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Title	将来の無線超高密度ネットワークのための高性能通信に関する研究
Author(s)	Yu, Yu
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Description	Supervisor:リム　勇仁，情報科学研究科，博士

JAPAN ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY

Japan Advanced Institute of Science and Technology

Abstract

In the past decade, one remarkable trend is the explosive growth of new generation mobile devices, such as smartphones, tablets and wearable smart devices. Moreover, such smart devices are relentless penetrating our daily life, not only into communication, but also into photography, travel (navigation), entertainment, social network, office working, action payment, safety, health care, etc. To satisfy all these different needs, the fifth generation of wireless system (5G) is under developing, which aims to achieve higher capacity, allows a higher density of mobile broadband users, supports ultra-reliable, low latency and massive machine communication since 2020. Depend on the development of wireless systems, the network is changing from homogeneous network to heterogeneous networks (HetNets), and will inevitably move to ultra-dense networks (UDNs). However, there are several key problems need to be solved in UDNs, such as, how to achieve best energy-efficient; how to manage the wireless interference, and how to success low latency communication in execution. This dissertation investigates the related techniques and 5G protocol stack to fulfil these key capabilities to realize high performance communication for future wireless UDNs.

The purpose of this dissertation is that to propose a high performance dense communication (HPDC) framework by focusing on energy-efficiency, low interference and low latency for wireless ultra-dense networks. The HPDC framework should support the protocol stack of 5G and beyond. Therefore, by using D2D communication, multihop fashion, and multi-RAT techniques, three key schemes, which are dense-aware adaptive transmit power control (DATPC) scheme, dense-aware adaptive carrier sense threshold (DACST) scheme, and dense-aware low-latency communication control (DLLCC) scheme will be proposed for future wireless UDNs. Besides of that, I will also propose some novel components to support these schemes in HPDC framework, such as spectrum sensing scheme, e.g., interference-based sensing, etc.; transmission (spectrum) sharing, e.g., concurrent transmission, sequential transmission, and mix of above two transmissions. More detail work is recalled briefly as below.

A dense-aware adaptive transmit power control (DATPC) scheme is needed to maximize end-to-end throughput with minimized the total interference power and reduce the total energy consumption. The core of the DATPC scheme is consensus transmit power control algorithm. It is the first distributed TPC algorithm that supports multiple flow traffics in D2D communication with multihop fashion for ultra dense situation. This scheme should be implemented into open wireless architecture (OWA) layer for 5G and beyond. Furthermore, based on the proposed DATPC scheme, the link to trans- mission sharing scheme for maximization also need to be discussed. The advantage of DATPC scheme is that different with centralized control, this is the space-division based distributed control scheme. Thus, DATPC scheme can be easily implemented on any devices.

To enrich DATPC scheme in ultra-dense networks, a dense-aware adaptive carrier sense threshold (DACST) scheme is necessary to achieve better network performance. The DACST scheme should cooperate with DATPC scheme to achieve higher user experienced data rate with dramatic improvements of energy efficiency for UDNs. Similar with DATPC scheme, the DACST scheme should also be implemented into OWA layer and also be linked with network layer. In addition, for the evaluation, not only based on simulation results, emulation results or results of real world test are essential. Thus, an advanced Starmesh emulator over the StarBED testbed is designed to further verify the performance evaluation of the proposed DATPC and DACST schemes. Due to the real devices (hardware specification) used for the emulation level evaluation, DACST scheme might not achieve its best performance. But, on the whole, the evaluation results should prove that the proposed DATPC and DACST schemes do increase the energy-efficiency and mitigate the interference level for UDNs.

Besides, a dense-aware low-latency communication control (DLLCC) scheme is necessary to solve the high latency problem, which is caused by end-to-end retransmission. The DLLCC scheme should be implemented into open transport layer with the function of multipath TPC. In mobile and wireless networks, controlling data delivery latency is one of open problems due to the stochastic nature of wireless channels, which are inherently unreliable. This scheme opens an opportunity to explore how the current best-effort throughput-oriented wireless services could be evolved into latency-sensitive enablers of new mobile applications such as remote three-dimensional (3D) graphical rendering for interactive virtual/augmented-reality overlay. The general system design is based on (i) spatially diverse data delivery over multiple paths with uncorrelated outage likelihoods; and (ii) forward packet-loss protection (FPP), creating encoding redundancy for proactive recovery of intolerably delayed data without end-to-end retransmissions. Analysis and evaluation are based on traces of real life traffic, which is measured in live carrier-grade long term evolution (LTE) networks and campus WiFi networks, due to no such system/environment yet to verify the importance of spatial diversity and encoding redundancy. Analysis and evaluation reveal the seriousness of the latency problem and that the proposed FPP with spatial diversity and encoding redundancy can minimize the delay of re-ordering. Moreover, a novel FPP effectiveness coefficient is proposed to explicitly represent the effectiveness of FPP implementation.

The proposed HPDC framework is evaluated by simulation in MATLAB, emulation with proposed StarMesh emulator, and using real-world data traffic traces. All of the results indicates that the proposed framework do significantly increase energy efficiency, mitigate the violent interference and achieve low-latency communication for high performance communication.

Keywords: High performance communication, ultra-dense networks, dense-aware adaptive transmit power control, consensus transmit power control, dense-aware adaptive carrier sense threshold, dense-aware low-latency communication control, spatial diversity, encoding redundancy