ENERGY EFFICIENT AND LOW-LATENCY COMMUNICATIONS FOR FUTURE WIRELESS NETWORKS

by

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Dissertation submitted in fulfilment of the requirements
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DOCTOR OF PHILOSOPHY

under the supervision of

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ABSTRACT

The ever-growing number of smart and mobile devices as well as their emerging applications call for novel solutions to address new challenges in energy efficiency and latency requirements. This thesis aims to develop novel protocols, resource allocation algorithms, and network architectures to enable low-latency services for mobile devices and applications (e.g., mission-critical applications in intelligent transportation systems, healthcare, gaming, and virtual/augmented reality applications). Specifically, we first introduce proactive resource allocation approaches to reduce the communications delay in machine type communications. Exploiting the correlation between smart devices (e.g., sensors), we propose an algorithm to proactively allocate uplink resources for these devices, and thereby reducing the expected uplink delay. Second, to address the energy efficiency problem for hardware-constrained devices, we propose a multi-tier task-offloading network architecture. In this novel network architecture, computation tasks from these devices can be offloaded to a network of computation-aiding servers or fog/edge nodes to minimize the energy consumption subject to the delay constraints of services. Because computing resources on fog nodes are usually limited, while task offloading demands from user devices are high, we develop an unprecedented model, allowing fog nodes and a powerful cloud server to collaborate to meet all tasks' requirements. Our experimental results demonstrate that the proposed solution can attain the optimal energy efficiency while meeting strict latency requirements for all devices and computing tasks. Finally, to address the fairness in allocating commu-

nication and computation resources of heterogeneous fog nodes for mobile devices considering diverse requirements (i.e., delay, security, and application compatibility), we adopt the proportional fairness criterion to develop a joint task offloading and resource allocation solution. The experimental results (i.e., fairness indexes, energy benefit, and energy consumption) show that the proposed scheme can attain the maximum proportional fairness in terms of the energy benefit (from offloading to fog nodes).

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Tien Thai VU, declare that this thesis is submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy, in the School of Electrical and Data Engineering, Faculty of Engineering and Information Technology, at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference of acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution.

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Journal publications

- **Tien Thai VU**, Diep N. Nguyen, Dinh Thai Hoang, Eryk Dutkiewicz, and Thuy V. Nguyen, "Optimal energy efficiency with delay constraints for multi-layer cooperative fog computing networks", in *IEEE Transactions on Communications*, 2021. (related to Chapter 3)

- "Proportional fairness for fog computing resource allocation", in *IEEE Transactions on Mobile Computing*, 2021 (under submission). (related to Chapter 4)

Conference publications

- **Tien Thai VU**, Diep N. Nguyen, and Eryk Dutkiewicz, "2D proactive uplink resource allocation algorithm for event based MTC applications", in *2018 IEEE Wireless Communications and Networking Conference (WCNC)*, 2018. (related to Chapter 2)

- **Tien Thai VU**, Nguyen Van Huynh, Dinh Thai Hoang, Diep N. Nguyen, and Eryk Dutkiewicz, "Offloading energy efficiency with delay constraint for cooperative mobile edge computing networks", in *2018 IEEE Global Communications Conference (GLOBECOM)*, 2018. (related to Chapter 3)

- **Tien Thai VU**, Diep N. Nguyen, Dinh Thai Hoang, and Eryk Dutkiewicz, "QoS-aware fog computing resource allocation using feasibility-finding benders decomposition", in *2019 IEEE Global Communications Conference (GLOBECOM)*, 2019. (related to Chapter 3)

- "Proportional fairness fog computing resource allocation using dynamic branch-and-bound benders decomposition algorithm", in *2022 IEEE Wireless Communications and Networking Conference (WCNC)*, 2022 (under submission). (related to Chapter 4)