QoS Routing Algorithms for Wireless Sensor Networks

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Foreword

This book provides a systematic introduction to the fundamental concepts, major challenges, and effective solutions in Wireless Sensor Networking (WSN). Distinguished from other books, it focuses on the networking aspects of WSNs and covers the most important networking issues, including network architecture design, medium access control, routing and data dissemination, node clustering, node localization, query processing, data aggregation, transport and Quality of Service, time synchronization, and network security.

This book is a collection of state-of-the-art research papers discussing current applications and deployment experiences, and also the network layer communication and Quality of Service issues that are fundamental in further developing solutions to applications.

With contributions from researchers, this book strikes a balance between fundamental concepts and new technologies, providing readers with unprecedented insights into WSNs from a networking perspective. It is an essential reading for a broad audience, including academic researchers, research engineers, and practitioners in industry. The readership of this book is intended to be postgraduate/postdoctoral researchers, and professional engineers. It is also suitable as a textbook or supplementary reading for computer engineering and computer science courses at the graduate level.

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Preface

Wireless Sensor Networks are composed of inexpensive, low powered micro-sensor nodes capable of sensing, processing, and communicating with limited computational resources. The sensor nodes organize themselves dynamically to form a network and communication is established between the nodes through broadcasting using radio signals. WSNs do not have a definite fixed infrastructure and hence the network topology changes continuously based on the type of sink, number of hops, types of nodes, and type of scheduling.

Wireless Sensor Networks basically keep track of the physical environment and co-operatively transmit data to the destination via the self organized network. A large amount of sensor nodes are widely deployed at high density regions where surveillance and monitoring is required, especially, at the frontiers of land, medical applications, commercial, industries, home automation, automobiles, chemical industries, in remote areas like forest, mountains, and valleys etc., where deployment of monitoring devices becomes impossible due to practical limitations. They can also be embedded in an environment to monitor variety of physical and environmental information, interact, assimilate, and interpret real time data in smart environmental applications. Emerging WSNs have a set of stringent Quality of Service (QoS) requirements that include timeliness, high reliability, availability, and integrity.

Chapter 1 introduces the basic idea of QoS in Wireless Sensor Networks and the unique design requirements and challenges for providing QoS in WSNs. The organization of the book is outlined in this chapter. QoS issues related to network layer and MAC layer routing are presented.

Chapter 2 presents Link Reliability based Two-Hop Routing (LRTHR) that explores the idea of incorporating Quality of Service parameters in making routing decisions, i.e., (i) reliability (ii) latency, and (iii) energy efficiency. The algorithm selects links providing greater Packet Reception Ratio (PRR) on the route, hence the throughput can be increased, lowering the Deadline Miss Ratio (DMR) and augmenting the energy efficiency of the forwarding nodes due to lower number of collisions and re-transmissions. The algorithm provides a two-hop neighborhood information scheme incorporated with the dynamic velocity assignment policy which provides enhanced foresight to the sender in identifying the node pair that can provide the largest velocity towards the destination.

In order to satisfy the QoS requirements and energy constraints for WSNs, hierarchical (clustering) techniques have been an attractive approach to organize sensor nodes based on their power levels and proximity. Chapter 3 proposes a Fault Tolerant QoS Adaptive Clustering Algorithm (FTQAC) that employs a dual cluster head mechanism in the cluster with respect to the working of the cluster head and guarantees the desired QoS by including delay and bandwidth parameters in the route selection process.

In order to sustain the QoS path when sensor nodes deteriorate and malfunction, node fault detection and recovery techniques are necessary. Expected Transmission Count and Round-Trip Time Delay (ETXTD) based Fault Detection Algorithm is explained in Chap. 4 that is able to identify working and faulty sensors in a computationally effective manner. The traffic is redirected to the working sensors and the QoS level is maintained throughout the duration of the connection.

Time synchronization is an important parameter for an event action, coordination among nodes and time measurements for common time on distributed sensor nodes. Chapter 5 proposes a Distributed QoS in Time Synchronized MAC (DQTSM) protocol that is a primary service for coordination of scattered sensor nodes regularly by exchanging messages in the WSNs applications in home automation, industrial automation, military, and medical etc. The DQTSM is important for the operation of WSNs in considering local clocks at each sensor node that need to be synchronized with reference to the clock at Master node. The synchronization error is due to the non-deterministic random time delay for a message transfer between the Master node and the Receiver nodes. DQTSM reduces sources of synchronization error at the MAC layer in channel contention and reduces the network traffic required for time synchronization.

Chapter 6 proposes an Efficient Retransmission Random Access Protocol (ERRAP) that retransmits a new frame within a pre-calculated time slot, which combines scheme of collision avoidance and energy management for low-cost, short-range wireless radios, and low-energy sensor nodes applications. This scheme focuses on efficient MAC scheme to provide autonomous Quality of Service (QoS) to the sensor nodes in one-hop QoS retransmission group in WSNs. The wireless sensor nodes joins the network only during random access time. The time interval between random access time could be small. Our simulation results demonstrate the performance of ERRAP protocol which increases the delivery probability and reduces the energy consumption.

It is challenging to design a hybrid MAC scheme for delay aware data traffic in WSNs. The Contention Based Hybrid MAC (CBH-MAC) protocol is proposed in Chap. 7, where each sensor node operates the reservation procedure used in cross and chain topology, resulting in energy efficiency, maximizing the packet delivery ratio, minimizing contention around the nodes, and reducing end-to-end delay. The neighboring sensor nodes of the receiver and sender receive their individual reservation control packets. The sender transmits data and receives Acknowledgment packets during the adaptive contention-free period. As the reservation packets pass through the sensor along the routing path, the sensor nodes reserve the time slots consecutively in multi-hop. The scheme has significant improvement of the end-to-end latency, packet delivery ratio, and energy efficiency.

Chapter 8 proposes a QoS Multi-hop Sensor Routing (QMSR) protocol that is developed for Mobile Wireless Sensor Networks (MWSNs). This protocol manages Admission Control Scheme (ACS) with minimum overhead resources for fresh flows without degrading the performance of the existing flows. ACS is an important strategy for regulating the parallel flows in a contention based channels to meet the requirements of QoS. QMSR estimates the available bandwidth before allocating the resources on a per hop basis. The protocol minimizes the overall energy consumption and guarantees the end-to-end delay.

Chapter 9 presents Passive Clustering. Passive Clustering does not employ control packets to collect topological information in a Mobile Wireless Sensor Network. In our proposal, we avoid making frequent changes in cluster architecture, due to repeated election and re-election of cluster heads and gateways. Our primary objective has been to make Passive Clustering more practical, robust and to minimize the quantity of cluster information on the data packets.

Chapter 10 proposes a Secure Aggregation for Approximate Queries in Wireless Sensor Networks (SAAQ) where Message Authentication Codes (MACs) are transmitted along with the synopses that are generated using primitive polynomials.

The authors appreciate the suggestions from the readers and users of this book. Kindly communicate the errors, if any, to the following e-mail address: venugopalkr@gmail.com.

Bengaluru, India K. R. Venugopal
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Contents

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Acronyms

ACK	Acknowledgement
ACS	Admission Control Scheme
AIS	Artificial Immune System
AODV	Ad Hoc On-Demand Distance Vector
ARQ	Automatic Repeat Request
BS	Base Station
BWER	Bandwidth Efficiency Ratio
CACP	Contention-Aware Admission Control Protocol
CBR	Constant Bit Rate
CCBR	Context and Content-Based Routing
CDA	Concealed Data Aggregation
CDMA	Code Division Multiple Access
CDS	Connected Dominating Set
CP	Contention Period
CR	Cognitive Radio
CSMA	Carrier Sense Multiple Access
CSMA/CA	Carrier Sense Multiple Access/Collision Avoidance
CSMA/CD	Carrier Sense Multiple Access/Collision Detection
CTS	Clear To Send
DCA	Dynamic Channel Assignment
DCF	Distributed Coordination Function
DMR	Deadline Miss Ratio
DMST	Directed Minimum Spanning Tree
DRAND	Distributed Randomized
DSDV	Destination Sequenced Distance Vector
DSR	Dynamic Source Routing
E2E	End-to-End
ECC	Elliptic Curve Cryptography
ECPP	Energy Consumed Per Packet
ETX	Expected Transmission Count

EWMA	Exponential Weighted Moving Average
FBS	Feedback Based Synchronization
FCFS	First-Come-First-Served
FDMA	Frequency Division Multiple Access
FHSS	Frequency Hopping Spread Spectrum
FTSP	Flooding Time Synchronization Protocol
GPS	Global Positioning System
GPSR	Greedy Perimeter Stateless Routing
HMAC	Hash Message Authentication Code
H-MAC	Hybrid Medium Access Control
ISM	Industrial, Scientific and Medical
MAC	Medium Access Control
MAC	Message Authentication Code
MANET	Mobile Ad Hoc Network
MAP	Multi-channel Access Protocol
MC-LMAC	Multi-Channel Lightweight Medium Access Control
MEMS	Micro Electrical and Mechanical Systems
MFS	Multipath Fairness Solution
MILP	Mixed Integer Linear Programming
MMSN	Multi-FrequencyMedia Access Control
MQO	Modern Query Optimization
MSN	Mobile Sensor Node
MWSN	Mobile Wireless Sensor Network
NCP	Non Contention Period
NS	Network Simulator
ODI	Order and Duplicate Insensitive
OLSR	Optimized Link State Routing
OMC-MAC	Opportunistic Multi-Channel Medium Access Control
PAC	Perceptive Admission Control
PCH	Primary Cluster Head
PCSA	Probabilistic Counting with Stochastic Averaging
PDEM	Path-Demand Packet
PDR	Packet Delivery Ratio
PREP	Path-Reply
PREQ	Path-Request
PRR	Packet Reception Ratio
QoS	Quality-of-Service
RBS	Reference Broadcast Synchronization
RF	Radio Frequency
RMAC	Routing-Enhanced Medium Access Control
RMS	Root Mean Square
RN	Receiver Node
RPR	Regular Packet Rate
RRP	Resource Reservation Procedure
RSSI	Received Signal Strength Indicator

RT-LINK	Real Time Link
RTP	Round Trip Path
RTS	Request To Send
RTT	Round Trip Time
Rx	Receiver
SCH	Secondary Cluster Head
S-MAC	Sensor Medium Access Control
SRP-MS	Square Routing Protocol with Mobile Sink
TDMA	Time Division Multiple Access
TMCP	Tree-based Multi-Channel Protocol
TPSN	Timing-sync Protocol for Sensor Networks
TTL	Time to Live
TTS	Two-hop Time Synchronization
Tx	Transmiter
WMEWMA	Window Mean Exponential Weighted Moving Average
WSNs	Wireless Sensor Networks