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

of

SEYED HAMED MOSAVAT-JAHROMI

MSc (University of Tehran, 2015)
BSc (Iran University of Science and Technology, 2012)

“Resource Management in Dense Wireless Networks”

Department of Electrical and Computer Engineering

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Remote Defence

Supervisory Committee:
Dr. Lin Cai, Department of Electrical and Computer Engineering, University of Victoria (Supervisor)
Dr. Xiaodai Dong, Department of Electrical and Computer Engineering, UVic (Member)
Dr. Alex Thomo, Department of Computer Science, UVic (Outside Member)

External Examiner:
Dr. Ping Wang, Department of Electrical and Computer Engineering, York University

Chair of Oral Examination:
Dr. Chris Nelson, Department of Biochemistry and Microbiology, UVic

Dr. Stephen Evans, Acting Dean, Faculty of Graduate Studies
Abstract

Recently, the wide range of communication applications has greatly increased the number of connected devices, and this trend continues by emerging new technologies such as Internet-of-Things (IoT) and vehicular ad hoc networks (VANETs). The increase in the number of devices may sooner or later cause wireless spectrum shortage. Furthermore, with the limited wireless spectrum, transmission efficiency degrades when the network faces a super-dense situation. In IEEE 802.11ah-based networks whose channel access protocol is basically a contention-based one, the protocol loses its efficiency when the total number of contending users grows. VANETs suffer from the same problem, where broadcasting and receiving safety messages, i.e., beacons, are critical. An inefficient medium access control (MAC) can negatively impact the network’s reliability. Effective resource management solutions are needed to improve the network’s reliability and scalability considering the features of different types of networks. In this work, we address the resource management problem in dense wireless networks in vehicle-to-everything (V2X) systems and IoT networks.

For IoT networks, e.g., sensor networks, in which the network topology is quite stable, the grouping technique is exploited to make the stations (STAs) compete in a group to mitigate the contention and improve the channel access quality. While, in vehicular ad hoc networks (VANETs), devices are mobile and the network topology changes over time. In VANETs, beacons should be broadcast periodically by each vehicle reliably to improve road safety. Therefore, how to share the wireless resources to ensure reliability and scalability for these dense static and mobile wireless networks is still a difficult and open problem.

In static IoT networks, we apply the Max-Min fairness criterion to the STAs’ throughput to group the STAs to ensure network performance and fairness. For formulation of the problem results in a non-convex integer programming optimization problem which avoids hidden terminals opportunistically. As solving the optimization problem has a high time complexity, the Ant Colony Optimization (ACO) method is applied to the
problem to find the sub-optimal solution. To support reliable and efficient broadcasting in VANET, wireless resources are divided into basic resource units in the time and frequency domains, and a distributed and adaptive reservation based MAC protocol (DARP) is proposed. For decentralized control in VANETs, each vehicle’s channel access is coordinated with its neighbors to solve the hidden terminal problem. To ensure the reliability of beacon broadcasting, different kinds of preambles are applied in DARP to support distributed reservation, detect beacon collisions, and resolve the collisions. Once a vehicle reserves a resource unit successfully, it will not release it until collision occurs due to topology change. Protocol parameters, including transmission power and time slots duration, can be adjusted to reduce collision probability and enhance reliability and scalability. Simulation of urban mobility (SUMO) is used to generated two different cities traces to assess the DARP’s performance.

Then, a distributed network coding-based MAC protocol (NC–MAC) is proposed to support reliable single-hop vehicle-to-vehicle (V2V) beacon broadcasting. We combine the preamble-based feedback mechanism, retransmissions, and network coding together to enhance broadcasting reliability. We deploy the preamble mechanism to facilitate the negative acknowledgement (NACK) and retransmission request procedures. Moreover, linear combinations of missed beacons are generated according to the network coding (NC) principles. We also use SUMO to evaluate the NC–MAC’s performance in highway and urban scenarios.

Group-casting and applying multi-hop communication can ensure reliability in V2X systems. As an extension of the proposed NC–MAC, a distributed grouping and network coding-assisted MAC protocol (GNC–MAC) is proposed to support reliable group-casting and multi-hop communication, which can address blockchain protocols’ requirement. We propose a new grouping protocol by combining preamble-based feedback mechanism, multi-hop communication, and network coding to improve group casting reliability. The preamble mechanism is responsible for reporting a NACK and requesting a retransmission due to beacon missing. The missed beacons are combined according to the NC principles and sent on a resource block.