Graduate School of Fundamental Science and Engineering
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博 士 論 文 概 要
Doctoral Thesis Synopsis

論 文 題 目
Thesis Theme

Studies on Congestion Control for Green Wireless Sensor Communications in Information-Centric Networking
情報セントリックネットワークにおけるグリーン無線センサ通信輻輳制御に関する研究

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The communication represents one of the most important parts of human interconnected world because the Internet is a fundamental technology that provides many beneficial applications for human society and daily lives. In the ongoing Big Data era, a large number of packets is required to communicate between hosts, due to the dramatically increasing number of users. This huge network traffic is a major cause of network congestion. In this context, several Internet architectures have been recently proposed for the Future Internet (FI), and Information-Centric Networking (ICN) has been considered as the global-scale FI paradigm, thanks to its benefits over the existing IP-based Internet designs. Typically, ICN can improve major network metrics, e.g., data rate, network utilization, and especially latency, compared to the current host-centric Internet because different from the existing host-to-host Internet design, the requested content data can be served by a replica from a content node in ICN interconnections, instead of only from the content source.

However, ICN deployment is still challenging as a huge number of the request packets is generated in ICN due to its packet flooding strategy, which causes high traffic, then increases the congestion rate and network devices power consumption. Recently, ICN congestion control mechanism has been studied, in the wireless environment but most of the existing ICN researches focus on the content consumers and publishers mobility. Moreover, the in-network caching capability in ICN also raises energy consumption problems due to additional energy for caching capability compared to an IP-based network system. The Energy Efficiency (EE) issue even gets more challenging in the sensor-enabled network because energy consumption is a critical key in the design of wireless sensor networks (WSNs), given that sensors are small devices with power-constraint due to their limited battery capacity. Also, although energy consumption is a major concern in the design of the future wireless communications, there is not much work about EE in ICN, especially in the wireless environment. These facts raise the need for a congestion control mechanism to realize a Green IoT sensor-enabled ICN for future communications, given that congestion control, and energy consumption are primary concerns in the design of wireless communications for the FI.

Therefore, this dissertation builds an adaptive ICN model with congestion control mechanism to improve the network performance for ICN-based wireless sensor networks in the context of IoT. The main objective is to enable an efficient flow control for the congestion control in ICN and to reduce the power consumption of the ICN wireless sensors for the FI. To enhance the network efficiency, this study proposes a flow control approach employing delay time of a content (dtc) for transmission process with associated content lifetime used to record lifetime of each content according to its popularity level. Also, this study classifies the sensor status for defining the optimal operating mode of sensor to realize the adaptive sensor scheduling strategy. For forwarding scheme, this work uses a chunk aggregation mechanism to calculate the appropriate number of chunks for chunk aggregation stage. This research also utilizes the cache management strategy with cache partitioning scheme which caches an appropriate number of content chunks for caching at the ICN nodes, and design a sensor power-based caching

mechanism for saving the sensor energy. Specifically, the proposed approach aims to diminish the number of the Interest packets needed for data transmission, and then reduces the congestion rate in ICN substantially. Besides, to resolve the Energy Efficiency (EE) problem in the sensor-enabled network, this research proposes an adaptive sensor scheduling and selective sensing to maximize sensor power savings. The dissertation then simulates the network scenario using ndnSIM (a widely-used ICN simulator) to evaluate and analyze the proposed model. Finally, the research shows the network performance improvement of the proposal compared to the alternative designs in the context of IoT, as well as analyze the need of the proposal implementation for congestion control in ICN.

This dissertation consists of six chapters and the detail of each chapter is described as follows:

Chapter 1 presents the dissertation problem statement. Next, this chapter states the research motivations and aims. The proposed approach and its contributions, and the dissertation organization are also presented in this chapter.

Chapter 2 surveys the research background and investigates the literature review on the ICN for the future Internet. Firstly, this chapter explains the ICN concept, ICN platforms including Named Data Networking (NDN) with its working mechanism and implementation. Next, the fundamental concept of network management policies, together with EE and congestion control schemes are indicated. Then, the major challenges and research trends in ICN are analyzed, with a focus on recent research efforts toward the ICN performance and EE problems in ICN.

Chapter 3 introduces the general system concept and explains the working mechanism of the proposed ICN model. Typically, this study proposes the content popularity-based delay time (i.e., dtc) together with priority-based content lifetime. In addition, this chapter defines the popularity-based cache partitioning strategy to cache content data at the Content Store (CS) to realize the effective content retrieval for the consumers. Also, this study presents the network performance evaluations.

Chapter 4 shows the IoT sensor congestion control scheme for efficient communications in ICN. Particularly, this chapter utilizes the dtc corresponding to the ranking of the content as the average of content popularity and priority for the data transmission. This work also proposes the chunk-by-chunk aggregated popularity-based cache partitioning scheme to further minimize the packet drop rate of the IoT sensor enabled network in ICN. Then, this chapter discusses the performance evaluations including the network scenario, key parameters, and simulation settings.

Chapter 5 presents the ICN congestion control mechanism and the respective energy efficiency model for the efficient communications in the Green IoT sensor-enabled ICN. Particularly, this study applies the Markov-based scheduling operating strategy for greening ICN-based IoT sensor networking by

implementing adaptive sensor scheduling and selective sensing policy, sensor-power based caching mechanism together with the popularity-based chunk aggregation for the forwarding scheme. In addition, this chapter proposes an energy efficiency analysis in terms of the total energy consumption per successfully transferred bit. Also, this research presents the network performance and EE evaluations, and discusses the system efficiency. The evaluation results using ndnSIM show that the proposal can decrease the number of packet drop rate and save about 40 percentage energy consumption for data transmission compared to the relevant related work in ICN. Moreover, this work discusses the need of the proposed system implementation for congestion control in ICN.

The final chapter (Chapter 6) summarizes and concludes all the content and major findings of the study. Particularly, this dissertation presents the considerable research finding in the networking field regarding congestion control and EE for deployable FI in the context of IoT. However, this study still has its limitation and several questions that remain unanswered. Also, this chapter then gives remarks and suggestions to the potential future studies in the field of congestion control and Green networking toward scalable and efficient future IoT sensor-enabled networks. Thus, this dissertation is a practical and feasible networking approach for the realization of the ICN-based efficient and scalable network communications towards practical sensor-enabled future Internet.

早稲田大学　博士（工学）　学位申請　研究業績書

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Articles in Refereed Journals	○ [1] A Smart Congestion Control Mechanism for the Green IoT Sensor-Enabled Information-Centric Networking, MDPI Sensors, vol. 18 (no. 9): Article no. 2889, 2018, **Rungrot Sukjaimuk**, Quang Nguyen**,** and Takuro Sato. ○ [2] Adaptive Congestion Control in Information-Centric Networking for the IoT Sensor Network, Journal of Advanced Simulation in Science and Engineering, 2018, pp. 17-28, **Rungrot Sukjaimuk**, Quang Nguyen**,** and Takuro Sato.
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