AAU PhD Degree

PhD Study Plan

Title

Energy Efficient Routing Protocols for Mobile Ad hoc Networks

PhD Candidate

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Doctoral Programme	: Wireless Communication
Study plan 2 months	:☐
Study plan 11 months	:☒
Project title	: Energy Efficient Routing Protocols for Mobile Ad hoc Networks
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Energy Efficient Routing Protocols for Mobile Ad hoc Networks

1. Project Summary/abstract:

A mobile ad-hoc network (MANET) is infrastructureless and complex network and dynamically organizes arbitrary and ad hoc topologies. Ad hoc networking concept is more than 20 years old with applications like automated battlefield, emergency services like disaster recovery operations, tele-medicine, education etc. Dynamic topology, decentralized infrastructure, bandwidth and power supply management are the challenges of the MANET.

The position of the nodes in the MANET network continuously varies due to which the performance of routing protocol also varies. Limited power supply is the biggest challenge of an ad-hoc network. MANET consists of battery operated heterogeneous nodes where each node acts as host as well as router. Routing is the main task of network layer and it has high load of route computations and communications. In order to support large and durable applications, it is necessary to design routing protocol which will be energy efficient and secure.

As MANET is specifically designed for military applications and disaster recovery operations, routing protocols should not only energy efficient, but also robust against security threats.

The proposed research will focus on developing multi-objective energy efficient routing protocol with the following objectives,

1. To maximize network energy lifetime by avoiding nodes with little energy.
2. To achieve link stability.
3. To assure secure communication by integrating trust.
4. To develop a security mechanism to reduce the effect of routing denial of service attack.

The research will be carried out using analytical and mathematical modeling along with simulations. The research objective is to develop routing protocol, which will be multi-objective, energy efficient and secure for MANET applications.

2. The scientific content of the PhD project

A. Background for the project

MANETs are autonomous wireless ad hoc networks that operate without a given infrastructure and are characterized by their dynamic topology and capabilities to self-organize. The devices in a MANET are highly mobile and have their application in various environments such as battlefield surveillance, emergency services like disaster recovery operations, tele medicine, education, etc.

MANET routing protocols are generally categorized as table-driven or on-demand driven. In table-driven routing protocols, each node maintains consistent, up-to-date routing information to every other node in the network on a periodic basis. These routing protocols are proactive in nature, which means that when a packet needs to be forwarded the route is already known and can be immediately utilized. With on-demand driven routing, routes are discovered only when a source node desires to communicate with other nodes [1].

Establishing correct and performance efficient paths is an important task in a MANET but establishing energy efficient and secure routes is a more challenging task when considering the features of the MANET, which include: Mobility, energy, multi-hop, multiple roles for each node, no infrastructure, bandwidth and security.

The main project aim is to develop secure and energy efficient routing mechanism based on the listed features and hence the restricted power constraints along with security will be covered to achieve the goal.

Multi-objective optimization (MOO) techniques encompass methods used to optimize two or more conflicting objectives subject to certain constraints. In routing, MOO techniques are useful in finding a set of paths that minimizes a number of objective functions [3] and these often include the sum of costs and /or the maximum bottleneck cost (minimax) in the path. In MANETs, obtaining routing paths using MOO is an advantage as it is possible to obtain routes that meet a certain tradeoff with respect to the routing criteria e.g. performance, energy, mobility and security. In the network itself, the objectives will include quality of service (QoS) measures both with respect to reliability (network life time, end-to-end delay, packet delivery ratio, etc.) and performance (energy cost, queuing delay and link stability cost) [4].

MANETs do not use specialized routers to perform this functionality and hence it is challenging to establish efficient routing. This problem can to some extent be solved using clusters, where one node will be elected cluster head (CH) and be responsible for all routing functions and the remaining nodes behave as ordinary nodes.

The proposed research work is concerned with investigating and proposing a novel multi-objective energy efficient routing algorithm for MANETs consisting of two main phases; the first phase is on multi-objective energy efficient routing algorithm for flat network architectures and the second phase is on a secure multi-objective energy efficient routing algorithm for cluster-based network architectures.

The proposed research work addresses objectives such as network lifetime, link stability, and integration of trust parameters for secure communication through the utilization of MOO techniques capable of handling conflicting objectives such as minimum end-to-end delay, maximize throughput, etc.

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

The state of the art gives an overview of MANET energy efficient routing protocols, multi-objective optimization, multi-objective optimization techniques and security attacks for MANET routing.

In order to maximize the network lifetime, Energy efficient MANET routing protocols ensure that all nodes equally deplete their power level and that efficient routing paths are selected to avoid low energy nodes [8]. To determine such optimized paths different routing performance metrics are used including hop count, delay and link quality.

Multi-objective optimization techniques are used in various real world problems where conflicting objectives are optimized to achieve efficient solution [3], such as product and process, finance, communication system, civil construction, vehicle design, etc.. In routing, the MOO approach is used to establish multiple paths between the communicating node pairs considering multiple objectives [11] such as maximizing packet delivery ratio or throughput while minimizing the end-to-end delay. MANET routing protocols are designed by using multi-objective techniques that give tradeoffs between the conflicting metrics. MANET routing decisions are made under different uncertainties such as dynamic topology (unknown node movement), latency, incomplete routing information, end-to-end delay of the node, residual energy of the node and cost of the path. Multi-objective energy efficient routing algorithms can be designed to address these issues in such a way that it will take advantage of multiple paths to improve the overall performance of the network.

Different approaches exist to solve multi-objective problems including evolutionary and genetic algorithms. Evolutionary algorithms are classified into three types, namely bi-objective, swarm intelligence and strength pareto evolutionary algorithms. In bi-objective algorithm two conflicting performance metrics are considered to achieve the goals. The bi-objective algorithms [9] deal with the objectives such as end-to-end delay and number of hops to achieve load balancing and link stability but it fails to address energy and security issue. An evolutionary algorithm [10] has been proposed to optimize the three performance metrics length of the path, current residual energy of the neighboring node and link stability to achieve advantages like low routing loads, less congestion loss, robustness, low routing overhead etc. The multi-objective evolutionary bi-objective algorithm with strength pareto evolutionary technique [11] minimizes path cost and end-to-end delay. In a proposed genetic algorithm [4], QoS is improved through encoding, initialization, crossover, mutation, fitness selection and route search and this algorithm focuses on the metrics throughput and end-to-end delay. A swarm intelligent technique algorithm [12] has been proposed to allow discovery of minimum drain rate (MDR) paths by preserving the energy and balance the data traffic through round trip time by considering the performance metrics end-to-end delay and load balancing. A-MHC and A-LB [13] are MOO swarm intelligent algorithms based on an ant colony mechanism and minimize hop count and traffic load balancing through the

performance metrics hop count and end-to-end delay. The MO-OLSR algorithm [14] uses prediction methods such as predicting queuing delay, energy consumption using double exponential smoothing and predicts the residual link lifetime to achieve robustness, network stability, maximized network lifetime, throughput and minimizes end-to-end delay by including the conflicting metrics end-to-end delay, network energy lifetime and packet delivery ratio. MO-AODV [15] does not pay attention to the environmental situations why mobility pattern and mobile nodes status and an optimum solution is obtained by considering throughput, control packet overheads and end-to-end delay performance metrics in different scenarios.

The above mentioned flat-based multi-objective routing protocols are majorly focused on the two performance metrics throughput and end-to-end delay. Hence it is necessary to address and integrate issues such as scalability, energy and security of routing protocols in MANETs. Clustering is a commonly used technique in order to restrict the amount of routing information stored and maintained at each node. Clustering is a process where the network is divided into non- overlapping subgroups called clusters and is often used to improve battery consumption in MANETs. There are different types of clustering schemes and one such is energy efficient clustering [19] where only the cluster head is selected using MOO and MOO is not applied as part of any other optimization.

The dynamic nature of a MANET makes it more prone to security threats where limited battery power is a potential threat to MANET routing applications and mobile nodes with inadequate protection are easy to compromise. Active attacks have the aim to damage other nodes in the network by interrupting the network operations while passive attacks are often referred to as selfish node attacks, which aim at saving the attackers own energy/battery life for future communication. MANET protocols are facing different routing attacks such as flooding, location disclosure, rushing, Sybil, byzantine, balckhole, wormhole, resource consumption, link withholding, link spoofing and colluding miserably attack [16]. The balckhole attack [17] has been identified as one of the most severe security problems in MANET routing as the malicious node uses the routing algorithm to broadcast wrong information to its neighboring nodes. It advertises itself as having the shortest path to the node whose data packet it wants to steal and while advertising wrong information, the malicious node circulates false objectives containing high energy, few hop neighbor or low transmission power to its neighboring nodes to attract the network traffic.

The proposed research will mainly focus on inter-cluster communication wherein the MOO approach will be utilized to find shortest and efficient paths between clusters. Implementation of multi objective techniques in inter-cluster communication will automatically decrease the number of nodes that will participate in the computation [18] and, hence, routing overheads, control message overheads and CPU time will be decreased. The research will also focus on development of a MOO algorithm for cluster-based networks in order to improve scalability,

throughput, routing table size, transmission overhead, load and energy efficiency [19]. Thus MOO with a clustering approach can be the efficient solution for MANET routing.

C. Project's objectives

MOO approaches have advantages in obtaining a set of efficient solutions, which provides flexibility and support for decision-making system. The research objective is to develop a MOO energy efficient and secure routing protocol for MANETs and this will be achieved by considering the following objectives,

- Maximize network lifetime by avoiding nodes with little energy.
- Increase link stability.
- Secure communication by integrating trust mechanisms and develop a security mechanism against denial of service security attack.

This will improve the overall scalability, throughput, routing table size, transmission overhead and energy efficiency of ad hoc network.

D. Key Methods

The research will be based on theory-assisted design and applied to practical situations. Simulators will be used to design and analyze the system according to the scenario. The first phase of the research is to investigate and develop a multi-objective energy efficient routing algorithm for flat network topologies and analyze the security attacks for the proposed algorithm. In the second phase, the research will focus on integration of trust parameters for secure communication. The third phase will concentrate on a multi-objective energy efficient routing algorithm for cluster-based networks. Hence, for inter-cluster communication, MOO techniques are used to compute a set of efficient paths.

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

The experiences and results obtained so far are,

- Evaluated and compared the performance of existing energy efficient routing protocols.
- Studied MOO techniques and analyzed which is best for the proposed research work.
- Analyzed different MANET routing security attacks and based on the result of multi-objective routing algorithm proposed a new security attack.

The expected outcome of the research will be a multi-objective energy efficient and secure routing protocol for MANETs providing scalability, throughput, fairness, latency, and increased node and network lifetime.

F. Time schedule with milestones

Task		Year 1				Year 2				Year 3			
1	Background study												
2	Literature survey												
3	Requirement analysis and												
4	Concept development and												
5	Framework design and												
6	Implementation												
7	Simulation												
8	Performance analysis and												
9	Result, conclusion,												
10	Attending PhD courses*												
11	Papers and conferences												
12	Writing 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 with tentative months planned to fulfill the PhD study:.

- **Milestone 1 (M1):** Literature survey and requirement.
- **Milestone 2 (M3):** Motivation, research challenges and problem specifications.
- **Milestone 3(M6):** Functional requirements
- **Milestone 4(M9):** Energy efficient routing schemes and approaches.
- **Milestone 5 (M11):** Performance metrics and comparison with existing work.
- **Milestone 6 (M12):** Courses, study of flat based MOO and publication.
- **Milestone 7 (M14):** Security attacks on MANET routing in general and the proposed algorithm in particular.
- **Milestone 8 (M17):** Clustered based approach with MOO: Evaluation and performance metrics.
- **Milestone 9 (M19):** Energy efficient multi-objective routing algorithm in cluster-based networks.
- **Milestone 10(M22):** Evaluation, performance metrics and comparison with existing work along with publication.
- **Milestone 11 (M19):** Trust mechanism to avoid selection of insecure nodes.

- **Milestone 12 (M22):** Evaluation and comparison with existing work along with publication.
- **Milestone 13 (M25):** Security measures in MOO MANET routing protocols.
- **Milestone 14 (M28):** Evaluation and comparison with existing work along with publication.
- **Milestone 15 (M30):** Simulations and initial thesis write-up.
- **Milestone 16 (M35):** Thesis write-up and publication.

G. Outline of Content of Thesis

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H. Publications Titles

Sonali V. Mote, Rasmus H. Nielsen, Neeli R. Prasad, Ramjee Prasad.

Publications Planned

1. "MOEER: Multi-objective Energy Efficient Routing Algorithm for Mobile Ad hoc Networks" to be submitted to conference.
2. "CMOEER: Cluster-based Multi-objective Energy Efficient Routing Algorithm for MANETs" to be submitted to conference.
3. "Comparison and performance improvements of the MOEER and CMOEER routing algorithms for MANETs" to be submitted to conference.
4. "Secure CMOEER routing algorithm for MANETs" to be submitted to journal.
5. "Secure multi-objective energy efficient mechanisms against security attacks in MANETs", to be submitted to conference/journal.

3. Agreement on the relationship between supervisor and student

The PhD student and supervisors maintain a regular PhD meeting schedule of every two weeks. Additionally meetings can be planned to discuss questions, feedback and academic guidance. Contact is maintained largely through email or face-to-face meetings. The supervisor must review and approve all publications and formal dissemination, providing feedback as necessary and recommendations to reach the targeted audience. The student is responsible for allocating her time and resources to complete tasks and disseminate work on schedule and maintain high quality of work.

4. Plan for PhD courses *

Courses	**Place/ Organizer**	**ECTS**	**General or**	**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
Management of Research and Development	Frank Gertsen	2.5	General	Completed
Bayesian Statistics, Simulation And Software - With A	Associate Professor Kasper K.	4	Project	Pursuing
PhD Entrepreneur	Frank Gertsen	2	General	Planned
Sensors and RFID Networks	Neeli Rashmi Prasad	2.5	Project	Planned
Network Coding: Theory and Applications	Professor Muriel Medard, Frank	4	Project	Planned
Advanced Topics in IT Security	Associate Professor Rene Rydhof Hansen	2	Project	Planned

Writing and Reviewing Scientific Papers	Prof. Jakob Stoustrup	3.75	General	Planned
Intellectual Property Rights	Morten Dahlgaard Andersen	2	General	Planned
Professional Communication, Fall 1	Prof. Anette Kolmos	2.5	General	Planned
Subtotal (Planned& Registered)		**22.75**		
Total (Completed)		**8.5**		
Total		**31.25**		

* 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	ICCICT-2012	Oct 19-20, 2012	Mumbai, India	http://conference.spit.ac.in/
2	ISETC-2012	Nov 15-16, 2012	Timis, Romania	http://www.etc.upt.ro/isetc2012/home.php
3	GLOBECOM 2012	Dec 03-07, 2012	CA, USA	http://www.ieee-globecom.org/2012/
4	ET2ECN-2012	Dec 19-21, 2012	Surat, Gujarat	http://www.svnit.edu.in/et2ecn2012/
5	WCNC-2013	Apr 07-10, 2013	Shanghai, China	http://www.ieee-wcnc.org/
6	CNC-2013	Feb 22-23, 2013	Chennai, India	http://cnc.theides.org/2013/
8	Wireless Personal Multimedia Communications	Journal	Springer	http://www.springer.com/engineering/signals/journal/11277
9	IEEE Communication Society Journals	Journal	IEEE	http://www.comsoc.org/publications/journals
10	IEEE/ACM Transactions on Communication & 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 LBHSST'S ICA (Hiray Institute) 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 LBHSST'S ICA (Hiray Institute), Mumbai.

9. Short References

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