University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

FEI TONG

MEng (Chonbuk National University 2011)
BEng (South-Central University for Nationalities, 2009)

"Protocol Design and Performance Evaluation in Wireless Ad Hoc Networks"

Department of Computer Science

Monday, October 31, 2016
10:00 A.M.
Engineering and Computer Science Building
Room 660

Supervisory Committee:
Dr. Jianping Pan, Department of Computer Science, University of Victoria (Supervisor)
Dr. Kui Wu, Department of Computer Science, UVic (Member)
Dr. Yang Shi, Department of Mechanical Engineering, UVic (Outside Member)

External Examiner:
Dr. Hossam Saad Hassanein, School of Computing, Queen's University

Chair of Oral Examination:
Dr. Neil Burford, Department of Chemistry, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

Benefiting from the constant and significant advancement of wireless communication technologies and networking protocols, Wireless Ad hoc NETwork (WANET) has played a more and more important role in modern communication networks without relying much on existing infrastructures. The past decades have seen numerous applications adopting ad hoc networks for service provisioning. For example, Wireless Sensor Network (WSN) can be widely deployed for environment monitoring and object tracking by utilizing low-cost, low-power and multi-function sensor nodes. To realize such applications, the design and evaluation of communication protocols are of significant importance. Meanwhile, the network performance analysis based on mathematical models are also in great need of development and improvement.

This dissertation investigates the above topics from three important and fundamental aspects, including data collection protocol design, protocol modeling and analysis, and physical interference modeling and analysis. The contributions of this dissertation are four-fold.

First, this dissertation investigates the synchronization issue in the duty-cycled, pipelined-scheduling data collection of a WSN, based on which a pipelined data collection protocol, called PDC, is proposed. PDC takes into account both the pipelined data collection and the underlying schedule synchronization over duty-cycled radios practically and comprehensively. It integrates all its components in a natural and seamless way to simplify the protocol implementation and to achieve a high energy efficiency and low packet delivery latency. Based on PDC, an Adaptive Data Collection (ADC) protocol is further proposed to achieve dynamic duty-cycling and free addressing, which can improve network heterogeneity, load adaptivity, and energy efficiency. Both PDC and ADC have been implemented in a pioneer open-source operating system for the Internet of Things, and evaluated through a testbed built based on two hardware platforms, as well as through emulations.

Second, Linear Sensor Network (LSN) has attracted increasing attention due to the vast requirements on the monitoring and surveillance of a structure or area with a

linear topology. Being aware that, for LSN, there is few work on the network modeling and analysis based on a duty-cycled MAC protocol, this dissertation proposes a framework for modeling and analyzing a class of duty-cycled, multi-hop data collection protocols for LSNs. With the model, the dissertation thoroughly investigates the PDC performance in an LSN, considering both saturated and unsaturated scenarios, with and without retransmission. Extensive OPNET simulations have been carried out to validate the accuracy of the model.

Third, in the design and modeling of PDC above, the transmission and interference ranges are defined for successful communications between a node pair. It does not consider the cumulative interference from the transmitters which are out of the contention range of a receiver. Since most performance metrics in wireless networks, such as outage probability, link capacity, etc., are nonlinear functions of the distances among communicating, relaying, and interfering nodes, a physical interference model based on distance is definitely needed in quantifying these metrics. Such quantifications eventually involve the Nodal Distance Distribution (NDD) intrinsically depending on network coverage and nodal spatial distribution. By extending a tool in integral geometry and using decomposition and recursion, this dissertation proposes a systematic and algorithmic approach to obtaining the NDD between two nodes which are uniformly distributed at random in an arbitrarily-shaped network.

Fourth, with the proposed approach to NDDs, the dissertation presents a physical interference model framework to analyze the cumulative interference and link outage probability for an LSN running the PDC protocol. The framework is further applied to analyze 2D networks, i.e., ad hoc Device-to-Device (D2D) communications underlaying cellular networks, where the cumulative interference and link outage probabilities for both cellular and D2D communications are thoroughly investigated.