AAU PhD Degree
PhD Study Plan of Research

Title:

Green and Secure Medium Access Control for Wireless Sensor Network

PhD Candidate

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AALBORG UNIVERSITET

Doctoral Programme **:** Wireless Communications

Study plan 2 months **:**☐

Study plan 11 months **:**☒

Project title **:** Green and Secure Medium Access Control for Wireless Sensor Network

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

Expected Date of

Completion **:** 14th March 2014

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15/03/2012 _____
Date PhD Student [Pranav Mothabhau Pawar]

Study plan approved

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Table of Contents

Green and Secure Medium Access Control for Wireless Sensor Network

1 Project summary/abstract

Wireless sensor networks (WSNs) have great application value and wide prospect in the fields of military, agriculture, environmental monitoring, medical health, industry, intelligent transportation, building monitoring, space exploration and many others. In a WSN, nodes are working under severe resource constraints such as limited battery power, limited communication bandwidth, limited computing power and limited memory.

As of today, energy consumption by a sensor node is a major constraint in a WSN where the main criterium is to extend the lifetime of the network without jeopardizing reliable and efficient communications. Energy is consumed at all layers network protocol, but the medium access control (MAC) layer consumes a significant share of the energy.

MAC plays a key role in determining the channel capacity utilization, network delays and most important, energy consumption. In order to support applications comprised of large networks, it is necessary to design good MAC layer protocols that are energy efficient with good throughput, latency, network lifetime, fairness, scalability and adaptability also in dynamic environments.

Recent applications of WSN are increasingly including sensitive information that adds to the security constraints on WSN communication. Hence, a WSN MAC protocol should not only be able to efficiently control the channel access, but should also be robust against security threats.

The proposed research will focused on investigating hybrid MAC mechanisms with the following objectives,

- Scheduling algorithms, which minimize conflicts and offer better synchronization.
- Transmission control mechanisms, which shift the modes according to traffic conditions.
- Reduce the effect on performance of security attacks in WSNs.

The research will be carried out using analytical and mathematical modeling along with simulations. The research target is to develop a MAC layer protocol, which will be energy efficient and secure and thereby satisfies the requirements of current and future WSN applications.

2 The scientific content of the PhD project

A Background for the project

A wireless sensor node is a tiny device that includes three basic components: a sensing subsystem, a processing subsystem and a wireless communication subsystem. In an operational WSN, a number of issues arise such as energy consumption, data processing and dissemination, topology management, security, etc. Two of the most important issues are energy consumption and security issues at the MAC layer [1, 2] and this research concentrates on these.

The MAC layer plays a central part in the design since it controls the active and sleeping state of each node. Good MAC protocols hence need to improve longevity, reliability, fairness, scalability, latency and throughput, but the design of a MAC protocol for WSNs is mainly impacted by strict energy constraints. The major causes of energy consumption are [3,4],

- Collision
- Overhearing
- Protocol overhead
- Idle listening

- Over-emitting

The design of a MAC layer protocol should be reliable not only in terms of energy consumption, throughput and latency but should also take care of security threats. Without proper security mechanisms, WSNs will be confined to limited and controlled environments, thus negating numerous of the promises they hold [5, 6]. Some of the most notable security attacks concern with the MAC layer are,

- Denial of service attack
- Synchronization attack
- Denial of sleep attack
- Collision attack

However the performance of the MAC protocol can be improved to make it better cope with energy efficiency and security simultaneously to achieve the WSN requirements [7,8].

B State-of-the-art for the PhD project

The state-of-art gives an overview of types of sensor MAC protocols, basic flow of hybrid MAC mechanisms, comparison of different hybrid MAC mechanisms and considered WSN MAC security attacks.

In WSNs, MAC protocols can be classified in contention- and schedule-based protocols according to the number of possible contenders upon a transmit opportunity toward a receiver node. In contention-based protocols; any of the receiver's neighbors might try its luck at the risk of collisions. Accordingly, those protocols contain mechanisms to avoid collisions or to reduce their probability. Scalability and adaptivity are the strengths of these protocols. In schedule-based protocols, only one neighbor gets an opportunity and collisions are avoided. These protocols have a TDMA component, which provides also an implicit idle listening avoidance mechanism: when a node knows its allocated slots and can be sure that it communicates only in these slots, it can safely switch off its receiver at all other times. Furthermore, new hybrid MAC protocols combine the strengths of contention- and schedule-based protocols while offsetting their weaknesses.

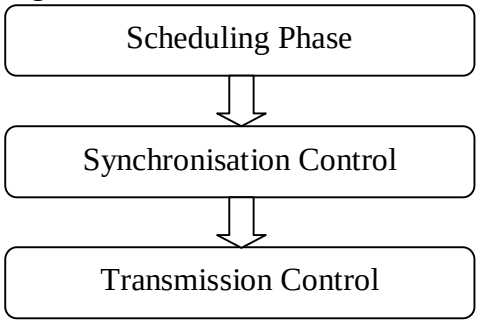

Figure 1: Basic flow of hybrid MAC mechanisms

The basic flow of a hybrid MAC mechanism is shown in figure 1. During the scheduling phase, nodes find one or two hop neighbors based on the requirements and prepare a neighbor list. This list is given as input to the slot assignment or scheduling algorithm, which assigns a slot to all nodes in the network based on a slot assignment algorithm. The period on which nodes decide to use a time slot for transmission is called a time frame and every node has to synchronize its time frame during transmission. The next phase is synchronization where nodes synchronize according to the respective slots, which can happen either through global or simple local synchronization. During the transmission control, nodes will transmit based on the modes set – contention- or schedule-based depending on traffic conditions. Nodes will use their assigned slot whenever nodes want priority over their traffic and will otherwise work in contention-based mode [9].

The below table explains different hybrid MAC mechanisms and provide a comparison between them.

Table 1: Comparison of hybrid MAC mechanisms

Protocol	Scheduling mechanism	Transmission control and framing	Clock synchronization	Advantages	Disadvantages	Security Addressed (Yes/No)
Z-MAC [10]	DRAND (Distributed RAND), no two nodes within two-hop communication neighborhood are assigned to the same slot.	Node shift from LCL (Low contention level) to HCL (High contention level) and vice versa depending on level of contention. Node will shift to HCL only when it will receive ECN (Explicit contention notification).	TPSN for global clock synchronization and RTP/RTCP for local clock synchronization.	Energy efficient with high channel utilization, Good fairness as compared with TDMA and CSMA MAC.	Scalability problems because of network wide deployment of TDMA schedule.	No
Funneling MAC [11]	Sink oriented scheduling, on-demand beaconing to trigger the localized TDMA in funneling region.	Consist of combination of CSMA and TDMA frame called super-frame. Transmission takes place by exchanging beacon, super-frame and schedule.	Light weight clock synchronization is embedded in beacon message	Avoid funneling effect, scalability problems are reduced by reducing TDMA scheduling only in funneling region. Maximize the throughput.	Extra overheads are incurs to avoid MAC interference. More signaling overheads.	No
Centralized Hybrid MAC [12]	Priority based centralized scheduling	Cluster based distributed communication. Super-frame consists of a device window (which is divided into a request period and, a header window, a data communication window, and an inactive period).	Beacons for network synchronization, centralized network wide synchronization.	Guarantee throughout access for selected users even under extremely high demand situations. Support periodic shutdown scheme for low-power consumption.	Not good for more dense network. The throughput degrades as the network density decreases.	No
HYMAC [13]	Breadth first search scheduling	Fixed length TDMA cycle composed of a number of frames. Each frame is divided into fixed time slots where during each slot contains a packet. It provides hello packet, schedule packet and data packet.	FireFly based hardware synchronization.	High throughput, bounded end-to-end delay across multiple hop, collision free operation and predictable lifetime. Energy efficient because of collision free operation.	Required hardware based synchronization	No
CRMAC [14]	Cluster based scheduling	Its operation is divided into rounds, and each round consist of a setup phase and several super-frame, which are further divided into slot reserve step, schedule assigned step and guaranteed data transmission step.	Beacon based network synchronization	Suitable for short packet transmission under low load networks. Nodes spend very small time in contention phase, so reduce the energy consumption. Good throughput	Suitable only for short packet transmission. Not suitable for heavy traffic.	No
EQ-MAC [15]	Cluster based random scheduling	Long messages get a schedule TDMA slot and short control messages get assigned random access slot. Uses data prioritization, four different queues for transmission purpose. Normal slot used for data transmission.	Mini-slot is used to maintain synchronization among nodes. It contains sync, request and receive scheduling.	Energy saving is achieved by differentiation between control and data messages. Achieve channel according to their traffic priority levels.	Introduces the larger amount delay under low priority traffic. Synchronization errors are neglected.	No
ER-MAC [16]	Separate slot for uni-cast and broadcast	Frame is divided into contention-free period and contention period.. Have pair of queue to high and low priority data. Two modes of transmission emergency mode and normal mode.	Local time synchronization using parent-children broadcast synchronization like root-neighbor synchronization of FTSP.	Flexibility to adapt to traffic and topology. Good for emergency WSN. Higher delivery ratio. Synchronized slot structure.	Not scalable for large density.	No

The next part of the state-of-art gives an overview of MAC layer attacks.

Collision Attack: When there is a packet transmitting on the channel, adversaries can easily conduct attacks through sending out some packets to disrupt it such as data packets, control packets sent by normal nodes[17, 18].

Denial of Sleep Attack: Energy aware sensor networks periodically place nodes to sleep in order to extend the network lifetime. Denying sleep effectively attacks each sensor node's energy resources and rapidly drains the network lifetime [19,20].

The above-mentioned state-of-art shows the trend in the development of hybrid MAC layer mechanisms for WSN.

C Project's objectives

Hybrid MAC is an efficient solution for WSN as it saves significant amounts of energy with good throughput. The research objective is to develop Green and Secure Hybrid MAC (GSHMAC) mechanism by considering,

- To develop cluster-based energy efficient and secure slot assignment mechanism for TDMA scheduling phase with better synchronization.
- Cluster-based transmission control to shift modes according to the traffic conditions.
- To develop a security mechanism to reduce the effect of the denial of sleep attack on a hybrid MAC mechanism.

D Key methods

The research will be based on theory-assisted design and application to practical situations. Simulators will be used to design and analyze the system according to the scenario.The first stage of the research is to investigate a cluster-based energy efficient slot assignment algorithm and to check its applicability with varying traffic conditions and mobility. In the second stage, the research will focus on development of secure slot assignment algorithm with better synchronization control. In the last stage, more concentration will be given to security mechanisms to integrate in hybrid MAC to protect it from malicious attacks such as denial of sleep attacks. Research will also focus on behavioral modeling of different denial of sleep attacks and to explore the possibilities of new attacks.

E Experiences and results obtain so far with project expected outcome

The experiences and results obtained so far are,

- The research evaluated and compared the performance of contention, schedule and hybrid MAC mechanisms and analyzed the requirements to design an enhanced hybrid MAC mechanism.
- The research analyzed the different WSN MAC security attacks and modeled the behavior of these attacks. The effect of these attacks on hybrid MAC mechanisms was also investigated and solutions to reduce the effect of attacks were proposed.
- The research also explored new possibilities of attacks on WSN MAC layer by considering some specific assumptions.
- The research proposed two cluster-based TDMA scheduling algorithms based on single and multi-coloring respectively and also compared their performance with existing scheduling algorithms in static and mobile scenarios.

Later research will focus on better synchronization in slot assignment, transmission control in cluster-based environments and security.

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

*3 months at AAU and 9 months in India every year.

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

These are the milestones planning to achieve as part of my PhD with tentative months.

- **Milestone 1 (M1):** Understanding WSN MAC protocols, their energy efficient applicability and security requirements.
- **Milestone 2 (M2):** Determining motivations, questions and research challenges, direction and problem specifications.
- **Milestone 3(M3):** Defining the functional requirements, which will cover detailed study of risks, mitigations, necessary extensions and novel developments. Survey paper will be published in conference and journal.
- **Milestone 4(M4):** Researching on different Energy Efficient MAC protocols and analyzed the requirement of better hybrid MAC.
- **Milestone 5 (M8):** Design of energy efficient TDMA scheduling algorithm.
- **Milestone 6 (M10):** Evaluating phases, defining performance metrics and comparison with existing works and writing conference/journal paper.
- **Milestone 7 (M12):** To do few courses during this 6 month period and submission of Journal Papers. Understanding effect of different security attacks on MAC efficiency. To develop the secure slot assignment technique and to publish it in journal or conference.
- **Milestone 8 (M14):** Studying the effect of synchronization on TDMA scheduling and to come with new synchronization algorithm.
- **Milestone 9 (M17):** Analyzing the transmission control mechanisms, to develop the cluster based transmission control mechanism and to check its effect by simulation.
- **Milestone 10 (M19):** To develop a defense mechanism against denial of sleep attack and simulate it.
- **Milestone 11 (M20):** Submission of Journal Paper.
- **Milestone 12 (M23):** To start writing thesis and simultaneously do refinements towards finishing PhD, by the end of M26.
- **Milestone 13 (M27):** Write up the PhD work, and publish all the work done.

G Outline of Content of Thesis

The thesis is expected to be in the form of a monograph with the outline:

Abstract

Preface

Acknowledgements

Publications

Contribution to Published Papers

List of Abbreviations

List of Figures

Chapter 1: Introduction

H Publications Titles

Co-authors

Pranav M. Pawar, Rasmus H. Nielsen, Neeli R. Prasad, Shingo Ohmori, Ramjee Prasad

Publication Completed

1. "Hybrid mechanisms: Towards an efficient wireless sensor network medium access control", WPMC 2011, Brest, France, 3-7 Oct. 2011.
2. "Behavioral Modeling of WSN MAC Layer Security Attacks: A Sequential UML Approach", Journal of Cyber Security and Mobility, Vol. 1, Issue. 1, River Publishers, Jan 2012.
3. "GCF: Green Conflict Free TDMA Scheduling for Wireless Sensor Network", 3rd Workshop On Energy Efficiency in Wireless Networks & Wireless Networks for Energy Efficiency (E2Nets), IEEE ICC 2012, Ottawa, Canada, 10-15 June 2012.

Publication Submitted

1. "M-GCF: Multicolor Green Conflict Free Scheduling for Wireless Sensor Network", IEEE 76th Vehicular Technology Conference: VTC-Fall 3-6 September 2012, Qubec City, Canada.

Publication Planned

1. "Single and Multicolor TDMA Scheduling Algorithms for WSN", To be submit to journal
2. "GSCF: Green and Secure Conflict Free Scheduling for Wireless Sensor Network", To be submit to conference.
3. "Activity Modeling and Comparative Evaluation of WSN MAC Security Attacks", To be submit to conference/journal.
4. "Tight Synchronization for Cluster Based TDMA scheduling", To be submit to conference.
5. "Performance Improvements of GCF and MGCF due to Tight Synchronization", To be submit to conference/journal.
6. "SSGCF: Synchronize and Secure Green Conflict Algorithm for TDMA Scheduling", To be submit to journal.
7. "GHMAC: Green Hybrid Medium Access Control for Wireless Sensor Network", To be submit to journal/transaction.
8. "Secure Hybrid Mechanism Against Denial of Sleep Attacks", To be submit to journal.
9. "GSHMAC: Green and Secure Hybrid Medium Access Control for Wireless Sensor Network", To be submit to journal/transaction.

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 and 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 equipment is 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 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 at least 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	General or Project course	Status
Design choices and tradeoffs in Computer Systems	Visiting Professor Bruce Shriver	3	Project	Completed
Distributed Source Coding and Multiple Description	Associate Prof. Jan Ostergaard	3	Project	Completed
Theory and Practice of Cognitive Radio	Associate Professor Petar Popovski	3	Project	Registered

Management of Research and Development	Professor Frank Gertsen	3	General	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
Intellectual Property Rights	Morten Dahlgaard Andersen	2	General	Planned
Subtotal (Planned& Registered)		**24.25**		
Total (Completed)		**6.00**		
Total		**30.25**		

* 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

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
1	COMM 2012	June 21-23, 2012	Bucharest, Romania	http://comm2012.ncit.pub.ro/
2	MOBISEC 2012	June 25-27, 2012	Frankfurt am Main, Germany	http://mobisec.org/2012/show/steering-com
3	ISWCS2012	August 28-31, 2012	Paris, France	http://www.iswcs2012.org/initial-submission
4	ENERGYCON2012	September 9-12, 2012	Florence, Italy	http://energycon.ieee-sezioneitalia.it/index.php?option=com_content&view=article&id=3&Itemid=5
5	IEEE CAMAD 2012	September 17-19, 2012	Barcelona, Spain	http://camad2012.av.it.pt/
6	WPMC 2012	September 24-27, 2012	Taipei City, Taiwan	http://wpmc2012.ntu.edu.tw/Venue.asp
7	ICCICT 2012	October 19-20, 2012	Mumbai, India	http://conference.spit.ac.in/important-dates/index.html
8	GLOBECOM 2012	December 3-7, 2012	California, USA	http://www.ieee-globecom.org/cfp.html
10	Wireless Personal Multimedia Communications	Journal	Springer	http://www.springer.com/engineering/signals/journal/11277
11	IEEE Communication Society Journals	Journal	IEEE	http://www.comsoc.org/publications/journals
12	IEEE/ACM Transactions on Communication and Networking	Transactions	IEEE/ACM	http://www.ieee.org http://www.acm.org

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

All the rights about patents obtained during the PhD course will be shared between the university and the PhD student, following the standard procedures in AAU.

7 External Collaboration

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

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 Sinhgad Technical Education Society, Pune, India

9 Short References

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