AAU PhD Degree
Tentative Detailed Plan of Research

Title:

Green Routing in Wireless Sensor Network

PhD Candidate

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Project title:	Green Routing in Wireless Sensor Network
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Expected date of completion:	14 NOV, 2012

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Table of Contents

Green Routing in Wireless Sensor Network

1 Research work Summary/Abstract :

Now a day Wireless Sensors Networks (WSN) have emerged as a promising tool for monitoring the physical world. A WSN is a system that consists of thousands of very small stations called sensor nodes. The sensor nodes are deployed in the target area, such as building, a wild nature, or a battlefield etc. These nodes form a network by communicating with each other either directly or through the other nodes. The main function of sensor nodes is to monitor, record, and notify a specific condition at various locations to other stations and end users. One or more nodes among them will serve as sink(s) that are capable of communicating with the user directly or through the existing wired network.

Each tiny sensor nodes, consists of four subsystems: Power Supply Subsystems, Sensing Subsystems, Processing Subsystems and Communication Subsystems. In WSN, a sensor node may simultaneously sense, process and transmit data. In most cases it is very difficult to recharge the battery as it has finite energy. Sensor nodes are useless when the batteries are drained. Therefore energy consumption by a node is a critical aspect in WSN in order to increase the network life time. It is also important to find a solution to extend the network lifetime even if part of sensor nodes dies.

Today the size and cost of sensors are decreasing and people are using large set of unattended, throwaway sensors. Since the sensors are tiny devices with limited storage, computational capability and power, it is necessary that all protocols at all layers in WSN must be energy efficient. Since the routing protocols might differ depending on the applications and the network architecture, in the design of WSN most of the attention should be given to the routing protocols in order to increase the life of the network.

A good understanding of wireless sensor networks and wireless communications is the main learning outcome. Specifically, the research will concentrate on energy consumption of the sensor node and in turn the entire Wireless Sensor Network. Efforts will be made either through the deployment of sensor nodes or through routing so that the total energy consumption of the sensor node will decrease and the overall life of the WSN will increase. This will be supported by simulation of a sensor network application performed with Network Simulator.

Research target is to find the mechanism to deploy the sensor nodes in the target area optimally and also to devise multihop routing strategy in order to maximize the lifetime of WSN for different parameters including energy efficiency, reliability and mobility.

2 The scientific content of the PhD project:

a. Background for the project

Now a day, WSN is an important new area in wireless technology.WSN can provide low cost solution to verity of real-world problems. E.g. habitat monitoring, battle field surveillance, disaster management, health monitoring or industrial control etc. Wireless sensor networks consist of a large number of sensor nodes distributed over a geographic area. As shown in Fig. 1 each tiny sensor nodes, consists of four subsystems: Power Supply Subsystems, Sensing Subsystems, Processing Subsystems and Communication Subsystems [1].

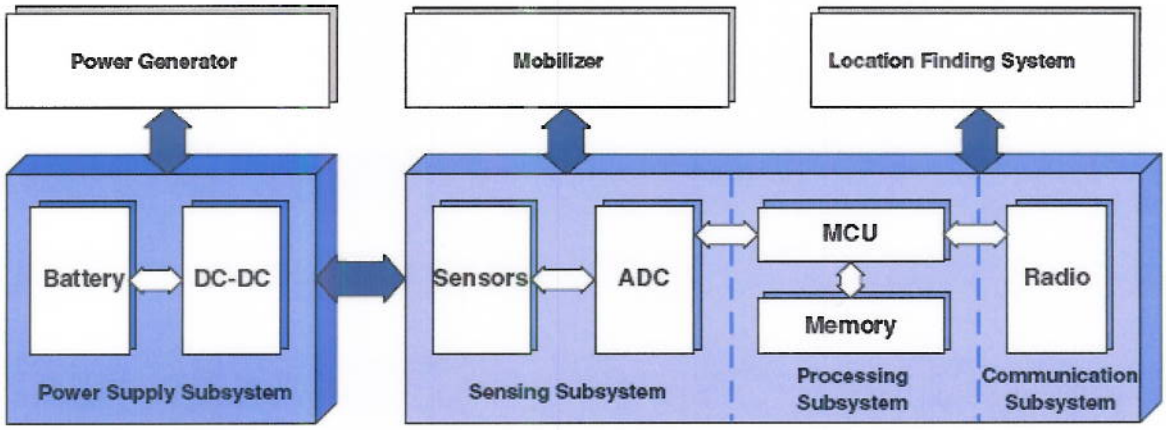

Fig. 1: Structural view of sensor node (source [1])

Among the basic issues of WSN like, sensing range, placement or deployment pattern, computational power, memory, battery power and the transmission capacities, the energy consumption by a node is a critical aspect, in order to increase the network life time [2][3]. In WSN, a sensor node may simultaneously sense, process and transmit data. In most cases it is very difficult to recharge or change the battery as it is having finite energy. Sensor nodes are useless when the batteries are drained. Thus, it is critical and challenging to design long lived WSN with the energy constraints [4].

Since the sensors are tiny devices with limited storage, computational capability and power, it is necessary that all protocols at all layers in WSN must be energy efficient. Since the routing protocols might differ depending on the applications and the network architecture, in the design of WSN most of the attention should be given to the routing protocols in order to increase the life of the network [5]. The performance of a routing protocol is closely related to the sensor node deployment which is application dependent.

b. State-of-the-art for the PhD project

The state-of-the-art gives an overview of the deployment strategies and the routing protocols used in WSN. Generally as shown in Fig. 2 the sensor nodes are deployed inside or close the aimed phenomenon to carry out detecting, processing data and reporting to the collection point called sink or base station. In WSN the deployment of sensor node is either random or fixed.

Random Deployment: Random deployment is the most practical way in placing the sensor nodes. When the target region is subject to severe change in condition or no a priori knowledge is available, random deployment is often desirable to achieve a relatively satisfactory coverage. Random deployment is also practical in military application, where wireless sensor networks are initially established by dropping or throwing. Though many scenarios adopt random deployment because of practical reasons such as deployment cost and time, random deployment may not provide a uniform distribution which is desirable for a longer system lifetime over the region of interest. By random deployment, the sensors are easily overly clustered and there is a small concentration of sensors in certain parts of the sensor field [6]. So in this case the coverage area might be less.

Fixed Deployment: Fixed Deployment produces highly uniform distribution. It minimizes the discrepancy between the distributions. As a result, Fixed Deployment systematically fills the specified area. So it increases the life time of the network. This deployment is not the practical way in placing the sensor nodes when the target region is subject to severe change. So in WSN to deploy

sensor nodes in the target area a new deployment strategy is needed which should be practical and which increases the total coverage area with minimal energy consumption.

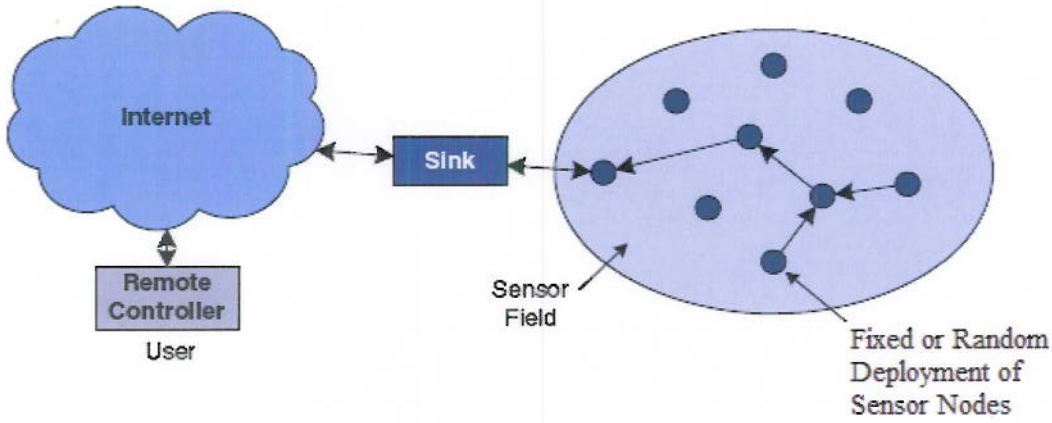

Fig. 2 : Wireless Sensor Network Architecture

Routing in WSN: The state-of-the-art gives an overview of the routing protocols in WSNs and summarizing few of them. The requirements of WSN routing protocols vary depending on the application. Aspects such as energy-efficiency, latency, Quality of Service (QoS), mobility, distribution density or cost, all influence the choice of routing protocol and its parameters. Therefore no single routing protocol that matches with different types of WSNs and the best results can only be achieved by tailoring the routing protocols for a specific application or scenario. Sensor network nodes are limited with respect to energy supply, computational capacity and communication bandwidth. To increase the lifetime of the WSN, designing efficient routing protocols is critical.

Routing Algorithms in WSN: Fig 3 shows the taxonomy of routing protocols.

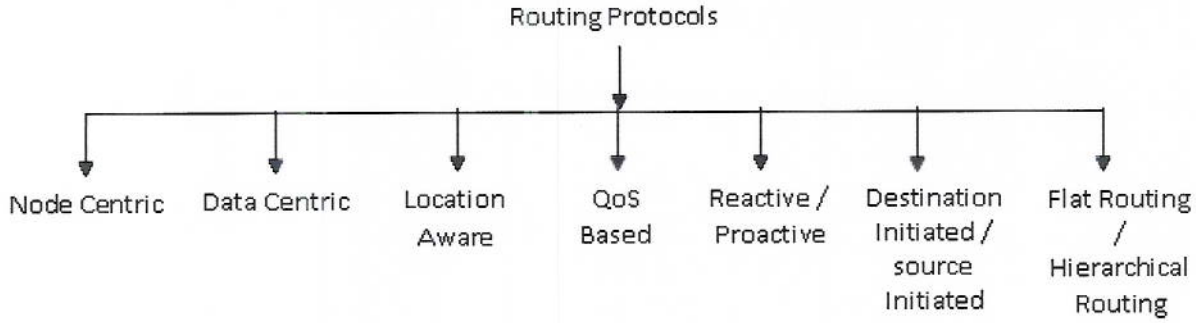

Fig 3: Taxonomy of Routing Protocols

Most Ad-hoc network routing protocols are Node Centric protocols where destinations are specified based on the numerical addresses (or identifiers) of nodes. In WSN, Node Centric communication is not used. Routing protocols designed for WSN are mostly Data Centric or Geo Centric. In Data Centric routing, the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute based naming is necessary to specify the properties of data. Here data is usually transmitted from every sensor node within the deployment region with significant redundancy. In Geo Centric routing nodes know where they are in a geographical region. Location information can be used to improve the performance of routing and to provide new types of services. In QoS based routing protocols data delivery ratio, latency and energy consumption are mainly considered. To get a good QoS (Quality

of Service), the routing protocols must possess more data delivery ratio, less latency and less energy consumption.

In proactive protocol routing paths are set before there is a demand for routing traffic. Paths are maintained even there is no traffic flow at that time. In reactive routing protocol, routing actions are triggered when there is data to be sent and disseminated to other nodes. Here paths are setup on demand when queries are initiated.

In a source-initiated protocol the routing paths are set upon the demand of the source node, and starting from the source node. Here source advertises the data when available and initiates the data delivery. A destination initiated protocol, on the other hand, initiates path setup from a destination node.

Routing protocols are also classified based sensor network architecture [7]. Some WSNs consist of homogenous nodes, whereas some consist of heterogeneous nodes. Based on this concept we can classify the protocols whether they are operating on a flat topology or on a hierarchical topology. In Flat routing protocols all nodes in the network are treated equally. When node needs to send data, it may find a route consisting of several hops to the sink. A hierarchical routing protocol is a natural approach to take for heterogeneous networks where some of the nodes are more powerful than the other ones. The hierarchy does not always depend on the power of nodes. In Hierarchical (Clustering) protocols different nodes are grouped to form clusters and data from nodes belonging to a single cluster can be combined (aggregated).The clustering protocols have several advantages like scalable, energy efficient in finding routes and easy to manage.

Comparison of Routing Protocols:
Following routing protocols according to their design characteristics are compared in Table 1

- SPIN [7][8] - Sensor Protocols for Information via Negotiation
- DD [9] - Directed Diffusion
- RR [10] - Rumor Routing
- GBR [11] - Gradient Based Routing
- CADR [12] - Constrained Anisotropic Diffusion Routing
- COUGAR [13]
- ACQUIRE [14] - ACtive QUery forwarding In sensoR nEtworks
- LEACH [15] - Low Energy Adaptive Clustering Hierarchy.
- TEEN & APTEEN [16] - [Adaptive] Threshold sensitive Energy Efficient sensor Network
- PEGASIS [17] - The Power-Efficient GAthering in Sensor Information Systems
- VGA [18] - Virtual Grid Architecture Routing
- SOP [19] - Self Organizing Protocol
- GAF [20] - Geographic Adaptive Fidelity
- SPAN [21]
- GEAR [22] - Geographical and Energy Aware Routing
- SAR [23] - Sequential Assignment Routing
- SPEED [24] - A real time routing protocol.

Table 1: Classification and Comparison of routing protocols in WSNs.

Routing Protocols Add references	Classification	Power Usage	Data Aggregation	Scalability	Query Based	Overhead	Data delivery model	QoS
SPIN	Flat / Src-initiated / Data-centric	Ltd.	Yes	Ltd	Yes	Low	Event driven	No
DD	Flat/ Data-centric/ Dst-initiated	Ltd	Yes	Ltd	Yes	Low	Demand driven	No
RR	Flat	Low	Yes	Good	Yes	Low	Demand driven	No
GBR	Flat	Low	Yes	Ltd	Yes	Low	Hybrid	No
CADR	Flat	Ltd		Ltd	Yes	Low	Continuously	No
COUGAR	Flat	Ltd	Yes	Ltd	Yes	High	Query driven	No
ACQUIRE	Flat/ Data-centric	Low	Yes	Ltd	Yes	Low	Complex query	No
LEACH	Hierarchical / Dst-initiated /Node-centric	High	Yes	Good	No	High	Cluster-head	No
TEEN & APTEEN	Hierarchical	High	Yes	Good	No	High	Active threshold	No
PEGASIS	Hierarchical	Max	No	Good	No	Low	Chains based	No
VGA	Hierarchical	Low	Yes	Good	No	High	Good	No
SOP	Hierarchical	Low	No	Good	No	High	Continuously	No
GAF	Hierarchical / Location	Ltd	No	Good	No	Mod	Virtual grid	No
SPAN	Hierarchical / Location	Ltd	Yes	Ltd	No	High	Continuously	No
GEAR	Location	Ltd	No	Ltd	No	Mod	Demand driven	No
SAR	Data centric	High	Yes	Ltd	Yes	High	Continuously	Yes
SPEED	Location/Data centric	Low	No	Ltd	Yes	Less	Geographic	Yes

c. Project's objectives

A Green (energy efficient) routing in wireless sensor network has several challenges, such as node mobility, ever-changing topology, data redundancy, tight energy constraint, short range of communication, multi hop routing, scalability, reliability etc. In this research work attempt will be made

1. To develop multihop routing strategy in order to maximize life of WSN for different parameters including energy efficiency, reliability and mobility.
2. Framework will be designed for integrating WSN into the "Internet of Things", where sensor nodes join the Internet dynamically, and use it to collaborate and accomplish their tasks.

d. Key methods.

The research will be based on theory-assisted design and application to practical situations. In WSN, for design and analysis powerful network simulators are available. In the network simulator system modelling will be done, keeping in mind the enterprise scenario. The first stage of the research will be based on a novel deployment strategy called as Quasi Random Deployment (QRD) used for

sensor nodes in the target area. The performance of QRD will be judged based on the energy efficiency of the sensor nodes and it will be compared with random and fixed deployment strategies. In the later stage of the research more concentration will be given on the energy efficient routing in order to increase the network life time.

e. Experiences and results obtained so far and Projects expected outcome

Results obtained so far:

We implemented AODV, DSDV and DSR protocols in NS-2 for both random and quasi random deployment of the sensor nodes in a sensing area of 100x100 m where the number of sensor nodes are varied from 0 to 50 in a step of 10. The results show that for the same energy consumption Quasi Random Deployment approach has better coverage as compared to Random Deployment approach. Based on these results a paper is published in IEEE international conference ICDeCom-11, at BIT Ranchi on February 24-25, 2011 (ISBN: 978-1-4244-9189-6 for Ref).

Expected outcome:

The expected outcome of the research is to develop energy efficient routing strategies to transfer sensor data from nodes to the end user for the purpose of maximizing the lifetime of WSNs.

f. Time schedule with milestones

	Task	Year 1				Year 2				Year 3			
1	Background Study												
2	Literature survey												
3	Requirement gathering and analysis. Feasibility study.												
4	Novel concept development and Problem Specification and Delineation												
5	Framework design and challenges												
6	Implementation												
7	Simulation												
8	Integrating WSN with IoT												
9	Performance analysis and optimization												
10	Result, conclusion, dissemination the PhD study.												
11	Attending PhD courses*												
12	Papers and Conferences												
13	Writing of the Thesis												
14	Stay Abroad												

* I will attend courses organized by Aalborg University through video conferencing and courses related to my research area in well known Institutes in India.

g. Outline of the Content of Thesis

Thesis will be a monograph and below is the brief outline of the thesis.

Affidavit
Acknowledgement
Abstract
Table of Content
List of Figures
List of Tables
List of Abbreviations
Chapter 1: Introduction
1.1 Motivation and Thesis aim
1.2 Thesis Contributions
1.2.1 Problem Statement

1.2.2 Summary of Contributions
1.3 Thesis Outline

Chapter 2:Background and Related Work

2.1 Wireless Sensor Networks
- 2.1.1 Wireless Sensor Networks vs. Traditional Wireless Networks
- 2.1.2 System Architecture and Design Issues
- 2.1.3 Sensor Network Challenges
- 2.1.4 Strategies and Techniques for Node Deployment in Wireless Sensor Networks
- 2.1.5 Applications of Wireless Sensor Network

Chapter 3: Routing in Wireless Sensor Network

3.1 Properties of WSNs affecting routing
3.2 Challenges in WSN Routing
3.3 State of the art of WSN Routing

Chapter 4:System Model (proposed)

4.1 Quasi Random Deployment of Wireless Sensor Node placement in wireless sensor networks
4.2 Design of Routing Algorithms / Protocols
4.3 Architectural Overview
4.4 Conclusions and Outlook

Chapter 5:Installation Simulation and Design

5.1 Simulation Environments
- 5.1.1 Parameters
- 5.1.2 Assumptions

5.2 Scenarios
5.3 Results Performance Evaluation, Analysis and Discussion

Chapter 6:Conclusions and Future Work

6.1 Conclusions
6.2 Future work

Appendix (Reference)

h. Publications

International Conference

[1] Vandana Rohoakale, Nandkumar Kulkarni, Horia Cornean, Neeli Prasad, "Cooperative Opportunistic Large Array Approach for Cognitive Radio Networks", 8th IEEE International Conference on Communications, Bucharest, Romania, 10-12 June 2010, ISBN – 978-1-4244-6360-2.

[2] Nandkumar Kulkarni, Ramjee Prasad, Horia Cornean, Nisha Gupta, "Performance Evaluation of AODV, DSDV & DSR for Quasi Random Deployment of Sensor Nodes in Wireless Sensor Networks", International Conference on Devices and Communications (ICDeCom-11), February 24-25, 2011, ISBN: 978-1-4244-9189-6.

Submission Plan

[1] Nandkumar Kulkarni, Ramjee Prasad, Horia Cornean, Nisha Gupta, Neeli Prasad, "Quasi Random Deployment Strategy in Wireless Sensor Network" **(Working Title)**, IEEE Journal on Selected Areas in Communications **(Last Quarter 2011)**

[2] Nandkumar Kulkarni, Ramjee Prasad, Horia Cornean, Nisha Gupta, Neeli Prasad, "Performance Analysis of Quasi Random Deployment Strategies in Wireless Sensor Network" **(Working Title)**, Springer Journal on Wireless Personal Communications **(First Quarter 2012)**

3 Agreement on the relationship between supervisor and student

Roles

- The student and the supervisors are together responsible for time management in the project. Time plan for the Ph.D. study should be reviewed every six months.
- Supervisor, Co-supervisor (India) will provide technical assistances and supervision.
- The student should be able to get access to lab equipment and technical assistance from both AAU and STES. In cases when advanced equipments are required, the student should make a request at least one month in advance and the supervisors should help the student as much as they can.

Type of collaboration

- Telephone conferences every second week of the month between the student ,the AAU and INDIAN supervisors.
- Workshops every six months.
- Minutes will be made for telephone conferences and workshops.
- Feedback regarding the progress and quality of work will be given during the meetings, conferences and workshops.

Supervision meetings

- Most meetings are scheduled and arranged jointly by the student and the supervisors. In case of special needs, both student and supervisors can call for a meeting.
- Agenda will be provided by the student one day prior to each meeting.
- Common documents will be distributed and maintained via e-mail and/or AFS servers at AAU.
- Every year 3 months PhD Student will be in direct contact with Supervisors at AAU and telephonic and video conferencing meetings with Indian co-supervisor. Remaining 9 months PhD Student will be in direct contact with Indian Co-supervisor and Telephonic and video conferencing with AAU Supervisors.

Workplace participation

- The student is involved in group activities at AAU and STES both.
- The student will frequently meet with research group at AAU and renowned Institutes and multinational companies in India
- Group meetings at STES are usually organized once in a year.

Development plans

- Building Professional network

Writing papers

- Paper writing is on the basis of collaboration between the student and the supervisors. In most of cases, the student prepares the first draft and the supervisors give feedback and comments timely.
- The student will present his/her work at biannual workshops.

Characteristics of and expectation to the research

- Novel Ideas towards standardizations and patents

Developing the cooperation and updating the agreement

- This agreement will be evaluated every six months.

4 Plan for PhD courses *

Courses	Place/ Organizer	ECTS	Joint or Project course	Status
Introduction To Internet Of Things	Nilee Prasad, Albena Mihovska, Zheng Hua Tan, Ole Brun Madsen, Aalborg	1	Project	Completed
Intellectual Property Rights	Lisbeth Tved Linde	2	Joint	Completed
Vehicle Communication	Tatiana Kozlova Madsen and Hans-Peter Schwefel	3	Project	Completed
Air Interface Design for Future Wireless Systems – Towards Real 4G and Cognitive Radio	Prof. Ramjee prasad Prof. Frederikson Suvra Shekhar Das Nicola Marchetti	4	Joint	Completed
"Sensors and RFID Network"	Nilee Prasad Prof. Pedro Jose Marron	3	Joint	Completed
Wireless Communications and Networks.	Dr. Suvra Shekhar Das IIT Khargpur, India	-	-	Completed
Seminar for scientists-patenting and commercialization	Nicolla Marchetti	1	Project	Completed
Bayesian Statistics, Simulation and Software – with a view to Application Examples	Associate Professor Kasper K. Berthelsen	3	Joint	Completed
Distributed Source Coding and Multiple Descriptions	PostDoc Jan Østergaard	3	Joint	Completed
Design Choice and Tradeoffs in Computer System	Prof. Bruce Shriver	3	project	Completed
Writing and Reviewing Scientific Papers, Fall 2	Professor Jakob Stoustrup	3.75	Joint	Applied
PBL In Engineering And Science – Development Of Supervisor	Professor Anette Kolmos	2	Joint	planned
Professional Communication	Professor Anette Kolmos	2.5	Joint	planned
Localization In Wireless Networks	Professor Bernard H. Fleury & Henrik Schiøler & Jakob Gulddahl Rasmussen & Hans-Peter Schwefel	3	Project	planned
Subtotal (Planned)		**8.25**		
Total (Completed)		**23**		

*Based on the PhD Courses Catalogue and this list may change according to the courses available in India.

5 Plan for dissemination of knowledge and findings from the project

- Most of the findings from the research work are going to be published in official conferences and included in the IEEE database according the standard proceedings.
- Furthermore, depending on the quality of the future results, other ways of dissemination -as newspaper articles, seminars, etc. will be considered.
- Depending on the solution and the application, some findings can be published as patents.

6 Agreements on immaterial rights to patents, etc. produced during the PhD project.

The outcome of the research work will be registered for IPR and all the rights will be shared between the Aalborg University and the PhD student, following the standard procedures at AAU.

7 Plans for external collaboration

I will work along with research groups from BITs, Ranchi, India.

8 Financing budget for the PhD project

- CTIF, Aalborg University will provide the research facility.
- Expenses for tuition fee, lodging, boarding and travelling will be borne by STES, Pune

9 Short References

[1] Giuseppe Anastasi , Marco Conti, Mario Di Francesco and Andrea Passarella, "Energy conservation in wireless sensor networks: A survey", Ad Hoc Networks 7 (2009) 537–568

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