AAU PhD. Degree
PhD Study Plan of Research

Title

"Energy Efficient Bandwidth Management in Wireless Sensor Networks"

PhD Candidate

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AALBORG UNIVERSITET

PhD Study Plan

Study plan 2 months: ☐

Study plan 11 months: ☒

Doctoral Programme **:** Wireless Communications

Project title **:** Energy Efficient Bandwidth Management in Wireless sensor Networks

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Date of Enrolment **:** 15th March 2011

Expected Date of

Completion **:** 14th March 2014

Signature

12/04/2012
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PhD student [Mantri Dnyaneshwar S.]

Study plan approved

Date Supervisor Ramjee Prasad

Date Head of Department Børge Lindberg

Date Head of Doctoral Programme Gert Frølund Pedersen

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"Energy Efficient Bandwidth Management in WSN"

SECTION 1: RESEARCH WORK SUMMARY / ABSTRACT

Wireless Sensor Network (WSN) is made up of number of tiny embedded devices as nodes, which are capable of sensing, processing and communicating. The information received from different node is used for monitoring and control of various applications, e.g., habitat monitoring, e-health, e-agriculture, smart homes, vehicle tracking and detection.
A common characteristic of these applications require high fidelity level, timely packet delivery and addictiveness to changing conditions. However, WSNs are constrained by several limitations such as low network bandwidth, unreliability of wireless links, low-power, memory and processing constraints on individual sensor nodes.
When large numbers of nodes are deployed in the formation of application specific network, then power utilized by sensor node decides the communication range between source and sink. If sources and sink are located at far distance from each other then processing capacity of these nodes enables to aggregate the data at one of the intermediate node. In this context energy consumption, network life time and communication bandwidth of WSN is greatly influenced by the changes in the network topology and the way of aggregating data. One of the efficient approaches is cluster based data aggregation and in network processing of data.
Also real-time applications require measurement of end- to- end delay for guaranteed throughput. The transmission of real-time traffic over such networks requires both energy and bandwidth. As source (sensor) nodes in the network provides information in the form of events, may cause the network become heavily overloaded at particular time and causes congestion leading to inefficient resource utilization. It is necessary to design an efficient protocol for dynamic bandwidth utilization and to minimize over head and congestion in WSN. The sink and cluster head decides how to allocate network bandwidth to sensor stream by considering a schedule based approach of aggregating the data. In addition management of network resources as energy and bandwidth are challenged by WSN design for increase in life time of network.
The main outcome of this thesis will be

- Developing an bandwidth efficient data aggregation technique
- Scheduling algorithm for proficient data aggregation to reduce overheads
- Improvements in data aggregation in terms of synchronization.

The research will be carried out using analytical and mathematical modeling along with simulations. The research target is to develop a scheme for dynamic bandwidth utilization with increase in energy efficiency and network life time to meet the changing requirement of WSN.

SECTION 2: SCIENTIFIC CONTENTS OF RESEARCH

a. Background of the project:

WSNs equipped with low-cost devices have communication capabilities that can directly interact with real-world business and physical processes. However, constrained imposed by the WSN includes low network bandwidth, unreliability of wireless links, low-power radio, memory and processing of data on individual sensor nodes [1].
In operational WSNs, deployment of node has number of issues regarding aggregation such as efficient delivery of data to sink, delay in in-network processing, topology maintenance, Scheduling and Synchronization of participating nodes. When nodes are self-organized into number of clusters, they can increase communication efficiency via cooperation. In the cluster based networks nodes communicate with its cluster head either in one hop or multi hop and have advantages over flat networks. The main advantage is clustering improves the scalability by stabilizing the network topology [2]. Also network is operational even if one cluster head fails. It also involves lower delay

since sensor nodes perform short range transmissions to the cluster head and have simple routing structure [3]. In the event based sensing, certain nodes detect the event and send data to its cluster head which will be routed to sink. If all cluster heads communicates to sink at a time, there will be probability of congestion and loss of data. In all, communication and processing overhead is caused by inefficient utilization of bandwidth, decreases in throughput and energy efficiency. To address these problems, research concentrates on Data aggregation approach with scheduling and Synchronization. Also control mechanisms for resource management will depend on the introduction of node specific condition and storage of network state information.
For the improvement in bandwidth utilization, Cross-layer design is optimum. It increases the level of coordination and interaction between communication layers. It has received increasing recognition as an efficient resource management design strategy for sensor network.

b. State-of-Art

The state-of-the-art represents an overview of different strategies and protocols used for energy efficiency bandwidth utilization. Data aggregation techniques are used to provide the effective bandwidth utilization when density of node in the network increases. Factors that affect on the effective utilization and management of bandwidth are density of nodes in the network, topology used, path loads, Time synchronization and formation of cluster. The main MAC protocols that are used in the WSN are either contention or Scheduled based. Normally for effective utilization of bandwidth with energy efficiency, schedule based protocols are preferred (TDMA or TDM-FDM). Also no single protocol matches with different types of WSNs and the best results can only be achieved by tailoring the protocol for a specific application or scenario.
The data aggregation protocols can be classified according to structure used for the formation of network, some protocols uses in network processing for the aggregation of data [3], this approach is suitable for the stationary sensors but need spatial considerations for the mobile nodes. In [4] author proved that the data centric routing approach is better than address centric for the aggregation of information. It shows that the performance is greatly affected by placement of sink and sources when the density of nodes in the network increases. In[5] author proposed the hybrid aggregation architecture with static tree based structure and dynamic cluster based structure it helps to improve the error probability and transmission cost by grouping the number of nodes in to spatial and temporal correlation but affects the performance if number of group increases. In [9] trade off between aggregation throughput and gathering efficiency is presented with single hop and multi hop length schemes. The aggregation is achieved using perfectly compressible function which shows MLH scheme is scalable. In [11] aspect of data aggregation is considered in accordance with delay performance with link scheduling and node specific interference models. This approach is suitable for small network size. In [12] author explained time-slotted, scheduled MAC algorithm by clustering the nodes in different frequency domains. Network provides high connectivity but due to limited time slot the network capacity degrades. When real time applications are considered normal routing does not match the time requirement. The problem can be solved using linear path programming approach [13]. To increase the efficiency of real time events with reduced uncertainty 802.11.4 based MAC protocol is used [14]. In [15] author explained the management architecture for heterogeneous WSN used for monitoring purposes. The network is divided by a node of the same type in one group and a wireless mesh network (WMN) operates as the communication gateway between these groups of nodes. Thus round trip time is reduced. It has problem of synchronization of nodes. The energy efficiency in management of WSN can also be achieved by utilizing unused space of data packet [16]. A survey of resource allocation, Scheduling and TDMA protocols have been reported in [17][18]. Another approach for bandwidth allocation is time frequency slot scheme used in cluster of nodes. Due to this approach network capacity increases with reduced channel interference. It considers the frequency reuse factor but has the drawback of time synchronization [19]. In [20] sink node gets the maximum information by considering the deadline constraint to achieve energy delay tradeoffs. It improves the quality of data received but

incures data loss. Author considers the one hop tree structure and interference model with deadline imposed by sink.

In all maximizing the network life time and reducing the number of transmissions from source to sink using optimal data aggregation tree has been shown to be NP hard. The comparisons of different algorithms used in data aggregation are presented in Table 1.

Table1. Data Aggregation algorithms

Algorithm	Topology used and aggregation. approach	Performance measures	Advantage	Disadvantage
ACO[6]	Aggregation tree [Routing] Hop count	It uses the search space for finding the aggregation node. It has initial delay in finding the path but shows reduced energy costs.	Energy saving increases due to shortest path for packet to travel. With nearest hop	Source node near the sink cannot aggregate the data packet also requires more runs to formation aggregation tree.
GRASS[7]	Tree In network Agg. + routing	Maximizing the network life time, low energy dissipation and latency. It uses the Aggregation overlap factor.	Reduces the overload due to less aggregation points	Selection of Aggregation node is difficult Need synchronization.
EEIA[10]	ree [Indexed Routing] Reduction in Query related message processing	Remaining power on each node to enhance the energy usage and improvement of network lifetime [the main constraint consider are energy, and memory]	Considerable power saving and increased network life time	Requires maintenance of index table for nodes with fewer thresholds. It has increased energy wastage.
LEO [21]	Tree Shortest path event driven	Network life time and energy efficiency.	Ensures reliability and congestion avoidance It considers multiple paths to forward the data. Reduces the Computational overhead.	Does not support mobility and heterogeneity of node
LEACH[2]	Cluster	Energy efficiency and delay in processing	Scalable to network changes	Not suitable for tracking movements of targets . nodes makes autonomous decisions without central control
CPDA [8]	Cluster [no..of bytes of all packets]	Privacy preserving efficiency, Accuracy, computational overhead.	Reduced communication overhead	Has computational complexity due to bidirectional links
ADA [22]	Cluster [Event driven]	Reliability with temporal and spatial aggregation degree, sensing range.	Scheme gives the reliable aggregation when state converges from any starting point.	Not scalable for dense WSN Performance affects with sensing range.
Dy DAP[23]	Privacy and End to end security	Transmission buffer overflow, Estimation accuracy and Energy efficiency.	Provides better estimation Accuracy with reduced buffer size, Avoids network congestion.	It requires the computational and power resources

The comparison shows the topology used, performance measure, advantages and disadvantages. It shows that present algorithms lacks in bandwidth utilization with energy efficiency.

c. Research Objectives:

The bandwidth constraint has direct impact on QoS and efficiency of WSN. The Bandwidth utilisation is affected largely because of protocols used in MAC and network layer of WSN protocol stack. Therefore it is necessary to improve it in terms of energy, life time and efficient bandwidth utilization of WSN. In this regard the research objective is to develop a mechanism by considering following strengths,

- Developing an bandwidth efficient data aggregation technique
- Cluster based Scheduling mechanism for proficient data aggregation.
- Improvements in data aggregation in terms of synchronization.

d. Key methods

The research will be based on theory assisted applications to practical situations. In WSN, for design and analysis powerful network simulators are available. The plan is to use NS-2 and Matlab possibly complimented by Omnet++. In the network simulator system modelling will be done. The first stage of the research work is to investigate the cluster based Data aggregation technique for energy efficiency and bandwidth utilization with static and mobile nodes. In the later stage of the research more concentration will be given on design of Schedule based data aggregation model. The analyses of the model will be done for determination of parameters and results will be verified with simulator. In the last stage more concentration will be given to mathematical modelling. Some of the key methods include mathematical analysis and experimentations on network simulator tools.

e. Experiences and results obtain so far with project expected outcome

The experiences and result obtained so far are,

- Analysed the functional requirement of efficient band width utilization
- Understood that data aggregation is one of the techniques, using that we can achieve the goal.
- Proposed the two level data aggregation protocol and working on its implementations.

The expected outcome of the research is to develop energy efficient bandwidth utilization strategy for the mobile nodes in WSN. It finds applications in vehicular sensor networks for an increase in efficiency and bandwidth utilization.

f. Milestones and Time schedule

These are the milestones planning to achieve as part of my PhD with relative duration in months.

- **Milestone1 (M2):** Understand literature of WSN according to application and requirement.
- **Milestone2 (M2):** Determining motivations, questions and research challenges, direction and problem specifications.
- **Milestone3 (M6) :** Defining the functional requirements which will cover detailed study of risks and mitigations ,necessary extensions and novel developments.
- **Milestone4 (M9):** Researching on different mechanism for design of band width management frame work.

- **Milestone5 (M12)**: Design of bandwidth management frame work and check for the feasibility including mobility of nodes, Submission of conference paper based on Data aggregation in WSN.
- **Milestone6 (M15):** Evaluating phases, defining of performance metrics and comparison with existing works and writing paper in conference or journal based on Cluster based approaches for stationary and mobile nodes.
- **Milestone7 (M18)**: Devising techniques and methods for evaluation Schedule based Data aggregation in WSN
- **Milestone8 (M21):** Do simulations according to modelling. To do few courses during this 6 month period and submission of conference Paper.
- **Milestone9 (M23):** Develop TDMA based adaptive bandwidth allocation scheme and submission of journal paper
- **Milestone9 (M24):** Analyse the effect of Synchronization on Data Aggregation with bandwidth efficiency and submission of conference Paper.
- **Milestone10 (M27):** To finish the courses and complete 30 ECTS .
- **Milestone11 (M30):** Based on the results of Synchronization Submission of Journal Paper.
- **Milestone12 (M33)**: To start writing thesis and simultaneously do refinements towards finishing PhD, by the end of M34.
- **Milestone13 (M36):** Wind up the PhD work, and publish all the work done.

- Time schedule with milestones (3 years plan)

	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 application												
9	Performance analysis ,optimization and refinements												
10	Result, conclusion, dissemination the PhD study.												
11	Attending PhD courses*												
12	Papers and Conferences												
13	Writing of the Thesis												
14	Stay Abroad												

***** 3 months at AAU & 9 months at INDIA (GISFI, Lonavala) every year

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

g. Outline of the contents of Thesis

The thesis will be organized as a monograph. The outline of the thesis contents are as mentioned below

h. Tentative Titles on Papers

Co-authors

Dnyanesh S Mantri, Neeli R Prasad, Jens M Pedersen, Shingo Ohmori, Ramjee Prasad

Publications planned	
1.	"Two tier cluster based data aggregation in Wireless sensor network", To be submit to conference.
2.	"Effect of mobility on cluster based data aggregation in Wireless Sensor Networks", To be submit to journal.
3.	"Bandwidth Efficient Schedule based Data Aggregation in WSN " , To be submit to Conference.
4	"TDMA based adaptive bandwidth Allocation in Wireless Sensor Network" ,To be submit to Journal.
5.	"Effect of node synchronization on Efficient Data Aggregation", to be submit to Conference.
6.	"Bandwidth Efficient Synchronized Data Aggregation in Wireless Sensor Networks", To be submit to Journal.

SECTION 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 PhD. 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

- Literature Survey and Research Report prepared by PhD student is reviewed by Supervisors through formal meetings and discussions.
- Telephone meetings every second week between the student and the AAU and Indian supervisors.
- Feedback regarding the progress and quality of work will be given during the meetings, conferences and workshops.
- Common documents will be distributed and maintained via e-mail and/or AFS servers at AAU. Large amount of data can be exchanged via optical disks or hard disks.

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.
- Telephone conferences every two months for all PhD students, supervisors and manager. Meetings once a week between the student and the Indian supervisors.
- Agenda will be provided by the student one day prior to each meeting.
- 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 a staff member of both India and AAU and gets involved in group activities in both places.
- The student will frequently meet with research group at AAU and renowned Institutes and multinational companies in India.

Development plans

- The student will present his/her work at biannual workshops.

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.

Characteristics of and expectation to the research

- Novel Ideas towards standardizations and patents.

Developing the cooperation and updating the agreement

- At Regular intervals PhD students and supervisors can discuss the potential needs for updating the agreement and for any modifications will consult with the department or the Research school.
- This agreement will be evaluated every six months.

SECTION 4: PhD COURSES PLAN

Courses	Place/Organized by	ECTS	General /project course	Status
Design Choice and trade off in Computer architecture	Bruce Shriver. Aalborg university	3	General	completed
Distributed source coding and multiple descriptions	Post Doc Jan Ø stergaard,	3	Project	completed
Analysis and design of high performance future internet infrastructure	Associate Professor Jens Myrup Pedersen, M.Tahir Riaz,	2	Project	completed
Management of Research and Development	Professor Frank Gertsen	2.5	General	Completed
	Subtotal	**10.5**		
Theory and Practice of Cognitive Radio	Associate Professor Petar Popovski	3	Project	Registered
Bayesian Statistics, Simulation And Software - With A View To Application Examples	Associate Professor Kasper K. Berthelsen	4	Project	Registered
Sensors and RFID Networks	Neeli Rashmi Prasad	2.5	Project	Planned
Network Coding: Theory and Applications	Professor Muriel Medard, Frank Fitzek	4	Project	Planned
Advanced Topics in IT Security	Associate Professo Rene Rydhof Hansen	2	Project	Planned
Writing and Reviewing Scientific Papers	Professor Jakob Stoustrup	3.75	General	Planned
Practical Project Management, Spring 2	Pia Bøgelund	1	General	planned
	Subtotal (planned)	**20.25**		
	Total ECTS	**30.75**		

* I will attend courses based on the PhD Courses Catalogue of Aalborg University and well known institutes in India. Courses will be decided in consultation with Supervisor.

SECTION 5: PLAN FOR DISSEMINATION OF KNOWLEDGE AND FINDINGS FROM PROJECT

Publication Plan:

I will publish papers on my research work in the following conferences and Journals

Sr. No	Name of the Conference and Journals	Conference Dates	Location	Conference Web Site
C1	ISWCS2012	August 28-31, 2012	Paris, France	http://www.iswcs2012.org/initial-submission
C2	WPMC 2012	September 24-27, 2012	Taipei City, Taiwan	http://wpmc2012.ntu.edu.tw/Venue.asp
C3	IEEE CAMAD 2012	September 17-19, 2012	Barcelona, Spain	http://camad2012.av.it.pt/
C4	ICCICT 2012	October 19-20, 2012	Mumbai, India	http://conference.spit.ac.in/important-dates/index.html
J1	Wireless Personal Multimedia Communications	Journal	Springer	http://www.springer.com/engineering/signals/journal/11277
J2	IEEE Communication Society Journals	Journal	IEEE	http://www.comsoc.org/publications/journals
J3	IEEE/ACM Transactions on Communication and Networking	Transactions	IEEE/ACM	http://www.ieee.org http://www.acm.org

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 papers will be published in 2013 and 2014 conferences.

SECTION 6: AGREEMENTS ON IMMATERIAL RIGHTS TO PATENTS

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.

SECTION 7: PLAN FOR EXTERNAL COLLABORATION

In connection with the project work the candidate will stay with Sinhgad Technical Education Society in India, except for two 3 month stays at Aalborg University during the first two years**.**

SECTION 8: FINANCING BUDGET FOR THE PHD

- CTIF, Aalborg University will provide the research facility.
- Expenses for tuition fee, lodging, boarding and travelling will be borne by Sinhgad Technical Education Society (STES), Pune, India.

SECTION 9: SHORT REFERENCES

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