Middle-East Journal of Scientific Research
24 (Special Issue on Innovations in Information, Embedded and Communication Systems): 151-157, 2016
ISSN 1990-9233; © IDOSI Publications, 2016
DOI: 10.5829/idosi.mejsr.2016.24.IIECS.23154

Energy Efficient Data Collection Protocol with Minimum Delay and Load Balancing for Heterogeneous Wireless Sensor Networks

M. Kalaiarasi and V.P. Sreekantha Kumar

Computer Science and Engineering, KCG College of Technology, Chennai, India

Abstract: Wireless Sensor Network (WSN) has many numbers of nodes which are used to sense wide range of applications. Efficient data collection with all constraints is the challenging task. Recent researches have proved that data collection can be efficient through Open Vehicle Routing (OVR) to provide best routes in Wireless Sensor Networks. To implement this approach, a routing protocol known as Energy-efficient, Delay Aware and Lifetime balancing (EDAL) is used. One result of OVR is taken and integrated in EDAL to prove that the given problem is NP-hard. Thus, a distributed heuristic to make the algorithm more scalable for a heterogeneous network is designed. However, this form of data collection may consume large amount of energy, since all the nodes will keep listening throughout the process, a sleep and wake technique is used in the proposed system. Dynamic sleep is used when sensor nodes are not in use. To reduce the traffic cost, compressive sensing is being integrated with the designed protocol. Thus, energy Efficiency is improved when compared with other techniques.

Key words: Wireless Sensor Network · Open Vehicle Routing · Compressive sensing · Heuristic algorithm · Mobile sink · Dynamic sleep- wake up

INTRODUCTION

Heterogeneous Wireless Sensor Networks (WSN) is used in wide range of applications like Field surveillance [1], environment monitoring, structural monitoring, health, military etc. Prolonging the network lifetime and packet Delivery in a specified time period in above mentioned applications are the major constraint to be considered and solved. Basically, the mobile sink in the sensor nodes are used to collect data in a single or a multiple hop. Nodes will Wake up only when mobile sink is nearing. The data will be already aggregated in a particular time. The mobile sink need not wait for the data from a collecting source. Since sensor nodes uses large amount of battery power, it leads to a problem of finding efficient data collection protocol.

Many previous researches had tried to achieve the issues like energy efficiency, delay and load balancing for a data collection protocol. Open Vehicle Routing [2] technique is used in order to overcome all these issues. In OVR, the shortest routes are selected in some means of algorithm and the packets or goods are transferred in a given time constraint with minimum cost. Taking this into account, issues like load balancing etc are achieved. A centralized heuristic is used in order to reduce the computational complexity and a distributed heuristics which uses ant colony gossiping algorithm for load balancing issue is used. Dynamic sleep and wake [3] method is being employed in order to avoid high energy usage of sensor nodes. Here, the nodes are put into sleep state when not used for collecting data; else they put in wake up state. Energy efficiency is achieved by this mean in a heterogeneous WSN.

The following are the objectives of this paper

- OVR is used in order to deliver the data in a shortest route with minimum energy and cost of sensors satisfied with given time deadline.
- To address the efficiency and load balancing problem, an efficient data collection protocol is designed.
- Distributed heuristics algorithm includes ant Colony Gossiping Algorithm.

Corresponding Author: M. Kalaiarasi, Computer Science and Engineering, KCG College of Technology, Chennai, India.

- Dynamic Sleep and wake-up is used in order to avoid wastage of energy consumed by the sensor nodes using mobile sink.
- Compressive sensing is integrated with the designed protocol in order to reduce the traffic cost in the network.

The remaining section of this paper includes 2. Background 3. Literature review 4. Problem or system model 5. Proposed algorithms and explanations in detail 6. Simulation based evaluation 7. Comparison Graph 8. Concludes the paper.

Background

Open Vehicle Routing (OVR) Problem: To perform data collect in a given network efficiently with given time, many procedures have been using OVR for finding the best routes in the network with given time constraint. Vehicle routing will find the best routes and the shortest routes using Travelling salesman Problem (TSP) or some shortest routes algorithm. The goods are considered to be data in a sensor node which are carried from the depot to the customers. Here it is considered as source to the sink node. The main constraint of using OVR will use less number of vehicles to carry large goods and deliver the goods within a given time. Thus, an efficient route with minimum consumption of energy is proposed.

Ozyurt *et al.* proposed an algorithm which says the nearest neighbors are connected with the farthest nodes in the give network. This process continues until all the nodes are connected with its nearest neighbor with minimum insertion cost to the sink node within the time deadline. This can be extended as Open vehicle routing with time deadline (OVR-TD). Once, Route is found many algorithms can be used to implement.

Compressive Sensing: All the data which are forwarded from the source to the sink are not useful or contains useful information. To avoid delivering unwanted data in the sensor, a new technique called compressive sensing [4] is being used here. This may compress the invalid data in order to improve the efficiency of the data collection protocol. Given N nodes in a network which are compressed into M nodes in a given network segment K. Where M<<N, the compressed data is less when compared to the original data.

Sleep and Wake-Up: Since each nodes in the sensor will monitor continuously in form that they listen constantly and gather data and send them to the base station. During this process, some amount of energy is being used by the sensors. But, all the nodes in the network will not be constantly listening. So, in order to save some amount of energy in nodes, the sensor is put into sleep state and will make them wake only when needed. This conserves a large amount of energy in order to equal energy efficiency in a data collection protocol.

A perfect synchronization is needed in order to wake-up the sensor from sleep state. Many synchronization algorithms are implemented in form of single hop or multi hop. The sensors will go to sleep by default. When certain threshold is met by the node, it will wake to listen to the data. Time Division Multiple Access - TDMA (MAC) [5] protocol is the traditional scheduling for sleep and wakeup.

Mobile Sink: Mobile Sink uses a special node called rendezvous point which collect the data from all other node in the mobile sink and forward them to the base station. Routing Point (RP) or mobile sink acts as a intermediate node for all the neighbor nodes in the network.

Literature Review: Many papers have proposed many ideas in energy efficiency for the WSN.

Haifeng Zheng, Shilin Xiao, Xinbing Wang, Xiaohua Tian proposed that the data gathering in an WSN can be done in an efficient way through compression sensing. A multi round random linear function along with a tree based protocol is implemented fro efficient collection of data in an WSN network. The complexity of computation shows that the protocol can save energy and reduce latency for data gathering when compared to traditional approach, by using the centralized format. The distributed approach, gossip-based approach is used to study the performance of energy and latency. They have certain disadvantages such as, the tree-based protocol is susceptible to the failure of nodes and links. Sink node failure will cause loss of energy in the network.

Liu Xiang, Jun Luo, Athanasios Vasilakos proposed that through joint routing compression [2] the energy efficiency in the network can be increased. A mixed integer programming along with the greedy heuristics is being used for obtaining the optimal and near optimal trees. By doing this, the energy efficiency is being increased. The problem in this is that it can consider the case where not all nodes are sources, which may require different heuristics to tackle.

Zhuofan Liao, Jianxin Wang, Shigeng Zhang, Jiannong Cao proposed a method for minimizing the movement for the target coverage and network connectivity in mobile sensors. Mobile sensor Deployment (MSD) is used for minimum nodes movement inside the network. Thus, this is split into two sub-problems. Target coverage and network connectivity problem. For target coverage, the radius is being doubled and Hungarian algorithm is used along with TV-greedy algorithm. Thus, the combination of both increases the life time in network and balance the loads in the network. But, there are obstacles in the task area. The mobile sensors are limited in moving directions or/and step length. A distributed solution to the MSD problem is very attractive because it takes advantage of robustness when facing network changes and sensor failures. The moving decisions need to be made locally. However, localized algorithms face the potentially complicated relationship between local and global behavior. Algorithms that are locally optimal may not perform well in a global sense.

Proposed System Model and Problem Statement: In this system, a process of converting OVR to a sensor network route is being done. A centralized and distributed algorithm is used to find approximate solutions.

Problem Model: A Directed Acyclic Graph (DAG) is considered for a collection of N number of nodes in a heterogeneous wireless sensor network.

$$G = (V, E) \quad (1)$$

G - Graph generated which has directions in it.
V - Number of vertices and
E - Wireless sensor links between the nodes.

For each node, the transmission power gets varied. All the links in the network are directional. Some node are considered as source and they have to deliver data within given time and at minimum cost to the sink. The link between the nodes from the source to the sink is mentioned as L_{ij}.

$L_{ij} = 1$, if link is found
Else
0 (no link found)

The main objective to choose OVR is

- All the routes must end at the sink.
- All the data must be delivered at a given time.
- Number of links joining the routes must be similar when leaving.

Mobile Sink or Routing points are used to collect the data from nearby or neighboring nodes. This helps in spending time in collecting data from individual node. Using OVR shortest path for routing data is found. Even though it has some restrictions, Sleep and wakeup with mobile sink is implemented in order to save a large amount of energy spent by the sensors in the heterogeneous networks.

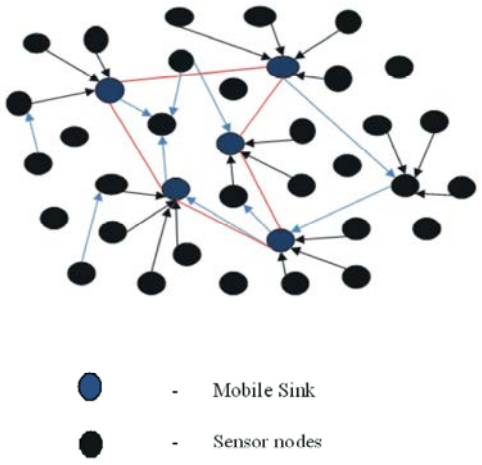

Fig. 1: System Model

In the system model, the sensor nodes are in a heterogeneous network. The nodes are divided into certain partitions and each have a single data collection point in them. The data collection point is known a mobile sink which will collect all the data from nearest neighbor. The best route is evaluated using OVR. The nodes are put into sleep state when not in use and will wake up only during data transmission and collection for improving the energy efficiency in heterogeneous wireless sensor network.

Proposed Algorithm

Distributed Heuristics: Distributed heuristics is used in order to overcome the problem in centralized heuristics. The problem with distributed heuristics is the information should be collected from every node to a centralized node. At the beginning of each period, every source node will select the most efficient node to transfer its data. The distributed heuristics algorithm is based on ant colony gossiping algorithm. The main objective of ant colony gossiping algorithm is selecting the node with highest energy to transfer data packets. By this, the information collected by the node is minimized.

Algorithm 1: Distributed heuristics for data collection protocol

Input: Topology graph G, source node s, neighbor node S, deadline D, remaining time RT and sink node T.
Output: Constructed routes with minimum insertion cost and D not avoided.
1: Ant colony is used to collect the status.
2: minimum path cost is estimated s to S to t using dijktras algorithm.
3: put all the nodes in source node S candidate list L.
4: if all for all distance(s, t)>distance (s_i, t) then
5: go to 14
6: end if
7: if route construction packet is received then
8: extract partially constructed routes rc and minimum packets.
9: if s is already assigned a route then
10: send the packet to inform previous node and then terminate.
11: end if
12: remove n belongs to pr and goto 14
13: end if
14: for all node si belongs to L do
15:compute the incremental total delay d_{incr} =delay(s, s_i)+delay(s_i, t)
16: compute the insertion cost as pathcost(s, s_i)+pathcost(s_i, t)
17: if the insertion cost is lowest, append si
18: update the remaining time of each packet
19: send construction packet to si and the payload
20: end if
21: if no candidate key s_i is found then
22: choose t as the next node and send the packet.
23: send construction packets to empty routes s_i
24: end if

Simulation Based Evaluation: Performance evaluation is made for heterogeneous wireless sensor network. The performance is compared in terms of network lifetime, packet delay etc. Simulation is done using NS2. Comparison graph for all the parameters like efficiency, delay, load balancing are constructed using GNU plot.

Comparison Graphs: Comparison between existing system, PEAS (Probing Based Density Control) mechanism and the designed EDAL protocol is generated in form of graph. X and Y axis in all graphs takes two different parameters for comparison. The results of simulations are given as thin lines in graph. The red line denotes existing systems performance and green line denotes proposed systems performance for every parameter in every graph. The four parameters taken for comparison are load, energy, time and throughput of wireless sensors in heterogeneous network.

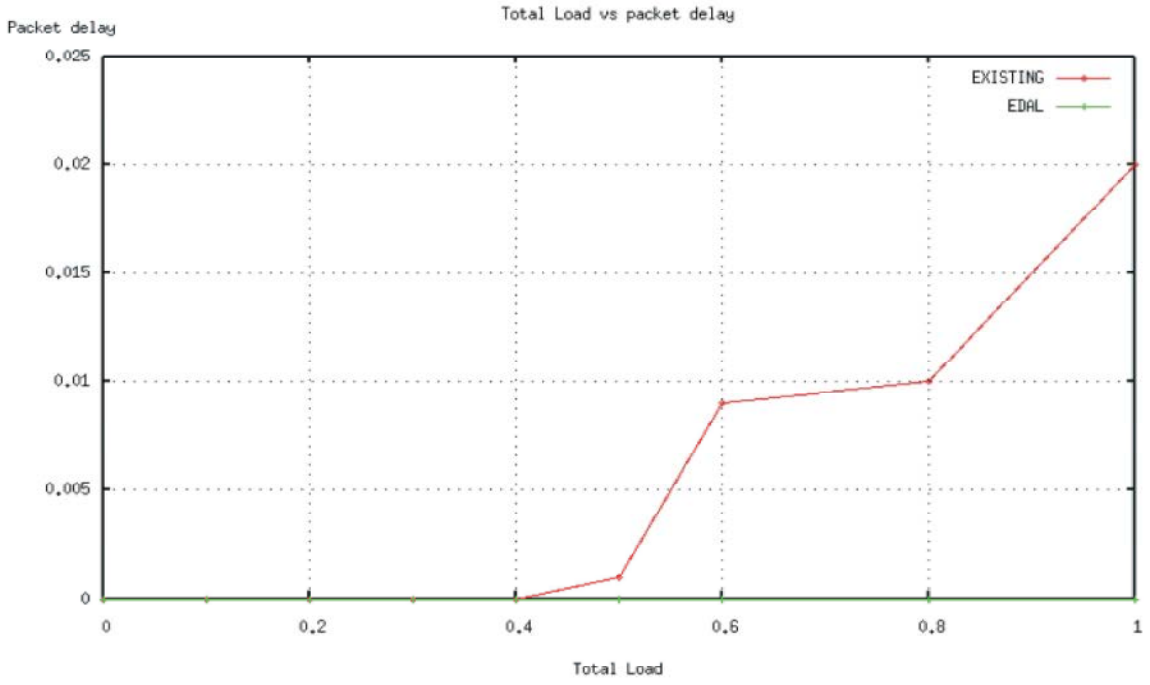

Fig. 2: Comparison graph for packet delay

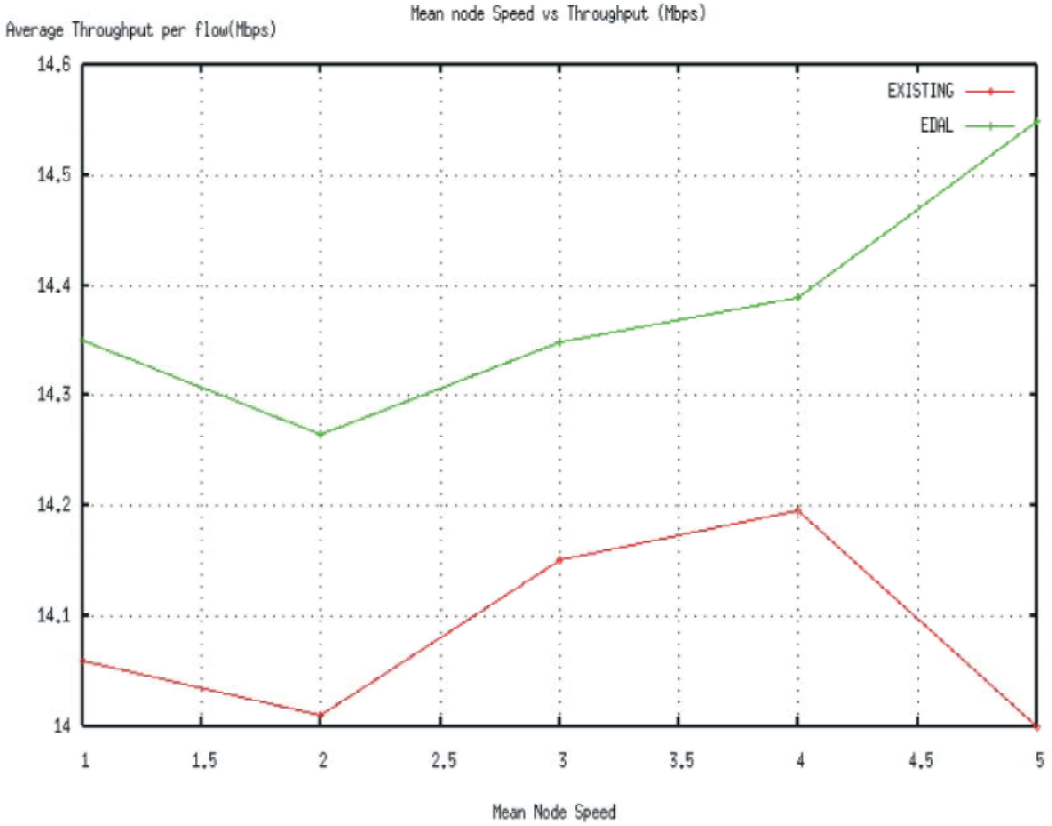

Fig. 3: Comparison graph for throughput

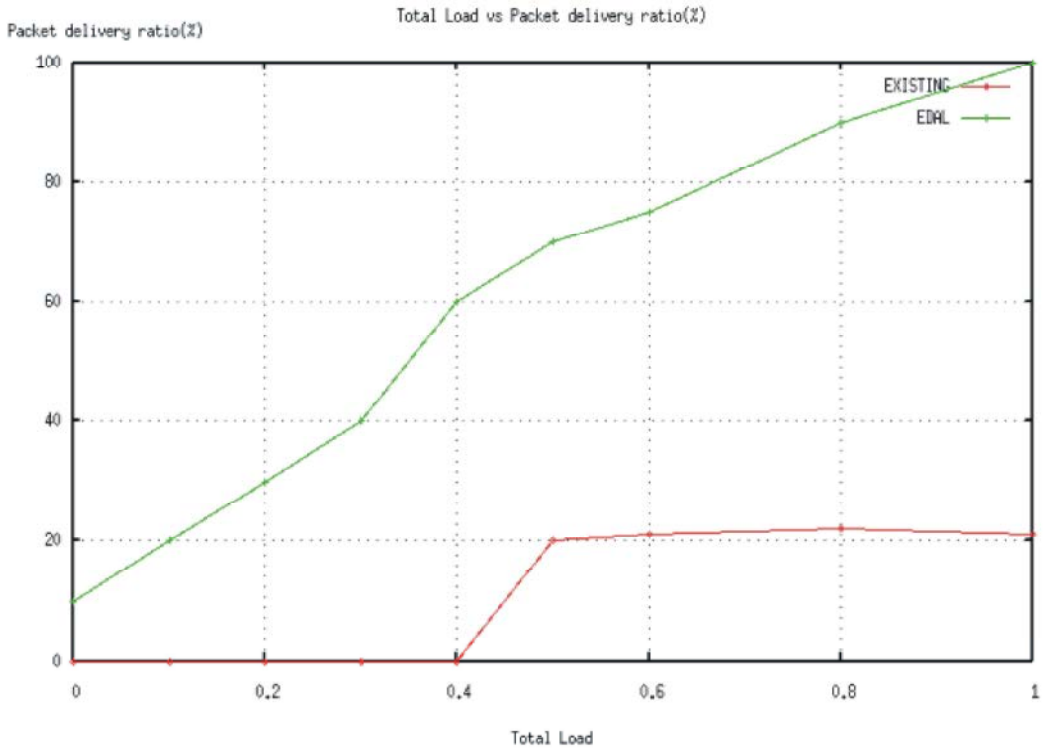

Fig. 4: Comparison graph for packet delivery

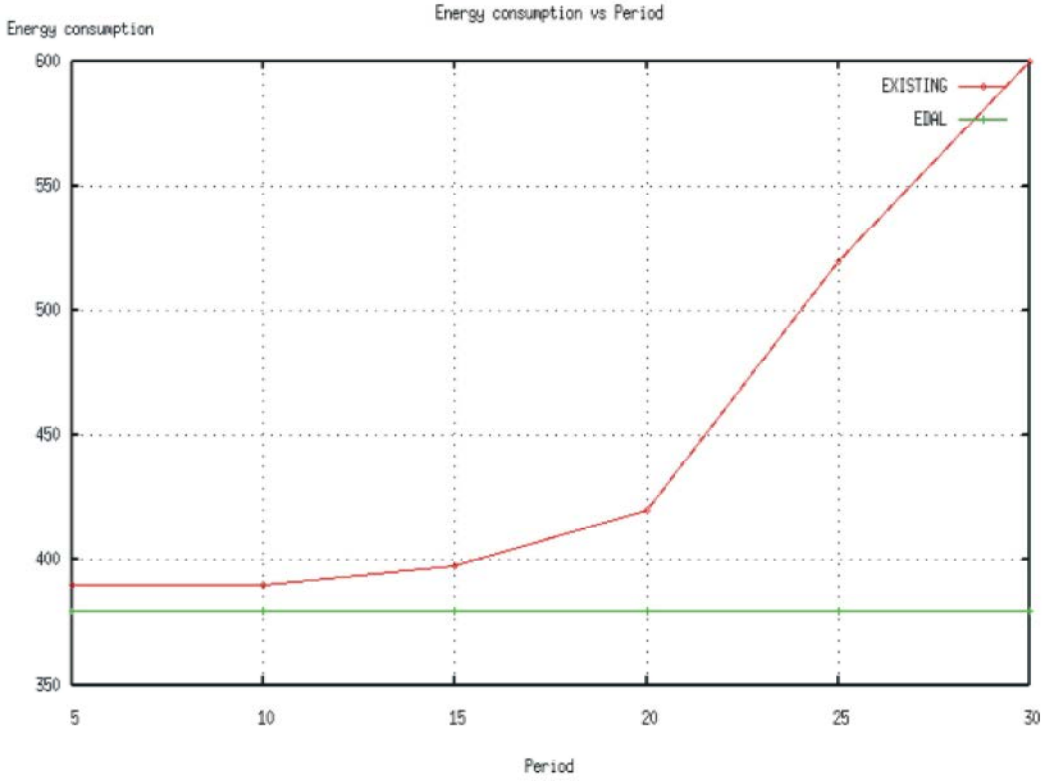

Fig. 5: Comparison graph for energy consumption

The above graph is generated for packet delay in a wires sensor network. In EDAL protocol, the packet delay is less when compared to PEAS. Data transmission is constant in the designed protocol.

Through put indicates the speed of data delivered with accuracy as well. The above graph is made for comparison of throughput and node speed on data delivery. Throughput is taken in x-axis and node speed in y-axis. The throughput is increased by means of designed protocol. The average node speed and mean node speed is compared in the above figure. The throughput for existing PEAS is less when compared to EDAL data collection protocol. Since all the nodes are not involved in collecting data, the energy of the sensors is minimized and throughput is increased.

In this graph, total load ratio is taken in x-axis and packet delivery in y-axis. The packet delivery ratio is increased when compared to existing PEAS protocol. The energy ratios in all the graphs are calculated in means of joules. Since the entire wireless sensor nodes are using energy in form of joules. Packet delay is considered as delay aware in generated proposed protocol for efficient data collection.

Period refers to the time taken to deliver data and collection of data.Energy consumption is stable in designed EDAL protocol. While in the existing protocol the consumption of energy gets varied at time period, which may lead to large amount of energy consumption.

CONCLUSION

An efficient data collection protocol is implemented in order to collect all the data from heterogeneous wireless sensor network in an energy efficient, delay aware and in load balancing manner. OVR technique is integrated in WSN in order to find the shortest routes and to deliver data within a given time deadline. A centralized heuristic algorithm is used (RPFI) to reduce computational complexity, sine it has a overhead. A distributed heuristics algorithm is used in order to improve scalability in a large network. To avoid maximum energy spent by the sensor nodes, sleep and wake up with mobile sink is used. The nodes will go to sleep state when not needed and will wake up during data collection. Compressive sensing technique is used to reduce the traffic cost in wireless sensor network. Thus a efficient data collection protocol is implemented when compared to existing systems.

REFERENCES

1. Xu, N., S. Rangwala, K.K. Chintalapudi, D. Ganesan, A. Broad, R. Govindan and D. Estrin, 2004. "A wireless sensor network for structural monitoring, " in Proc. 2nd ACM SenSys, New York, NY, USA, pp: 13-24.
2. Liu, L., X. Zhang and H. Ma, 2010. "Optimal node selection for target localization in wireless camera sensor networks, " IEEE Trans. Veh. Technology, 59(7): 3562-3576.
3. Yan Wu, Sonia Fahmy, Ness B. Shroff, 2009. "Sleep/Wake Scheduling for Multi-hop Sensor Networks: Non-convexity and Approximation Algorithm", October 7, 2009.
4. Wang, X., Z. Zhao, Y. Xia and H. Zhang, 2010. "Compressed sensing for efficient random routing in multi-hop wireless sensor networks, " in Proc. IEEE GLOBECOM Workshops, pp: 266-271.
5. Bo Jiang, Binoy Ravindran and Hyeonjoong Cho "Energy Efficient Sleep Scheduling in Sensor Networks for Multiple Target Tracking", 2009.