Annual Report of Technical Committee on Network Systems

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1. Introduction

This report covers the annual activities of the IEICE Technical Committee on Network Systems (NS). It describes activities at the monthly technical meetings, recent research topics of the committee, and the research awards for 2021.

2. Technical Meetings

During the period between April 2021 and March 2022 there are 10 NS technical meetings, 1 workshop [1], and additionally, 3 technical meetings of Network Software (NWS) sub-committee (as shown in Table 1). Several meetings are co-located with the OCS (Optical Communication Systems), PN (Photonic Network), SeMI (Sensor Network and Mobile Intelligence), RCS (Radio Communication Systems), SR (Smart Radio), RCC (Reliable Communication and Control), IN (Information Networks), CS (Communication Systems), NV (Network Virtualization), ICM (Information and Communication Management), and CQ (Communication Quality) technical committees. All technical meetings in 2021 were held Online or Hybrid due to COVID-19.

Recently presented papers mainly focus on technologies that support new generation networks, wireless and mobile networks, IoT, applications, security issues, network virtualization, SDN/NFV, cloud computing, Mobile Edge Computing (MEC), ICN/CCN, blockchain, and Quality of Service/Experience (QoS/QoE). In addition, the number of presented papers related to AI and machine learning is increasing rapidly in recent years.

At each technical meeting, we host lectures by invited speakers who are experts in their research fields. During this fiscal year, we have invited lectures on network virtualization and softwarization, applications of AI and machine learning, network design, IoT, and other topics. In fiscal 2021, we had 174 presentations from academia and 59 from industry in the NS technical meetings.

Since June 2003, we have been encouraging research of young researchers who have presented papers at NS technical meetings by inviting them to give follow-up

Table 1: Technical meeting schedule for fiscal 2021. (Gray cells indicate technical meetings of NWS sub-committee)

Date	Location	Theme	Co-location with
April 15-16	Online	Traffic, Network Evaluation, Resource Control and Management, Network Reliability and Resilience, Network Intelligence and AI, etc.	
May 13-14	Online	High Level Protocol, Networking Technologies, IP Network Application Technologies, Network System Related Technologies, Security, Blockchain etc.	
June 5	Online	Network Software in the After-Corona Era	
June 24-25	Online	Core/Metro System, Photonic Network System, Optical Network Design, Traffic Engineering, Signaling, GMPLS, etc	OCS, PN
July 14-16	Online	AI/ML-based Network, M2M (Machine-to-Machine), D2D (Device-to-Device), IoT(Internet of Things), , etc.	SeMi, RCS, SR, RCC
September 9-10	Online	SIP, IMS, Cloud/Data Center Network, SDN/NFV, IPv6, Machine Learning, etc.	CS, IN, NV
October 6-8	Online	Network Architecture (Overlay, P2P, Ubiquitous Network, Active Network, NGN, New Generation Network), Grid, etc	
October 22-23	Online	Network Software for Robotics	
November 25-26	Hakata/ Online	Network Quality, Network Measurement and Management, Network Virtualization, Security, Network Intelligence, etc.	CQ, ICM, NV
December 16-17	Nara/ Online	Multi-hop/Relay/Cooperation, Sensor/Mesh, Ad-hoc Network, D2D/M2M, Wireless Network Coding, VoIP, IoT, Edge etc.	RCS
January 27-28	Online	Network Software, Network Application, SOA/SDP, NGN/IMS/API, Distributed Control/Dynamic Routing, etc.	
		Network Software for the After/With Corona	
March 10-11	Online	General, IN/NS Workshop (March 4)	IN

talks several months later. We call these the "encouragement talk." We invited six young researchers to give such talks in the past year. We will continue this activity.

3. Research Awards 2021

The Technical Committee selected the recipients of Network System Research Award from among 160 regular papers that had been presented at monthly NS technical meetings from January to December in 2021. The award is given to each of the authors of the three or four best papers of each year. The abstracts of the four papers that won the award in 2021 are as follows.

Takamitsu Iwai et al. "Bandwidth Allocation Method Preserving Slice Quality Fairness in a Wireless Environment," [2]

Network slicing, which allocates appropriate resources according to the application, has been proposed to improve the user experience and diversify network services. Various application traffic coexists in the same network in the current wireless networks, where we can not satisfy each application requirement. Hence, 5G wireless communications are expected to have various types of links (e.g., eMBB, mMTC, URLLC) and provide application-specific network slicing for high-bandwidth and latency-sensitive applications such as autonomous vehicles.

However, in a wireless environment with fluctuating link capacity, we need to adjust each slice's bandwidth dynamically while maintaining the user experience when we can not satisfy the requirements specified by each application due to insufficient link capacity. In addition, network operators need to assign the bandwidth based on an explicit metric since we need to allocate bandwidth for the clients who do not use slicing. We propose a novel control method that sets a utility function, called slice quality, for each slice and adjusts each slice's bandwidth depending on the link capacity to keep these qualities fair. We set different utility functions for the normal slice, a typical slice that requires a fixed bandwidth, and the residual slice, a best-effort slice that manages the non-slicing users' bandwidth. We update the allocated bandwidth so that each slice's quality is fair based on the link capacity at each point in time. We show a median improvement of 65% in the slice quality's fairness than a simple bandwidth allocation policy while keeping the quality degradation of normal slices below 10%.

We believe this research can contribute to more precise and diverse network slicing for mobile applications. The 5G wireless communications bandwidth fluctuates significantly under high-speed mobility. Our method will provide dynamic network slicing for such an extreme communication environment.

Shunya Kida et al. "Distributed Deployment of Aerial Base Stations with RF Energy Harvesting" [3]

An unmanned aerial vehicle (UAV)-mounted aerial base station (ABS) can be considered a promising technology to enhance the capacity and coverage in future mobile communication networks. Owing to its flexible mobility, ABSs can adaptively respond to a sudden traffic increase such as in open-air concerts. In addition, ABSs can assist the existing terrestrial networks when they fail due to disasters. Although ABSs have high flexibility, determining their optimal placement that maximizes the overall communication quality of ground users is a challenging problem because of complicated air-to-ground channel characteristics and inter-cell interference among ABSs. Moreover, ABSs are faced with the problem that their available power resources are limited. This study considers an ABS network in which ABSs perform radio frequency (RF) energy harvesting from terrestrial base stations and proposes a distributed ABS deployment method for maximizing the performance of RF energy harvesting and downlink transmission to users simultaneously. We assume that ABSs perform the RF energy harvesting and downlink transmission to a user in successive time slots and if both have sufficient quality, the user is covered by an ABS. By considering the number of covered users as the performance metric, we formulate an ABS deployment problem and present a distributed algorithm to solve it. In our method, each ABS updates the position by using only its local information and exchanging information with neighboring ABSs. Such a distributed method has an advantage over centralized ones proposed in many existing studies because distributed methods can respond to user dynamics rapidly by local information exchange/computations, whereas centralized methods have large overhead of information gathering from the whole network with relatively large communication delay. We evaluate the proposed method by simulation and the results demonstrate that our method improves both the energy harvesting and communication quality of users.

Shino Shiraki et al. "Indoor Localization for Pedestrians Using Contact Information Between Smartphones," [4]

Indoor localization using wireless communication technology is an important research topic in the field of wireless sensor networks, and a method based on estimated distances among multiple known-location anchor nodes and a pedestrian smartphone is particularly well known. In this method, distance between each anchor node and the smartphone is estimated directly from the received signal strength of wireless signal emitted by the anchor node. However, a problem with this method is that the received signal strength varies greatly depending on the wireless propagation environment.

Recently, primarily in response to the COVID-19 pandemic, digital contact tracing applications for smartphones have entered widespread use. This has caused us to conjecture that smartphone contact information could also be used for indoor localization. With that point in mind, this study proposes two indoor localization algorithms (multilateration and cooperative) that utilize contact information obtained from smartphone Bluetooth Low Energy (BLE) beacons. In our methods, each node (smartphones and anchor nodes) establishes proximity relationships among other nodes in the vicinity based on the received signal strength of the BLE signal emitted by those nodes, and each node periodically sends the identifiers for those nodes to the server. Next, the server estimates distances between nodes based on their proximity relationships. An advantage of our proposed method is that it is less dependent on changes in the radio propagation environment because it estimates distances from node proximity relationships. Finally, the pedestrian smartphone locations are estimated using the proposed algorithms.

Cooperative localization can be seen as an extended version of multilateration, and our simulation results show that it improves localization accuracy compared to multilateration. More specifically, the average localization error is about 2 m when using cooperative localization. Additionally, in terms of localization error, the standard deviation for the cooperative localization is smaller than that for the existing centroid method, thus indicating that stable localization is possible using our proposed method.

Takumi Shiohara et al. "Maximum Delay Analysis of Fixed Backoff in IEEE 802.11 Considering Significant Interference for In-Vehicle Wireless Communication," [5]

Mission-critical periodic communication using CSMA/CA are under active research. One of them is in-vehicle wireless communication using IEEE 802.11 ad/ac/ax. In in-vehicle communication, each in-vehicle sensor terminal transmits small-sized data (tens to hundreds of bytes) in a cycle of several milliseconds to tens of milliseconds. Therefore, all terminals need to successfully transmit data within this cycle. In other words, there is a requirement that the total delay, such as backoff delay and retransmission time due to the contention window (CW), must be kept within the allowable value determined by the above cycle. In this study, we define the maximum value of this delay as the maximum delay, and analyze its characteristics.

We propose a delay distribution analysis method for the IEEE 802.11(CSMA/CA) fixed CW, which has already been proposed for efficiently accommodating many terminals for mission-critical periodic communication with interference. We also show that the delay distribution derived from the analytical model is an upper bound on the delay distribution of the fixed CW method. In the proposed analysis method, we focus on the fact that the transition of the number of terminals and the upper bound of the collision frequency distribution can be approximated by a binominal distribution. The proposed method consists of the following two steps. The first step is to derive the distribution of the total number of slots required for all terminals in the target network in the system to leave from a two-dimensional Markov model that focuses on the number of terminals. In the second step, we derive the delay distribution by transforming the obtained total number of slots distribution into real time, focusing on the upper bound of the distribution of the number of events that can occur in a slot time. By the proposed method, we can obtain the communication delay characteristics by theoretical analysis even in the communication model which is very different from the conventional one, where terminals exit from contention one by one due to successful communication.

4. Future Plans

The Technical Committee will have 10 NS technical meetings in this fiscal year. In case it is difficult to host on site meetings due to concerns on COVID-19, we will hold online meetings.
(For more information, please see our home page.
URL: https://www.ieice.org/cs/ns/eng/index.html)

5. Reference

[1] Masahiro Yoshida, Kotaro Mihara, and Takashi Ikebe: "Fiscal 2021 Report of Research Trends in Technical Committee on Network Systems," *IEICE Tech. Rep.*, May 2022.
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[3] Shunya Kida, Tatsuaki Kimura, and Tetsuya Takine: "Distributed Deployment of Aerial Base Stations with RF Energy Harvesting," *IEICE Tech. Rep.*, NS2021-35, July 2021.
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