様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

# 科学研究費助成事業　　研究成果報告書

令和　４ 年　 ５ 月 ３０ 日現在

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研究期間：2018～2021
課題番号：１８Ｋ１１２５５

研究課題名（和文）見守りシステムのためのコンテクスト・アウェアなIoTプラットフォームの研究開発

研究課題名（英文）Research on Context-aware IoT Platform for Lifestyle Monitoring System

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交付決定額（研究期間全体）：（直接経費）　　2,600,000円

研究成果の概要（和文）：本プロジェクトでコンテキストアウェアなセンサーやルーターを実装。センサー名やデバイスIDなどのコンテキストをデータパケットのトレーラに付加。IoTルータは、パケットがネットワークに入る際にセンサーのコンテキスト情報を取得し、それに応じてデータ処理を行う。
本プロジェクトで複数のアプリケーションの開発も実施。一例として、キャンパス内でのCOVID-19の感染拡大を抑制するため、人口推定を目的としたIoTシステムを構築した。これは大学で授業が再開した際の「新しいライフスタイル」を見守ることに役立つものであり、実用的な価値が高いシステムである。また、海洋環境モニタリングなどアプリケーションも開発した。

研究成果の学術的意義や社会的意義
学術的意義では、設計されたコンテキストアウェアネットワークアーキテクチャは、パケットトレーラにアドレス指定可能でルーティング可能なコンテキスト情報を初めて定義したものである。このアーキテクチャは、データ指向ネットワーク（ICN）の利点と、現在のインターネットに漸進的に展開できる利点を兼ね備えている。
社会的意義では、複数のアプリケーションを開発した。一例として、キャンパス内でのCOVID-19の感染拡大を抑制するため、キャンパス内の人口推定を目的としたコンテキストアウェアIoTシステムを構築した。このように、3Cシステムは人々の「新しいライフスタイル」を見守るという点で、強い実用性を持っている。

研究成果の概要（英文）：For architecture area, we have implemented context-aware IoT sensors and routers. We attach the context-info such as sensor name and sensor device id to the trailer of data packet. When packets enter into the network, the IoT routers get the context-info of the sensor data, and perform data processing accordingly. We also prototype context-aware private LTE/5G network and also integrate it with public LTE.
For application area, we have developed multiple use applications. For example, we have developed context-aware IoT system on campus for population estimation to slow the spread of COVID-19. Our 3C system is a typical application of our proposed context-aware IoT system that has a strong practical value in helping people to monitor the “new lifestyle” when people are gradually returning to the office. We have also deployed IoT sensors and gateways in Hiroshima to monitor the ocean environment to support the local fisheries industry.

研究分野：情報通信 / 情報ネットワーク

キーワード：Internet-of-Things (IoT)　Mobile Network　Context-aware

様　式　C－１９、F－１９－１、Z－１９（共通）

1. 研究開始当初の背景

(1)　With the development of LTE/5G mobile technologies, Internet-of-Things (IoT) has been playing an important role in human life (Fig.1).　Not only conventional smartphones and tablets, but also emerging massive Machine Type Communication (mMTC) including cars, drones, industrial machines, and sensors are being interconnected through mobile services with low cost, low latency, and low energy consumption.

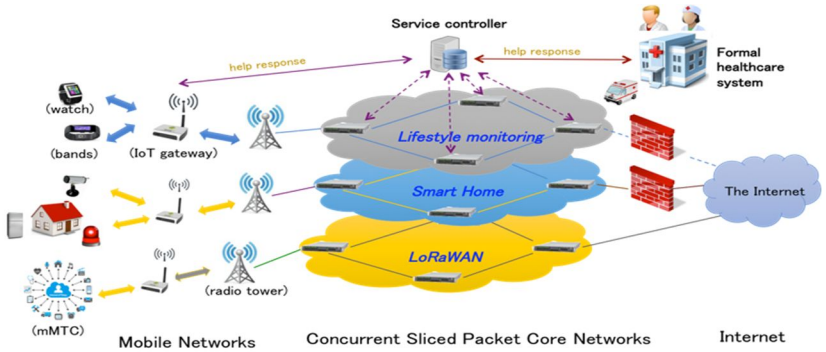


Fig 1 Architecture of IoT Mobile Network

(2)　Although IoT has broad application prospects in a variety of fields, these advances are limited by the rigidity of the current network infrastructure that is designed in a host-centric manner suitable for point-to-point communication, which is inefficient in supporting new Internet use cases such as data-oriented IoT applications. When an IoT data packet is transmitted into Internet,　the contextual information of the data is hidden from network appliances unless performing deep packet inspection (DPI) on packets. On the other hand, many IoT applications support in-network computing and caching or storage, which requires exposing high-level application-layer contexts (such as service) and low-level sensor-layer contexts (such as device, location, time) to in-network appliances.

2. 研究の目的

(1) The main goal of this research project is to design and implement a context-aware IoT network infrastructure that can handle IoT traffic based on contextual information exposed from both high application-layer and low sensor-layer, to fill the gap between IoT and IP network leveraging Software-defined Networking (SDN) and Network Function Virtualization (NFV).

(2) The second goal of this research project is to implement use case applications on the proposed IoT platform to show the feasibility of the designed IoT platform.

３．研究の方法

(1) The main idea is to attach contextual information to the packet trailer of IoT applications so that the proposed IoT network architecture can be deployable in current IP-based Internet where conventional routers and switches forward/process packets based on packet headers. Meanwhile, our custom IoT packet gateways can forward and process packets on the packet trailers. In this research project, contextual information is attached to the packet trailer of IoT

applications so that customized packet gateway can process and forward the packets based on attached contextual information. The context-aware IoT network architecture can be incrementally deployable in current IP-based Internet where routers and switches process packets based on packet headers and treat packet trailers as a part of payload.

(2) To guide study and design, the platform is developed together with some IoT applications such as lifestyle-monitoring system, which help to test and improve the platform during its development process. We develop multiple kinds of sensors and IoT applications in a real environment such as on campus to get real users. Then we can improve our context-aware system via the feedback from users.

## ４．研究成果

(1) Context-ware IoT mobile router. We have designed and created IoT mobile router, which consists of Raspberry board, Sensor HAT board and LTE modem board. We attached the context-info such as sensor name and sensor device id to the trailer of data packet. The packet gateway, built with our deeply programmable FLARE node, will get the context-info of the sensor data, and will perform traffic engineering accordingly. The prototyped system has been demonstrated in Japan IT week at Tokyo Big Sight during 2019/5/8-5/10.

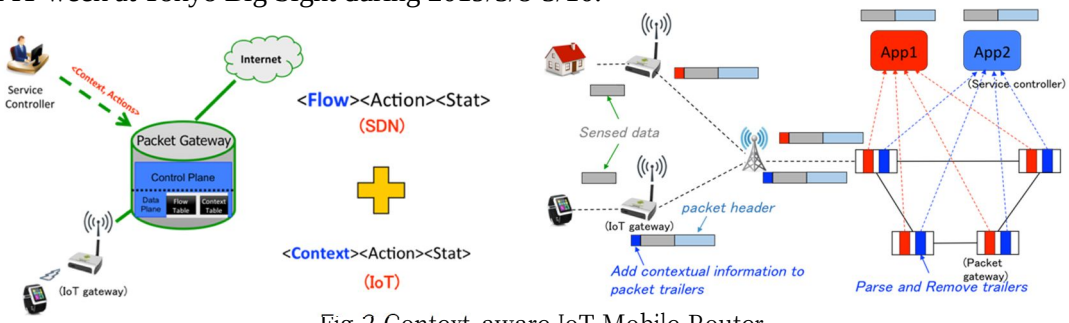


Fig 2 Context-aware IoT Mobile Router

(2) Context-ware IoT sensors and gateways. We have developed multiple kinds of IoT sensors (including temperature, humidity, atmospheric pressure, GPS) and gateways (including Arduino version and Raspberry version) for monitoring people's lifestyle. We have deployed multiple IoT sensors and gateways in Hiroshima to monitor the ocean environment to support the local fisheries industry.

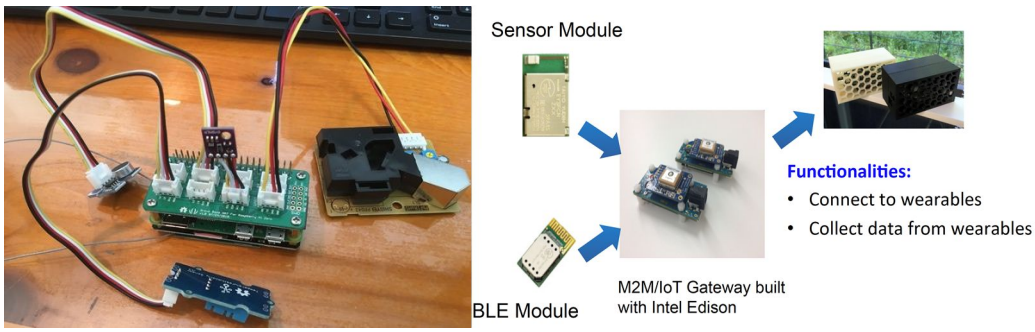


Fig 3 Context-aware IoT Sensors and Gateways

(3) Context-aware Private LTE/5G Network. We have prototyped a context-aware UE slicing architecture utilizing in-network deep learning. In our implementation, we tag the downlink packets with the identified context info utilizing deep learning at the packet gateway (PGW) and transmit them to RAN slice with different spectrum resource blocks (RBs) and scheduling

algorithms. The context info can be defined be as application name, location info or others as user defined. The work has been published in 3 papers and one paper got IEICE ICM English Session Encouragement Award.


Fig 4 Context-aware Private LTE/5G Network

We cooperated with a mobile network carrier to integrate our private LTE with a public LTE network, where a user can migrate between the private LTE and the public LTE network with only one SIM. We have also integrated our IoT systems into our Local 5G system, where the sensor data is transmitting via Local 5G network. We are integrating the IoT system with satellite link, where an NB-IoT eNB will be deployed on LEO satellites to provide ubiquitous coverage.

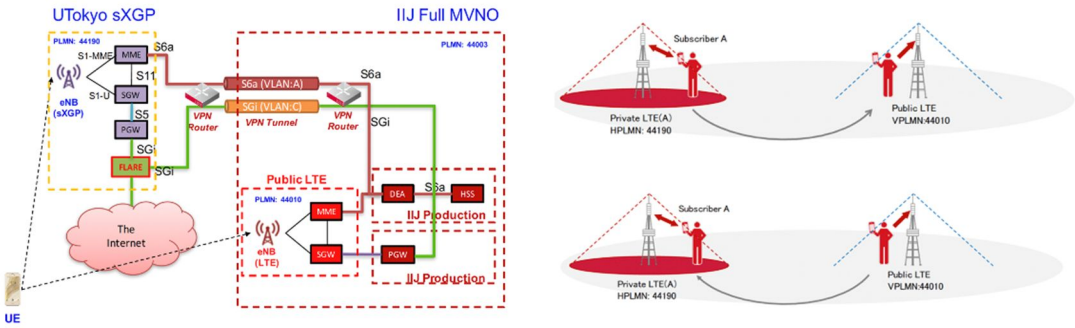


Fig 5 Integrate Private LTE/5G Network with Public LTE network

(4) <u>High-speed PPPoE Router for home IoT network.</u> We build a compact 10Gbps software PPPoE router on a commercial mini-PC for home IoT network, which can achieve much higher throughput than a commercial PPPoE router tested in a production environment. The related work has been presented at a conference, and the paper has been recommended for IEICE journal paper.

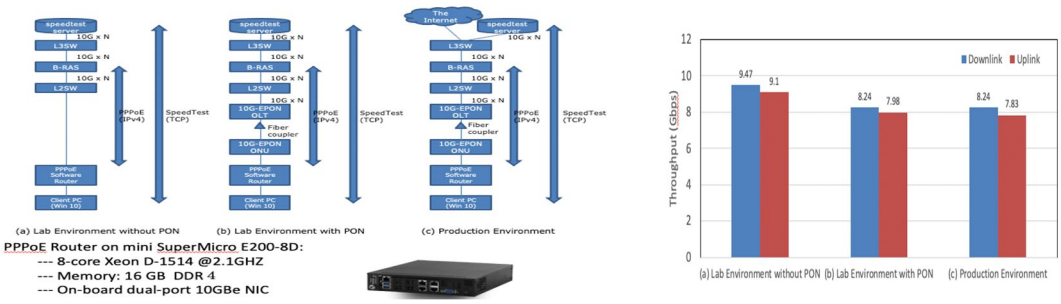


Fig 6 High-Speed PPPoE Router for IoT Home Network

(5) <u>Life-style monitoring system for COVID19.</u> We have developed context-aware IoT system on campus for population estimation to slow the spread of COVID-19. Our 3C system is a typical application of our proposed context-aware IoT system that has a strong practical value in helping people to monitor the “new lifestyle” and contribute to slowing the spread of COVID-19 through reducing densely areas when people are gradually returning to the office. We design

and deploy sensors and base stations at specific locations to monitor the communication from nearly devices installed COCOA App and count the number of devices to estimate the population density.

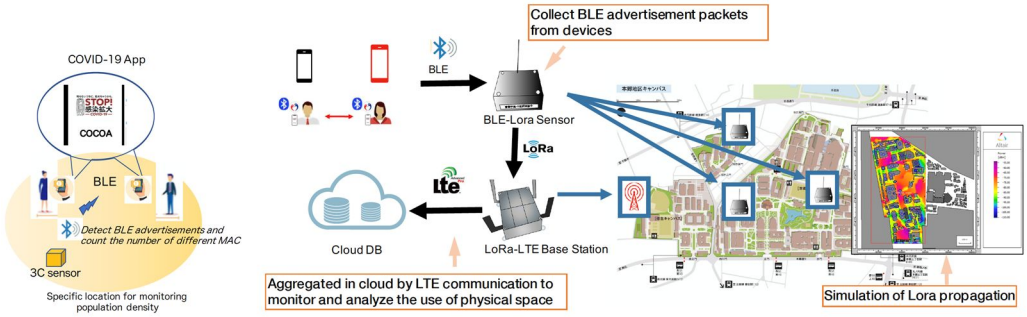


Fig 7 Life-style mentoring system for COVID19 deployed on Campus in the University of Tokyo

Totally, we have deployed more than 200 sensors and 30 base stations in the classrooms, libraries, and cafeterias on four campuses in the University of Tokyo. Our web service of the population estimation has about 1000 page views per day. The feedback shows the service is highly-evaluated by students and administration. Moreover, we have been invited to deploy our 3C systems in business facilities. For example, we have also deployed 30 sensors and 10 base stations to monitor the number of climbers at various inspection points on Mount Fuji area in real time to protect the safety of climbers.

We have integrated the 3C Sensing into 5G CPEs so that the Local 5G network itself can detect population density in the 5G area. We have also done some research in the 5G network slicing that is assumed to support IoT in a 5G slicing. The results have been published as two international conference papers and one technical report.

５．主な発表論文等

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| 掲載論文のDOI（デジタルオブジェクト識別子）<br>10.1587/transcom.2019EBT0002 | 査読の有無<br>有 |
| オープンアクセス<br>オープンアクセスではない、又はオープンアクセスが困難 | 国際共著<br>－ |

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〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

| | 氏名<br>（ローマ字氏名）<br>（研究者番号） | 所属研究機関・部局・職<br>（機関番号） | 備考 |
|---|---|---|---|

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

| 共同研究相手国 | 相手方研究機関 |
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