

**DEVELOPMENT OF LOCALIZATION AND
ROUTING ALGORITHMS FOR SENSOR
NETWORKS IN AN INTEGRATED APPLICATION
FRAMEWORK**

by
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**Bharti School of Telecommunication Technology and
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Submitted

in fulfilment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

SEPTEMBER 2013

I dedicate this thesis to my teachers.

Certificate

This is to certify that the thesis titled “*Development of Localization and Routing Algorithms for Sensor Networks in an Integrated Application Framework*” being submitted by Mr. Sanat Sarangi in fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Bharti School of Telecommunication Technology and Management, Indian Institute of Technology Delhi is a record of bona fide work carried out by him under my supervision and guidance. It is also certified that this work has not been submitted to any other Institute or University for the award of any other degree or diploma.

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Acknowledgements

I am deeply indebted to my supervisor, Prof. Subrat Kar, who created a stimulating and ever-evolving environment for the work undertaken in this thesis to be completed. His versatility, foresight, quick assessment of situations, and strong administrative abilities is an extremely rare combination of qualities which I am fortunate to have had a chance to witness. I am grateful to Prof. Santanu Chaudhury, Prof. Huzur Saran and Prof. Bresh Lall for their valuable inputs throughout my work. Prof. Chaudhury's suggestions and critical feedback helped me explore many new areas and refined my perspectives. Prof. Saran and Prof. Lall were very supportive at all times.

I thank my friends and colleagues, Sarika, Akshat, Vijay, Rupesh, Vikas, Neeru, Sagarika, batchmates from Masters and PhD programs, and staff-members of Bharti School and the Electrical Engineering Department, for the wonderful time I have spent with them in IIT and on the various trips we undertook for deployments and site-inspections. I thank all the students from different parts of the country who did their GIPEDI internship with me, which was very enriching.

I thank my parents, grand-parents and relatives for their constant support and encouragement. Finally, I am grateful to the Almighty for giving me the courage and strength to take appropriate decisions at various stages in the course of my work.

September 20, 2013

New Delhi

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2009BSZ8524

Abstract

We propose novel algorithms for localization and routing in sensor networks. We also develop an application framework for deployment of geographically-distributed customized sensor network applications. The proposed algorithms seamlessly integrate with the application framework to facilitate their rapid deployment.

The application framework consists of (a) a scriptable rapid application deployment framework called RAPIDSNAP which addresses end-to-end requirements of heterogeneous sensor network deployments and (b) a novel Internet-of-Things (IOT) repository called the Wireless Sensor Knowledge Archive (Wisekar), hosted at <http://wisekar.iitd.ac.in>. Wisekar supports a variety of data inputs and archival capabilities.

We propose the concept of Graded Precision Localization (GPL), which refers to the ability to localize mobile nodes to different precision levels using a common infrastructure with a combination of coarse-grained localization, fine-grained localization and inertial navigation. Two algorithms for GPL—GRADELOC and IGRADELOC—are proposed, analysed and validated with an implemented prototype.

We propose a set of localization extensions—LORECOS—to a reactive routing algorithm—AODVjr, thereby leveraging its route-discovery phase for hop-distance based location estimation. An anchor node placement algorithm ANCHREG is proposed, which helps mobile nodes using an extended form of LORECOS to be able to estimate their region of presence in a deployment area. The geometric properties of the deployment area are used by

ANCHREG to arrive at an optimal anchor node placement configuration. Performance of machine learning models is compared for region prediction—a part of the region estimation process.

We propose a multi-hop routing algorithm called PARTROUTE for partially mobile sensor networks where reactive routing is coupled with partial route (trace) preservation over a set of stationary nodes to minimize packet overheads. We extend the use of mobility awareness to achieve energy-efficient clustering in sensor networks by proposing GAROUTE. GAROUTE uses genetic algorithms to arrive at optimal cluster configurations in a sensor network.

The impact of the proposed work is discussed in the context of a wireless sensor network based gait assessment system called Gaitsense which has been developed and implemented by us.

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Glossary

ANCHREG	Anchor Node Placement Algorithm for Region Estimation
ANN	Artificial Neural Networks
AOA	Angle of Arrival
AODV	Ad-hoc On Demand Distance Vector (Routing)
APIT	Approximate Position in Triangle
CA	Create-trace acknowledgement packet
CCA	Curvilinear Component Analysis
CG-NTL	Coarse-grained NTL in a GPL setup
CLOC	Location obtained by computing centroid of HRP packets
CRAWDAD	Community Resource for Archiving Wireless Data At Dartmouth
CSV	Comma Separated Values
CT	Create-trace packet
CTR	Create-trace request packet
DBMS	Database Management System
DES	Discrete Event Simulation
DLOC	Location discovered from routing path
DR	Dead Reckoning
DSR	Dynamic Source Routing
DSS	Decision Support System
DTD	Document Type Definition
EEG	Electroencephalography
EEML	Extended Environments Markup Language
EFG-NTL	Extra-fine-grained NTL in a GPL setup
EJB	Enterprise JavaBeans
EML	Environmental Markup Language
EVK	Event packet with location
FG-NTL	Fine-grained NTL in a GPL setup
GA	Genetic Algorithm

GPL	Graded Precision Localization
GPS	Global Positioning System
GRADELOC	Algorithm for Graded Precision Localization
HLOC	Location obtained from one HRP packet
HRP	Hello reply packet
HRQ	Hello request packet
IGRADELOC	Algorithm for Improved GRADELOC
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IOT	Internet of Things
ISM	Industrial, Scientific and Medical
Gaitsense	A wireless sensor network based gait assessment system
GAROUTE	Genetic Algorithm based Clustering Algorithm
GAROUTE-V	GAROUTE with variable-range radio nodes
GAROUTE-F	GAROUTE with fixed-range radio nodes
GWT	Google Web Toolkit
JMS	Java Message Service
JPA	Java Persistent API
JSON	JavaScript Object Notation
LAN	Local Area Network
LORECOS	Algorithm for Location Estimation with Reactive Routing in Resource Constrained Sensor Networks
LOS	Line of Sight
M-RREQ	A variant of RREQ used by mobile nodes in PARTROUTE
M-RREP	RREP generated for an M-RREQ in PARTROUTE
M2M	Machine-to-Machine
MAC	Media Access Control
MAE	Mean Absolute Error
MANET	Mobile Ad-hoc Network
MEMS	Micro Electro-Mechanical Systems
MVC	Model-View-Controller (Design Pattern)
NLOS	Non Line of Sight
NP	Non-deterministic Polynomial (Time)
NTL	Node to be localized
OGC	Open Geospatial Consortium

ORM	Object Relational Mapping
OWL	Web Ontology Language
O&M	Observation and Measurement
PARTROUTE	Algorithm for routing with partial route preservation
RAPIDSNAP	Rapid Sensor Network Application Deployment Framework
RDF	Resource Description Framework
REFN	Infrastructure reference node in a GPL setup
REPLY-NODE	Node which sends an RREP for an RREQ
REST	REpresentational State Transfer
RMSE	Root Mean Square Error
RPK	RREP packet with location
RPU	RREP packet without location
RREP	AODV route reply packet
RREQ	AODV route request packet
RQK	RREQ packet with location
RQU	RREQ packet without location
RSSI	Received Signal Strength Indication
S-RREQ	A variant of RREQ used by stationary nodes in PARTROUTE
SOAP	Simple Object Access Protocol
SOSANET	Service Oriented Sensor and Actuator Network
SVM	Support Vector machines
SWE	Sensor Web Enablement
SWRO-AO	Sensor Web Resources Ontology for Atmospheric Observation
TDOA	Time Difference of Arrival
TOA	Time of Arrival
UML	Unified Modelling Language
WAN	Wide Area Network
Wisekar	Wireless Sensor Knowledge Archive
WSDL	Web Services Description Language
XML	Extensible Markup Language
XSD	XML Schema Definition