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Routing for Wireless Multi-Hop Networks

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Preface

Wireless communication provides great advantages that are not available through their wired counterparts such as flexibility, ease of deployment and use, cost reductions, and convenience. However, these advantages come at the expense of some drawbacks, the most prominent of which is the limitation of the transmission range of wireless nodes. This limitation is due to the characteristics inherent in wireless communication such as fading, frequency reuse, noise, interference, and receiver sensitivity. As a result, a wireless node can only communicate directly with nodes within its transmission range. In order to communicate with out-of-range nodes when wireless nodes are deployed in an ad hoc setup with no infrastructure, a wireless node has to depend on other intermediate nodes for relaying its messages until they reach the intended destination. This communication paradigm is known as "multi-hop" communication, where each node can act as a source, a destination, or a router relaying messages.

In a wireless multi-hop network, one of the important challenges is how to route packets efficiently. The availability of many intermediate nodes between a source and a destination results in having many optional paths/routes to follow. The challenge is to pick the optimal path that satisfies the needed performance requirements, and this is the responsibility of a routing protocol. Choosing an optimal path from a source to a destination can be done by optimizing one or more routing metrics (such as number of hops, distance, delay, packet loss rate, and energy consumption). The selection metric is chosen based on application requirements such as delay-sensitivity or on constraints such as limited energy or frequent topology changes.

There are four wireless network paradigms falling under the category of wireless multi-hop networks. These paradigms are Mobile Ad Hoc Networks (MANETs), Wireless Sensor Networks (WSNs), Wireless Mesh Networks (WMNs), and Vehicular Ad-Hoc Networks (VANETs). In these four network paradigms, routing plays a vital and critical role and is considered one of the most important design elements of these networks.

Following a component-based approach, routing protocols for wireless multi-hop networks can be decomposed into smaller functional components. A routing protocol can be a combination of some or all of these components depending on the characteristics of the network that this protocol is proposed for and on the application requirements as well. Some of these routing components are core and should be a part of the skeleton of any routing protocol. These fundamental components are route discovery, route selection, and route representation and data forwarding. Some other components are network-dependent and will be activated and used only based on network needs. Examples of such auxiliary components are route maintenance and route energy efficiency.

Being categorized as wireless multi-hop networks, the four aforementioned network paradigms share some commonalities in terms of their routing function. However, as each of these network paradigms has its own unique characteristics and environment/application needs, each has some distinct aspects that distinguish its routing approaches from the others. The target of this brief is to show the unifications and distinctions of the routing functions of the various multi-hop network paradigms.

Over the past years, many surveys have addressed routing protocols for each of the aforementioned wireless multi-hop networks. Yet, there are many questions that need to be answered: Why is there not a unified set of routing protocols that can be used for all these types of networks based on the fact that they are all wireless multi-hop networks? Why does each type of network require the design of its own routing protocols? What aspects distinguish each of these networks in terms of routing? etc. In addition to discussing the commonalities, this brief answers these questions with the objective of showing the distinguishing features of the routing functions of the various wireless multi-hop networks.

The brief is organized as follows: as a common ground, in Chap. 1, we present an overview of wireless multi-hop networks along with a brief introduction to each of the four aforementioned wireless multi-hop network paradigms. In Chap. 2, we show the "*unifying features*" of routing by presenting an overview of routing in wireless multi-hop networks, its basic concepts, and the various routing components that can form a wireless multi-hop routing protocol. Both core and auxiliary components are highlighted. In addition, we introduce a generic routing model that can be the foundation of the wireless multi-hop routing function and can be inherited by any wireless multi-hop routing protocol. In Chap. 3, to highlight the "*distinguishing features*", we present the requirements and design considerations of each of the four aforementioned wireless multi-hop network paradigms. Also, the popular classification of routing protocols for each network paradigm is presented. Furthermore, we discuss the routing components that should be activated and included as core parts of a routing protocol for each network paradigm along with some various functionalities of each component and some examples of routing protocols that adopt these functionalities. In addition, we summarize the distinctions part by providing an abstraction for the general routing functionalities of each of the four network paradigms. Finally, in Chap. 4, we present some concluding remarks along with some potential open issues.

This brief is intended for readers interested in getting an overview about this field of research and for researchers interested in further research and contributions. It provides an exhaustive view of the wireless multi-hop routing components and aspects along with in-depth discussions about the wireless multi-hop network paradigms in terms of the commonalities and distinctions of their routing functions. We hope that this brief will be an inspiration for many ideas and contributions in the near future and will open doors for fruitful research avenues.

Kingston, Ontario, Canada, August 2012

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Contents

Abbreviations

ADAS	Advanced Driver Assistance Services
ADV	Advertisement
AODV	Ad-hoc On-Demand Distance Vector
AODV-ST	Ad-hoc On-Demand Distance Vector-Spanning Tree
ARPANET	Advanced Research Projects Agency Network
A-STAR	Anchor-based Street and Traffic Aware Routing
BLC	Bottleneck Link Capacity
BS	Base Station
CAR	Capacity-Aware Routing
CAR	Connectivity-Aware Routing
CBF	Contention-Based Forwarding
CBRP	Cluster Based Routing Protocol
CEDAR	Core-Extraction Distributed Ad Hoc Routing
CFR	Congestion Free Routing
CGSR	Cluster-head Gateway Switch Routing
CH	Cluster-Head
DAG	Directional Acyclical Graph
DARPA	Defense Advanced Research Projects Agency
DCAR	Distributed Coding-Aware Routing
DD	Directed Diffusion
DREAM	Distance Routing Effect Algorithm for Mobility
DSDV	Destination Sequence Distance Vector
DSR	Dynamic Source Routing
DV	Distance Vector
ENT	Effective Number of Transmissions
ETT	Expected Transmission Time
ETX	Expected Transmission Count
ExOR	Extremely Opportunistic Routing
FSR	Fisheye State Routing
GA	Genetic Algorithm
GBR	Gradient-Based Routing

GEAR	Geographical and Energy Aware Routing
GPCR	Greedy Perimeter Coordinator Routing
GPS	Global Positioning System
GPSR	Greedy Perimeter Stateless Routing
GPSR+AGF	Greedy Perimeter Stateless Routing + Advanced Greedy Forwarding
GRANT	Greedy Routing with Abstract Neighbor Table
GSR	Geographic Source Routing
HWMP	Hybrid Wireless Mesh Protocol
IARP	IntrA-zone Routing Protocol
IERP	IntEr-zone Routing Protocol
IRMA	Integrated Routing and MAC Scheduling Algorithm
ITS	Intelligent Transportation System
LAN	Local Area Network
LAR	Location Aided Routing
LBAR	Load-Balanced Ad-hoc Routing
LCMP	Light Client Management routing Protocol
LEACH	Low Energy Adaptive Clustering Hierarchy
LIBRA	Load and Interference Balanced Routing Algorithm
LQSR	Link Quality Source Routing
LS	Link State
MAC	Medium Access Control
MANET	Mobile Ad-hoc Network
MCFA	Minimum Cost Forwarding Algorithm
MIC	Metric of Interference and Channel-switching
MMESH	Multipath Mesh
MORE	MAC-independent Opportunistic Routing & Encoding
MPR	Multi-Point Relay
MR-LQSR	MultiRadio-Link Quality Source Routing
NCLBR	Node Centric Load Balancing Routing
OBU	On-Board Unit
OLSR	Optimized Link State Routing
ORR	Orthogonal Rendezvous Routing
OTR	Optimized Tree-based Routing
PEGASIS	Power-Efficient Gathering in Sensor Information Systems
PRENET	Packet Radio Networks
QoS	Quality of Service
REAR	Reliable Energy Aware Routing
ROMER	Resilient Opportunistic Mesh Routing
RREP	Route Reply
RREQ	Route Request
RSU	Road Side Unit
SADV	Static-Node Assisted Adaptive
SPIN	Sensor Protocol for Information via Negotiation
TBR	Tree-Based Routing
TORA	Temporally Ordered Routing Algorithm

VADD	Vehicle-Assisted Data Delivery
VANET	Vehicular Ad-Hoc Networks
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WAVE	Wireless Access for Vehicular Environment
WCETT	Weighted Cumulative Expected Transmission Time
WMN	Wireless Mesh Network
WMR	Wireless Mesh Router
WMSN	Wireless Multimedia Sensor Network
WRP	Wireless Routing Protocol
WSN	Wireless Sensor Network
ZHLS	Zone-based Hierarchical Link State
ZRP	Zone Routing Protocol