University of Victoria | Graduate Studies

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

of

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## "Machine-Type-Communication in 5G Cellular System"

Department of Electrical and Computer Engineering

Friday, August 17, 2018
10:00 A.M.
Engineering and Computer Science Building
Room 468

Supervisory Committee:
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**Abstract**

The rapid development of Machine-Type-Communication (MTC) has brought big challenges to cellular networks such as super-dense devices and high-shadowing channels which may substantially decrease the spectrum efficiency and increase devices' power consumption. It is pressing to improve the transmission efficiency for MTC due to the limited wireless spectrum. Lower efficiency may also lead to longer transmission time and more energy consumption which conflict with MTC's requirement of lower power consumption.

In order to address the above issues, we propose to apply Network Coding (NC) and Device-to-Device (D2D) communications to MTC devices. Our approach introduces an additional delay for local packet exchange, which is acceptable given that MTC traffic typically has the feature of delay tolerance to certain degree. The benefit of the proposed approach is that the cellular transmissions are no longer user-specific, and thus an additional multi-user diversity gain is achieved. The cellular transmission efficiency will also be increased. How to apply the proposed approach for both downlink and uplink has been studied. For the downlink, in addition to the reduction of cellular resource consumption, the MTC devices' feedback load can also be significantly reduced because the cellular transmissions are not sensitive to user-specific errors. In the uplink, besides the enhanced transmission efficiency for full-buffer traffic, an additional small-data aggregation gain is achieved for MTC small-data traffic. Theoretical performance analyses for both downlink and uplink and the corresponding numerical evaluations are given.

Though the proposed NC and D2D approach can improve the transmission efficiency by exploring multi-user diversity gain, poor-quality MTC channels still exist which affect system performance. When the whole group MTC devices in an area experience high shadowing and penetration loss, we have to increase either the resource consumption or the transmitting power to overcome the poor-quality channels. The existing small-cell solution can improve the MTC channel quality, but MTC's unique traffic characteristics and quality of service requirements, as well as other practical issues,

make the small-cell deployment unprofitable. Therefore, we propose a solution using Floating Relay (FR) given the mature technologies of Unmanned Aerial Vehicle (UAV). We first target on the high-shadowing channels of the MTC devices and introduce the FR into the cellular system to improve the transmission efficiency and maximize the system capacity. An optimization problem, given the capacity limit of the FR's back-haul link and the maximum transmission power of each user, is formulated and then theoretically solved. An effective on-line flight path planning algorithm is also proposed.

Then, we extend the FR concept to a bigger picture and propose the UAV-assisted heterogeneous cellular solution. Detailed system design and comprehensive analyses on FR-cells deployment including frequency reuse, interference, backhaul resource allocation, and coverage are given. For UAV assisted networking systems, mobility and topology play important roles. How to dispatch a UAV to the optimal location in a mesh network to enhance the coverage and service of the existing network is a critical issue. Given the topology of existing service nodes, a new supplementary UAV can be sent to improve the quality of service especially for the users with poor-quality channels. The location of a newly added UAV is optimized to improve the service quality to the worst point.

In summary, we propose two means to improve the transmission efficiency for MTC in this thesis work. The NC and D2D approach can be used when some of the MTC devices have chances to experience better channels because of the fast fading and uneven shadowing. Otherwise, the FR can be applied to proactively improve the channel quality for MTC. The NC and D2D approach sticks to the latest standard in the cellular system and thus provides a down-to-earth and backward compatible MTC solution for 5G cellular system. The UAV-assisted heterogeneous cellular solution and UAV mesh networks can enable mobile Internet and ultra-reliable low latency communications, respectively. These solutions together effectively and efficiently support MTC, which is key to future proliferation of Internet of Things.