallel and Distributed Systems*, vol. 19, no. 9, Sep. 2008.
- [11] Elham Hajian, Kamal Jamshidi, Ali Bohlooli, "Improve Energy Efficiency Routing In WSN by Using Automata," in *International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC)*, vol.1, no. 2, pp. 1-7, June 2010.
- [12] Bo Jiang, "End-to-end Delay Analysis for Event-driven Wireless Sensor Network Applications," Doctor of Philosophy, Comp. Engg., Virginia Poly. Instt. and State Univ., Blacksburg, Virginia, May 4, 2009.
- [13] Ewa Niewiadomska-Szynkiewicz, Piotr Kwaśniewski, Izabela Windyga, "Comparative Study of Wireless Sensor Networks Energy-Efficient Topologies and Power Save Protocols," in *Journal of Telecommunications and Information Technology*, pp. 68-75, 2009.
- [14] Chun Tung Chou, Rajib Rana, Wen Hu, "Energy efficient information collection in wireless sensor networks using adaptive compressive sensing," in *IEEE 34th Conference on Local Computer Networks (LCN 2009)*, pp. 443-450, Zürich, Switzerland, Oct. 2009.
- [15] Javad Rezazadeh, Marjan Moradi, Abdul Samad Ismail, "Mobile Wireless Sensor Networks Overview," in *IJCCN International Journal of Computer Communications and Networks*, vol. 2, issue 1, Feb. 2012.