

INVITED PAPER *Special Section on Emerging Communication Technologies in Conjunction with Main Topics of ICETC2020*

# Comprehensive Survey of Research on Emerging Communication Technologies from ICETC2020

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**SUMMARY** The 2020 International Conference on Emerging Technologies for Communications (ICETC2020) was held online on December 2nd–4th, 2020, and 213 research papers were accepted and presented in each session. It is expected that the accepted papers will contribute to the development and extension of research in multiple research areas. In this survey paper, all accepted research papers are classified into four research areas: Physical & Fundamental, Communications, Network, and Information Technology & Application, and then research papers are classified into each research topic. For each research area and topic, this survey paper briefly introduces the presented technologies and methods.

**key words:** ICETC2020, physical, fundamental, communications, network, information technology, application

## 1. Introduction

The 2020 International Conference on Emerging Technologies for Communications (ICETC2020) was held online on December 2nd–4th, 2020 [1], and this conference was organized by the Communications Society of the Institute of Electronics, Information and Communication Engineers (IEICE). This was the first international conference on all the technical fields covered by the IEICE Communication Society, and the objectives of the conference were to provide synergistic effects beyond the technical fields, expand research areas, encourage the development of young researchers, and provide a place for discussions. For this objective, this conference allows for the presentation of not only excellent research results, but also preliminary results in the early stages of research.

In this conference, 213 research papers that included 96 papers and 117 short papers were accepted in four research areas shown in Fig. 1, which are *Physical & Fundamental*, *Communications*, *Network*, and *Information Technology & Application*. Figure 2 shows the number of papers and short papers in each research area. The number of research papers in the Physical & Fundamental area was 44, and that in the Communications area was 74. In addition, the number of research papers in the Network area was 47, and that in the Information Technology & Application was 48.

Many of the research papers presented in ICETC2020 are at the cutting edge of their research areas, and these provide stimulating content to advance and develop their

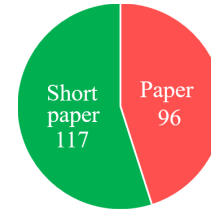


Fig. 1 Number of research papers and short papers.

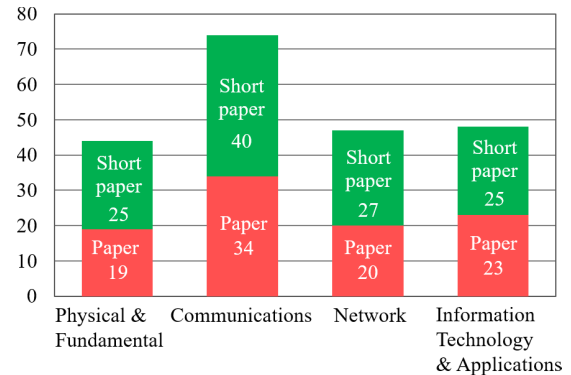


Fig. 2 Number of research papers in each research area.

respective fields. These studies are expected to contribute greatly to the development of the fifth generation (5G) and Beyond 5G (B5G) networks, future innovative network applications, and so on. Therefore, in this survey paper, all research papers are classified into the four research areas and research topics, and all papers are surveyed briefly for each research topic.

The rest of this paper is organized as follows. Section 2 classifies all research papers depending on the four research areas and topics. Section 3 provides a brief survey of research papers in the Physical & Fundamental area, while Sect. 4 does the same in the Communications area. Section 5 gives a brief survey of research papers in the Network area, and Sect. 6 does the same in the Information Technology & Application area. Finally, Sect. 7 concludes this survey paper.

## 2. Classification of Research Papers

In ICETC2020, all accepted papers were presented in oral sessions and all accepted short papers were presented in short presentation sessions for the four research areas according to the conference program shown in Fig. 3.

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JST	December 2 (Wed.)	December 3 (Thu.)	December 4 (Fri.)
9:00	Opening		
9:15	Video presentation		
9:30	Short Presentation Session 1 (Parallel Session)	Oral Session 2 (Parallel Session) A2, B2, C2, D2, E2	Oral Session 4 (Parallel Session) A4, B4, C4, D4, E4
9:45	F1, G1, H1, I1, J1, K1, L1, M1, N1, O1, P1	<b>PROGRAM PDF S</b>	<b>PROGRAM PDF S</b>
10:00	<b>PROGRAM PDF S</b>	Video presentation	Video presentation
10:15	Video presentation		
10:30			
10:45			
11:00	Keynote 1 and 2 Hiroyuki Morikawa Zhisheng Niu	Keynote 4 Abbas Jamalipour	Keynote 6 Satoshi Konishi
11:15	Video presentation	Video presentation	Video presentation
11:30			
11:45			
12:00			
12:15	Lunch Break	Lunch Break	Lunch Break
12:30			
12:45			
13:00			
13:15		Short Presentation Session 2 (Parallel Session)	Special Session 2 on IEICE Communications Society Editorial Board (Parallel Session) SC, SD
13:30	Invited Session 1 (Parallel Session)	F2, G2, H2, I2, J2, K2, L2, M2, N2, O2, P2	
13:45	IA1, IB2	<b>PROGRAM PDF S</b>	
14:00	<b>PROGRAM PDF S</b>	Video presentation	
14:15	Video presentation		<b>PROGRAM PDF S</b>
14:30			Video presentation
14:45			
15:00			
15:15			
15:30	Oral Session 1 (Parallel Session)	Oral Session 3 (Parallel Session)	
15:45	A1, B1, C1, D1, E1	A3, B3, C3, D3, E3	
16:00	<b>PROGRAM PDF S</b>	<b>PROGRAM PDF S</b>	Invited Session 3 IA3, IB3
16:15	Video presentation	Video presentation	<b>PROGRAM PDF S</b>
16:30			Video presentation
16:45			
17:00	Keynote 3 Takehiro Nakamura	Keynote 5 Shinya Tachimoto	Keynote 7 Lajos Hanzo
17:15	Video presentation	Video presentation	<b>SLIDES PDF S</b>
17:30			Video presentation
17:45			
18:00	Tutorial Geoffrey Ye Li	Special Session 1 on IEICE International Sections (Parallel Session) SA, SB	Invited Session 3 IA3, IB3
18:15	<a href="#">Detailed</a>		<b>PROGRAM PDF S</b>
18:30	<b>SLIDES PDF S</b>		Video presentation
18:45	Video presentation		
19:00			Closing Video presentation
19:15			
19:30			
19:45	Invited Session 2 (Parallel Session)		
20:00	IA2, IB2		
20:15	<b>PROGRAM PDF S</b>		
20:30	Video presentation		
20:45			
21:00		Award Ceremony and Reception	
21:15			

Fig. 3 Conference program of ICETC2020.

All submitted papers were reviewed by two experts, and accepted papers were decided by the Technical Program Committee (TPC), which consists of TPC co-chairs, Dr. Yohei Hasegawa and Prof. Takuji Tachibana; TPC track chairs, Prof. Masaki Aida, Prof. Masaki Bandai, Prof. Keizo Cho, Prof. Fumiaki Maehara, Prof. Satoshi Ohzahata, Prof. Eiji Okamoto, Prof. Hirokazu Tanaka, and Prof. Daisuke Umehara; and TPC members shown in [2]. Accepted papers were published on IEICE Proceeding Series [3], and the four best papers, five best short papers, and 26 excellent student presentations were selected [4].

The four research areas mainly include but are not limited to the following technology and keywords:

- Physical & Fundamental
  - Antennas and Propagation
  - Electromagnetic Compatibility
  - Satellite Telecommunications
  - Wireless Power Transmission
- Communications
  - Energy Engineering in Electronics and Communications
  - Healthcare and Medical Information Communication Technology
  - Optical Communication Systems
  - Optical Fiber Technology
  - Radio Communication Systems
  - Sensor Network and Mobile Intelligence
  - Short Range Wireless Communications
  - Smart Radio
  - Space, Aeronautical and Navigational Electronics
- Network
  - Communication Quality
  - Communication Systems
  - Information and Communication Management
  - Network Systems
  - Photonic Network
- Information Technology & Application
  - Information Networks
  - Internet Architecture

Table 1 shows the classification of all research papers and the Section number for each of the four research areas. As shown in this table, papers from a wide range of research areas were accepted and presented without any bias toward any particular field. In addition, Tables 2, 3, 4, and 5 show the classification of papers in each research area and the Section number for each research topic.

### 3. Brief Review of the Physical & Fundamental Area

#### 3.1 Millimeter Wave and Terahertz Communications

In 5G mobile communications, millimeter wave (mmWave) is used to provide high-speed, high-capacity, low-latency, and massive device connectivity. In addition, B5G mobile communications and terahertz (THz) communications are

**Table 1** Classification of papers into four research areas.

Research area	Section	Papers
Physical & Fundamental	3	[5]–[23], [101]–[122], [131], [156], [160]
Communications	4	[24]–[47], [49]–[53], [59]–[63], [123]–[130], [132]–[155], [157]–[159], [161]–[165]
Network	5	[48], [54]–[58], [64]–[73], [79]–[82], [166]–[185], [203]–[205], [212], [213], [216], [217]
Information Technology & Application	6	[74]–[78], [83]–[100], [186]–[202], [206]–[211], [214], [215]

**Table 2** Classification of papers in Physical & Fundamental area.

Topic	Section	Papers
Millimeter wave and terahertz communications	3.1	[5], [15], [131]
Sensing and monitoring	3.2	[7], [8], [10], [13], [17]–[19], [21], [22], [105], [107], [113]–[115], [117], [119], [156], [160]
Antenna	3.3	[6], [14], [16], [20], [23], [101]–[104], [112], [118], [120]–[122]
Electromagnetic fields	3.4	[12], [106], [109], [110], [116]
Wireless power transmission	3.5	[9], [11], [108], [111]

**Table 3** Classification of papers in Communications area.

Topic	Section	Papers
Optical communication technology	4.1	[25], [49]–[52], [134], [137], [146]–[149]
MIMO and beamforming	4.2	[27], [36], [42], [43], [126]–[128], [157], [158], [161], [164], [165]
Spectrum sharing and access	4.3	[26], [29], [34], [37], [44], [133], [140], [141], [159], [163]
Coding and decoding	4.4	[145], [151]–[153], [155]
Wireless technology and application	4.5	[24], [31], [32], [59], [61], [125], [130], [136], [139], [142]–[144], [150]
Modulation and multiplexing	4.6	[28], [41], [62], [135], [138], [154]
Wireless networks and communications	4.7	[30], [33], [35], [45]–[47], [60], [63], [123], [124], [129], [132], [162]
Visible light communication	4.8	[38]–[40], [53]

**Table 4** Classification of papers in Network area.

Topic	Section	Papers
Virtualization	5.1	[73], [79], [171], [180], [213]
NDN and ICN	5.2	[72], [172], [174], [216]
Server and computer management	5.3	[69], [167], [169], [176], [182], [203], [205], [212]
Security and redundancy	5.4	[65]–[68], [71], [80], [82], [166], [177], [179], [204]
Congestion control	5.5	[70], [81], [168], [170], [183], [184]
Optical networks	5.6	[54], [55], [58], [64], [178], [217]
Wireless, ad-hoc, and sensor networks	5.7	[48], [56], [57], [173], [175], [181], [185]

**Table 5** Classification of papers in Information Technology & Application area.

Topic	Section	Papers
Social networks	6.1	[74], [77], [89], [100]
Peer-to-peer computing and blockchain	6.2	[85], [87], [91]–[93], [191], [192]
QoE	6.3	[78], [95]
Network control and management	6.4	[83], [84], [86], [88], [97], [187], [195]
Networking with AI/ML	6.5	[75], [76], [94], [188], [194], [196], [197], [202], [207]–[211]
Network graph and topology	6.6	[96], [186], [190], [206]
Network applications and services	6.7	[90], [98], [99], [189], [193], [198]–[201], [214], [215]

expected to be used [218], [219].

In [5], the authors investigated the system capacity of mmWave and THz communications with respect to delayed waves as well as molecular absorption and rain using a proposed approach that incorporates the frequency selectivity into the performance evaluation. For mmWave propagation, [15] proposed a power control method of each beam that is able to cover the specific area for the interference control. In addition, [131] studied and discussed the characterization of 28 GHz mmWave communication in the indoor office environment using large-scale computer simulations.

### 3.2 Sensing and Monitoring

For the realization of attractive concepts such as Industry 4.0 or Society 5.0, sensing and monitoring technologies are expected to play a main role in multiple applications [220], [221]. In [10], to ensure the reliability of civil engineering structures such as bridges, buildings, tunnels, and other vital infrastructures, the authors proposed a distributed torsion sensing technique using a four-fiber ribbon for structural health monitoring. For underground fiberglass-reinforced plastic mortar (FRPM) pipelines, [107] proposed a non-destructive inspection method that uses temporal synthesis of microwave guided-modes propagating along a FRPM pipe-wall. For detecting bedsores, [17] developed a noncontact detection system with a patch antenna operating at 24 GHz. In addition, for a medical telemeter transmitter attached to a patient, [119] measured the electric field strengths in a standing position and a supine position. A circuit simulation was constructed for a time-domain reflectometry (TDR) method to sense ground faults in a three-phase power distribution network in [105], and [160] improved the estimation accuracy for multiple targets with a compressed sensing algorithm called M-FOCUSS. For active sensing systems, [114] proposed a sparse deconvolution with the iterative shrinkage-thresholding algorithm (ISTA) for solving circular convolution problems. Moreover, in [117], the authors described the fundamental effect of reflection ratio on acoustic distance measurement (ADM) based on the comparison of two types of ADM. [8] utilized the tensor theory to develop a novel structure for the blind source separation (BSS) technique that can exploit the second-order statistic in terms of the tensor format.

Recently, for sensing and monitoring technologies, mmWave is also a key component due to its higher bandwidths and higher potential data rates [222]. [19] presented an active mmWave imaging system using the leaky-wave focusing antenna to obtain a clearer image of conducting objects. For mmWave frequency-modulated continuous wave (FMCW) radar, [13] proposed a vital signs monitoring method based on improved complete ensemble empirical mode decomposition with adaptive noise (ICEEMDAN). In [7], a human's position was detected using a 77 GHz mmWave FMCW radar attached to the ceiling. By using the 77-GHz band mmWave FMCW radar, [18], [113], and [156] detected pedestrians and obstacles on a narrow bicycle and

pedestrian road. [21] also acquired a heartbeat waveform, and [22] and [115] estimated a human heart rate.

### 3.3 Antenna

For 5G/Local 5G and B5G mobile communications, advanced and innovative antenna technology and design are required [223]. In [6], the authors proposed a 920-MHz Internet of Things (IoT) platform via a low earth orbit (LEO) satellite with multiple antennas employing feeder link multiple-input multiple-output (MIMO) technology. [14] investigated the structure of sheathed dipole antenna with a polyvinyl chloride (PVC)-cover based on the transmission line theory by calculating the input impedance behavior, and [16] proposed a concept of a dual-band differential rectenna where 2.45-GHz and 5.8-GHz band two-element array antennas are stacked. [20] proposed an invisible antenna integrated within a touch screen panel for 5G smartphone, and [23] designed a dual-beam switchable self-oscillating active integrated array antenna with four antenna elements, a phase-shift keying (PSK) modulator, and a push-push oscillator. [101] put forward a spherically linear arrangement of primary radiators in dielectric lens antenna for realizing a wide beam scan angle, and [120] designed a dual-band and wideband circular microstrip antenna fed by an L-probe. [102] proposed a transmitting antenna, which consists of two coil elements and a matching circuit, for implantable medical device communication, and a 28 GHz simple loop antenna that emits perpendicular polarized waves was designed in [122].

For a wearable device, [112] designed a planar inverted-F antenna operation in 920 MHz and global positioning system (GPS) bands and [104] studied the characteristics of an electromagnetic resonance antenna to obtain cardioid-shaped radiation patterns and the directivity on the feeding side. In addition, [118] presented a fast method of moments for large-scale reflectarrays, and [121] proposed a transmission-line transition for perpendicular connection between hollow waveguide and differential line. In [103], the authors evaluated the impact of element patterns of a transmitting antenna on two block beamforming algorithms in a multi-user MIMO system.

### 3.4 Electromagnetic Fields

For electromagnetic (EM) fields, [109] designed an EM wave absorber using a square metallic pattern array sheet, and [116] investigated the measurements of a near magnetic field on the opening surface of a metallic enclosure from the simulation for the magnetic fields of a high-power equipment enclosure. [110] proposed the scale model for the power line communication (PLC) system to measure EM noise easily, and [106] put forth bandpass space filters that use a conductive film grid instead of a metal wire grid. In [12], the authors developed the architecture of a compensating technique for light-load operation and a simple voltage mode control in the automotive application for voltage regulator modules, and then they proposed the use of the control for a



mixed-signal circuit to improve line and load regulation.

### 3.5 Wireless Power Transmission

Recently, the utilization of wireless power transfer (WPT) technologies has been considered for several different applications, such as medical devices and unmanned aerial vehicles (UAVs) [224].

To charge devices and sensors by supplying power from mobile devices, [9] proposed a square spiral coil as a receiving antenna for the WPT system between the mobile devices and the sensor on the fingertip. For capsule endoscopes, [11] investigated the effectiveness of the trilateration method for position estimation and [108] developed the Archimedean two-arm spiral antenna and a helical antenna that are used as the transmitting and receiving antennas. In the WPT system using magnetic field resonance coupling, [111] evaluated the effectiveness of parasitic capacitance associated with large coils.

## 4. Brief Review of the Communications Area

This section first surveys research papers on optical communication technology, and then surveys research papers on wireless communication technology.

### 4.1 Optical Communication Technology

The development and progress of optical communication technologies are indispensable to support 5G and B5G, and Japan is leading in this research area [225]–[229].

For cable television (CATV), [49] proposed a 10 Gbps baseband transmission line coding method for the coexistence of sub-carrier multiplexing (SCM) and a 10 Gbps baseband without an additional optical fiber by reducing power in the low-frequency band of the 10 Gbps baseband. In addition, [52] demonstrated a low-nonlinearity, dispersion-compensated transmission line for an ultrahigh-speed coherent Nyquist pulse transmission, and [25] investigated the restoration of the waveform after transmission through a four-mode fiber using signal processing by a neural network (NN). [146] investigated the dependence of fiber fuse suppression in a single-mode fiber on the input power of an amplitude modulation, and [147] studied the quality of the received signal numerically when Kramers–Kronig reception is applied to unrepeated long-haul transmission. The authors of [134] proposed a support vector machine (SVM)-based optical nonlinear equalization scheme, while the authors of [137] investigated the performance of an artificial NN-based digital nonlinear equalizer for optical nonlinearity compensation.

In terms of multi-core fiber (MCF), [51] presented detailed measurements of the guided acoustic wave Brillouin scattering (GAWBS)-induced depolarization noise for a four-core fiber and analyzed the noise theoretically. [50] then numerically evaluated the side-view intensity profile by simulation and investigated the effects of core layouts and index

profiles on the fiber rotation detectivity. [148] experimentally showed that an inter-core crosstalk in an MCF link spliced with a Subscription Channel (SC) connector can be estimated as a sum of the individual components, and [149] fabricated a 200  $\mu\text{m}$ -coated 4-core fiber with a length of 100 km and revealed that its micro-bending loss can be reduced, resulting in ultra-high core density optical fiber cables.

### 4.2 MIMO and Beamforming

Multiple-input multiple-output (MIMO) and massive MIMO technologies are basic technical elements in 5G and B5G mobile communications [230]. In [27], the authors considered MIMO techniques for downlink transmission of a single LEO satellite equipped with multiple antennas in order to increase the capacity of LEO satellite systems. [36] additionally proposed a system in which singular value decomposition (SVD)-MIMO transmission and polar coding are combined to improve the correction capability of polar codes. [43] proposed a packet transmission technique for improving the reliability and throughput performances of 5G ultra-reliable and low-latency communication (URLLC) in a line-of-sight (LOS) environment by utilizing dual-polarized MIMO transmission with adaptive multiplexing and diversity, and [126] evaluated the performance of the proposed optimal transmission scheduling in overloaded wireless MIMO switching.

For massive MIMO systems, [42] developed and evaluated 28-GHz band trial equipment that employed a base station cooperation technology with digital beamforming to track the mobility of mobile stations, where each base station has a massive MIMO antenna. In contrast, [161] expanded an analytical formulation of maximal ratio transmission (MRT) precoding by modifying the power distribution of the inter-user interference (IUI) power distribution, while [164] proposed a precoding scheme based on the iterative approximation approach that exploits simple equal gain transmission and IUI cancellation components. A semi-blind interference suppression in which a higher-order modulation is adapted on multi-cell massive MIMO uplink was presented in [158], and user scheduling with beam selection based on IUI for massive MIMO systems was proposed in [165]. [157] verified the accuracy of messages passed from observation nodes for Gaussian belief propagation (GaBP) in a massive MIMO detection factor graph.

[128] studied the performance of high-precision mmWave analog beamforming using a 28 GHz eight-element linear array antenna by simulation and experiment, and [127] formulated the search for the optimum combination of repeaters as an optimization problem and subsequently considered a method to reduce the calculation load to a constant value.

### 4.3 Spectrum Sharing and Access

For spectrum sharing, [29] evaluated the inter-system in-

interference reduction effect by an adaptive band selection method in multi-band wireless communication systems and [44] evaluated the performance of a 5G receiver with interference cancellation in different radio systems. To improve interference management utilizing a spectrum database, in [26], the authors extended a single objective problem with relaxed stochastic constraint to a case of priority users whose signal-to-interference-plus-noise ratio (SINR) is attempted to be maximized and solved it using an evolutionary algorithm. [34] also proposed the data compression scheme based on adaptive time span for compensating the noise components and compressing the sensing results, and [163] proposed a clutter loss model by compensating the clutter loss and considering the altitude difference.

In [159], the radio resource allocation for a cognitive radio network through a dynamic spectrum access system was investigated and two multi-armed bandit algorithms were proposed to tackle this problem. [37] also presented a primary protection for dynamic spectrum access in which a secondary system uses a frequency band assigned to a primary system. In [140], a simulation result shows that the proposed method significantly improves the system capacity compared to a conventional method when the number of antennas is small. Additionally, in [141], the impact of memory size for measuring the channel occupancy ratio was clarified. Finally, [133] proposed an information collection protocol for avoiding packet collisions in event-triggered access.

#### 4.4 Coding and Decoding

[153] evaluated the convergence properties of the polar code construction using genetic algorithm (GA) with initialization based on Bhattacharyya bounds, and [155] proposed a new decoding scheme based on the successive cancellation decoding by exploiting the characteristics of polar codes' generator matrix. In order to reduce the decoding latency, [151] proposed an NN decoder for the convolutional polar codes. [152] investigated the characteristics of bit error rate in consideration of the synchronization performance in the hybrid pulse position modulation (PPM) on-off keying (OOK) signaling turbo coded system with the racing counters scheme, while [145] put forward an alternative symbol-wise decoder for punctured convolutional codes for continuous-phase frequency shift keying (FSK) signaling.

#### 4.5 Wireless Technology and Application

As IoT wireless technology, [32] investigated the predicted possibility that another person exists from signals received via human body communication channels, and [59] proposed a method of separating IoT signals by feature quantity extraction using short-time Fourier transform.

[31] investigated the performances of different coil designs that are advantageous for small sized devices and their space limitation and provided a deeper understanding of optimizing the parameters of coil and resonant frequency in mag-

netically coupled resonator (MCR) wireless power transfer. [130] proposed a method for predicting received power in indoor environments deterministically, and this method can learn a prediction model from a small amount of measurement data via transfer learning. [61] put forth a phase noise compensation method based on a least mean squares algorithm and a phase locked loop for single-carrier transmission using frequency domain equalization.

[24] investigated the effectiveness of shared extended global platform (sXGP) in a 1.9-GHz band by measuring its diffraction effect in comparison with other frequency bands. [125] proposed a modified primary user detection under superposed time division duplex-long term evolution (TD-LTE) signal, which shows improving performance under the non-static traffic of secondary users through a computer simulation.

[136] proposed two radio propagation models with deep learning, and [139] proposed an extrapolation method by exploiting an idea of deep convolutional generative adversarial networks. [142] suggested a method for reducing the angle error in the position estimation of a moving target, while [150] estimated indoor location with various altitudes by utilizing multiple items of sensed information. In [144], differential time series of zenith total delay (ZTD) was introduced to rainfall nowcast in order to improve accuracy, and [143] proposed a synchronous streaming protocol for backscatter communications.

#### 4.6 Modulation and Multiplexing

For orthogonal frequency division multiplexing (OFDM) that is utilized in 5G and B5G, [135] proposed a time-domain equalizer using an online-trained NN for OFDM systems without a cyclic prefix. In contrast, [138] proposed a preamble-less symbol timing synchronization method for OFDM systems using convolutional neural networks (CNN) to learn the characteristics of spectra and support synchronization. [154] investigated the influence of adjacent-channel interference (ACI) on the asynchronous OFDM/filter-bank multi carrier (FBMC) systems under multipath fading channels.

[62] presented individual computation processes for the partial demodulation reference signal (DM-RS) sequence that are suitable for the DM-RS multiplexing scheme in a synchronization signal (SS)/physical broadcast channel (PBCH) block, and [41] proposed an automatic modulation classification using CNN with constellation diagrams in an additive white Gaussian noise channel. In [28], the system capacity of polarized orbital angular momentum (OAM) multiplexing was investigated by comparing it with OAM multiplexing without polarization for the same number of antenna elements.

#### 4.7 Wireless Networks and Communications

For satellite communication, [60] evaluated the time lag between the attenuation and rainfall using both the vector auto

regressive (VAR) model and impulse response function in addition to the cross-correlation function. For the wide area network (WAN), [162] proposed measurement tools for long range (LoRa)/LoRa WAN to establish cell deployment using the LoRa/LoRa WAN. In the wireless local area network (LAN), [35] proposed the application of the throughput drop estimation model to the channel assignment of access points (APs), and [46] recommended a dynamic control method of AP placement and radio parameters of each AP for improving throughput in congested areas. The localization accuracy for indoor using channel state information (CSI) of Wi-Fi was focused on and clarified using SVM in [129]. [33] proposed a cross-layered rate adaptation for robust and low-latency video transmissions for multiple APs and [63] developed a drifting wireless camera-based sewer inspection system. [30] also proposed a received power prediction scheme that uses deep neural network (DNN)-based camera object detection in indoor environments for wireless LAN. In [47], the authors proposed the throughput allocation method for concurrently communicating with two or three hosts in wireless LAN.

For the personal area networks (PAN), [123] analyzed the ultra-wideband (UWB) pulsed EM-field in the vicinity of a driver's head for intra-vehicle UWB radio design, and [124] proposed the construction of a channel assignment table for achieving both high-precision sensing information and high-precision separation of sensor information. In [132], a novel backoff-based opportunistic routing that enables it to select an appropriate path even in an environment with asymmetric links was proposed. For a radio frequency identifier (RFID) that is wireless for short-range communication, [45] investigated the interference between RFID tags attached to clothes and presented a guideline for an RFID triage system.

#### 4.8 Visible Light Communication

For light-emitting diode (LED) visible light communications (VLC), [38] evaluated the performance of the digital pre-distortion method followed by compander to compensate for nonlinear distortion, and [39] compared the communication performance of three modulation schemes—luminance modulation, spatial modulation, and both luminance and spatial modulation—for intelligent transport system (ITS) image sensor communication systems. To improve the transmission efficiency and positioning accuracy of VLC, [40] proposed a parallel RGB LED transmission for VN-CSK with modified prime sequence codes (MPSC) and modified pseudo-orthogonal M-sequence (MPOM). In addition, [53] presented a collaborative linearization method that employs digital pre-distortion processing for LED non-linear distortion in both the transmitter and receiver.

### 5. Brief Review of the Network Area

#### 5.1 Virtualization

Virtualization technologies such as software-defined net-

working (SDN), network slicing, and network function virtualization (NFV) are utilized to provide many kinds of 5G and B5G services appropriately over communication networks [231]. In [79], the authors implemented and tested a multipath multicast that uses Reed-Solomon (RS) coding in the OpenFlow network, which is one of the SDN networks. [171] applied a resource pool architecture called the virtual reconfigurable communication processor (VRCP) to a remote center management system for a highly secure and manageable packet switching network.

For network slicing, [73] applied the network control method based on the cognitive process of a human brain to the resource allocation of each slice for connected vehicles, and [213] proposed a resource adjustment method using deep reinforcement learning for slices with different priority classes. In addition, for NFV, [180] proposed a service chain construction with efficient virtual network function (VNF) sharing based on model predictive control.

#### 5.2 NDN and ICN

Named data networking (NDN) and information-centric networking (ICN) are promising technologies for supporting data-centric and location-independent communications. For the IoT system, content management technologies are also expected [234].

In NDN networks, [172] proposed a location-based forwarding mechanism that retrieves data from devices by leveraging low-power wide-area (LPWA). On the other hand, for ICN, [72] discussed the cooperation among the interworking points in the IoT data exchange platform. In addition, [174] proposed a routing method with ant colony optimization in a case where users in different locations request the same content after one user has retrieved it, and [216] put forward a simultaneous approach of user movement recommendation and content placement control.

#### 5.3 Server and Computer Management

In 5G and B5G, edge servers are required to achieve ultra-low latency [232], [233]. For multi-access edge computing (MEC), [167] proposed a task assignment for shared and non-shared edge servers using an optimization problem. In addition, for three-stage Clos networks that can be used in a data center, a fast parallel algorithm was proposed for a case in which the component switch sizes have a power of two in [69].

In addition, [203] investigated the input/output (I/O) performance of a mixture of dynamic random-access memory (DRAM) and non-volatile RAM (NVRAM) memory with dynamic data migration, while [205] investigated the performance of the file fragmentation called striping layout in the hard disk drive (HDD). [212] studied the proposed method that improves sequential I/O performance with the fourth extended file system (Ext4) on HDD in fully distributed mode, and [176] evaluated the performances of multiple cache management methods that consider the negative

temporal locality of the reference in a storage area network (SAN) environment. In [169], the authors evaluated the performance of a key-value store (KVS) caching function that runs on an application switch for reading and writing operations. The clustering of automatically generated server name indication (SNI) of transport layer security (TLS) was investigated in [182].

#### 5.4 Security and Redundancy

For cyberattacks, [65] developed a malware-free non-stop router so as to dynamically lower the priority of the active router, and [66] proposed a route inheriting scheme using a route server to maintain only clean dynamic routes even if the packet forwarding table of the in-use router has been tampered with. In addition, for an environment where the in-use virtual network is replaced with the initialized virtual network periodically to counter cyberattacks, [71] proposed a network switching scheme in which only the ingress function of every edge router is switched exclusively in the first stage and the egress function is multi-homed to both the in-use and the initialized virtualized networks.

In [177], the authors experimentally investigated the effectiveness of the proposed service provisioning in a reliable multipath network, while those in [67] determined the egress node that is the exit of the segment routing section for all destination nodes with only three shortest-path tree calculations. The upper limit of call blocking probability for general calls during disasters was derived in [68], and an analytical model and impact measure for cascading failure on power networks were presented in [80]. For multiple routing configuration (MRC) that is a fast recovery technique, [82] proposed an extended MRC to be used in network slices effectively, and [166] developed an automatic generation program of routing tables for implementing MRC with programming protocol-independent packet processors (P4). In comparison, [204] implemented MRC in a different manner with P4 so as to be used in SDN environments, and [179] implemented a failure detection method using P4.

#### 5.5 Congestion Control

For transmission control protocol (TCP), [183] proposed a control method for the congestion window size of TCP congestion control from the user space outside the kernel space. For TCP bottleneck bandwidth and round-trip propagation time (BBR), [168] investigated the fairness of throughput between multiple TCP BBR. In addition, [170] and [184] conducted a detailed investigation on the fluctuation of throughput between TCP BBR and CUBIC TCP.

In [81], the authors implemented and evaluated a Multipath TCP (MPTCP)-based IoT router that utilizes multiple radios to connect a server. For a practical delay-based end-to-end congestion control called Copa, [70] proposed an adaptive time window to reduce control delay adequately and prevent severe overshoot of the congestion window size.

#### 5.6 Optical Networks

[54] proposed a multipath routing method with traffic grooming considering path lengths. [55] also proposed a dynamic multicast routing method that avoids packet collisions in the optical packet switching networks with high-speed and large-capacity.

[64] put forth a parallelization method that utilizes multiple wavelengths and cores simultaneously in multi-core fibers to achieve higher throughput in optical packet switching (OPS) networks, and [217] proposed a lightpath establishment method to improve fairness in elastic optical networks. For optical access network, [58] presented a successive interference canceller for a power-domain non-orthogonal multiple access (PD-NOMA)-based passive optical network (PON) system, and [178] proposed a wavelength-swapping wavelength division multiplexing (WDM)-PON system.

#### 5.7 Wireless, Ad-Hoc, and Sensor Networks

In [48], the authors proposed a proportional differentiation model with different quality of service (QoS) requirements using slotted aloha for reservation-based medium access control (MAC) protocols. The authors of [185] proposed a trust-based routing that is aided by base stations partially to avoid tampering by malicious nodes in mobile ad-hoc networks, and those of [175] suggested user cooperative mobility for social ad-hoc networks that have dynamic routing for QoS.

[57] proposed a data collection platform with LoRa and Wi-Fi for running cars, and [181] investigated the performance of a proposed intra-vehicle wireless communication method for more accurate and practical situations by using measurement values as simulation parameters. A low-cost runner tracking system with LPWA was designed to support a trail running event in [173], and a proximity-based localization method was experimentally evaluated using passive infrared ray motion sensors in [56].

### 6. Brief Review of the Information Technology & Application Area

#### 6.1 Social Networks

In regards to social networks, [100] introduced a design methodology that allows the damping coefficient to be used to counter the flaming phenomena even when the damping coefficient depends on the eigenfrequency, and [89] confirmed that the fundamental equations of different matrix representations lead to the same result in the oscillation model that describes the user dynamics.

For social networking services (SNS), the authors of [74] proposed a trust model consisting of semantic and surface features for information dissemination, and those of [77] proposed a model in which users are influenced by other users via social media such that their opinions change.



## 6.2 Peer-to-Peer Computing and Blockchain

Peer-to-peer (P2P) computing technologies are suitable for IoT, 5G, and B5G applications [235]. [91] proposed a distributed training management scheme for deep learning based on the distributed skip mesh list, where each node has multiple connections for some parent nodes, and [92] recommended a query transfer method that enables efficient search even for spatially autocorrelated data due to its use of two types of skip graphs. In [93], the authors proposed a BitTorrent-based group-aware file sharing method so that nearby peers can create a collaborative group to improve the download efficiency. The authors of [192] performed experiments on PPTV, which is one of the P2P video delivery service (P2PTV) applications, and they investigated the effectiveness of the proposed traffic classification method for PPTV.

Blockchain, which is typically managed by a P2P network, was invented by an unknown person/group of people called Satoshi Nakamoto in 2008, and it can be integrated into multiple areas, including IoT [236]. In this conference, [85] proposed a method for improving the performance of the transaction process without changing the block size or the time interval of block creation when adding information, and [87] proposed a reward-penalty-based mechanism for proof of stake (PoS), which is one of the consensus algorithms. In [191], the authors proposed a blockchain system for exploiting semi-structured overlay networks with flexible routing tables to obtain both communication efficiency and safety.

## 6.3 QoE

Quality of experience (QoE) is a metric of overall service quality that measures user perception, expectations, and experience of the service, and it has been attracting attention as an indicator for the service quality from the user's point of view [237]. [78] investigated the joint effect of the QoE-based video output scheme called switching between error concealment and frame skipping (SCS) and moving picture experts group media transport application-level forward error correction (MMT AL-FEC) on the QoE of H.264 video and audio transmission. For video viewing users, [95] proposed a method that estimates QoE with a genetic algorithm (GA) from users' electroencephalogram (EEG) data.

## 6.4 Network Control and Management

Network control and management are important for the appropriate accommodation of a large amount of IoT traffic and 5G/B5G traffic [238]–[240]. [83] proposed a method that uses a table-based access control list and fog computing to prevent the distribution of IoT data to unintended users, and [84] applied a predictive control technique for remote-controlled unmanned vehicles (UVs) to enhance their reliability. In [88], the authors proposed a multi-commodity

distributed route selection scheme based on a gradient descent method in which the time-dependency among agents' road usage for vehicular networks is considered. Additionally, a fluid model for multipath additive increase and multiplicative decrease (AIMD) window flow control in ICNs was constructed in [187].

The authors of [86] developed a user programmable HTTP load balancer that runs as a userland application on Linux. In [195], the authors investigated the performance of file download and discussed the relationship between its performance and packet loss rate. For controlling intelligent transportation, [97] applied a predictive control method based on the cognitive process of a human brain to avoid congestion by suggesting routes.

## 6.5 Networking with AI/ML

For future communication networks, artificial intelligence (AI) and machine learning (ML) are indispensable for the effective networking, and [241] explained how network systems can be optimized based on the optimization problem using NNs that are implemented on the coherent Ising machine. In [196], the authors used a recurrent neural network (RNN) for position estimation to elucidate the time series data of RSSI, and [194] proposed a two-step position estimation of AP using an NN. In addition, [210] proposed an automatic generation method of RSSI data for position estimation that utilizes supervised learning. For wireless sensor networks, [188] considered a distributed method that divides the intermediate layers of deep learning into individual sensors, while [208] proposed lightweight and adaptive distributed compressed sensing with multi-sensor collaboration based on multi-agent deep reinforcement learning.

The authors of [94] proposed a mobile traffic generation method for a large amount of traffic data without coarse-grained data that uses a generative adversarial network (GAN). [197] put forth a scattered pilot-aided channel estimation method that performs radial basis function (RBF) interpolation in the frequency domain and general regression neural network (GRNN) interpolation in the time domain, and [207] investigated the practical performance of the Tug-of-War (ToW)-based channel selection with reinforcement learning via an experiment using multiple wireless modules based on IEEE 802.15.4g/4e. [209] proposed a direction of arrival (DOA) estimation method that combines two DNNs to reduce the estimation error, and [211] proposed a CNN-aided signal to noise ratio (SNR) estimation method that uses In-phase and Quadrature-phase (IQ) constellation images. In [75], an estimation method of  $K$ -factor using CNN from a single packet spectrogram in wireless communications was presented.

[202] proposed a delay estimation method with graph-based NNs, where the delay information from multiple reference nodes are utilized, while [76] recommended a method that can approximate delay by using a simple algorithm when persistent homology is used.

## 6.6 Network Graph and Topology

In [96], the authors determined the coverage areas that satisfy the transmission delay requirements for TV remote production in Tokyo for the Japan photonic network model, which is a network topology model. [190] investigated the relationship of the shortest path lengths between any two vertices in a large-scale graph and a coarsened graph, and [206] proposed an estimation technique that utilizes the trajectory of random walks for the effective graph resistance of a network topology. To simulate and evaluate a mobile ad-hoc network-based system, the authors of [186] developed a visualizing framework that controls the users' behavior, i.e., network topology, in a simulator by Unity.

## 6.7 Network Applications and Services

The authors of [201] proposed the root data domain gateway applied to the wildlife monitoring system for FIWARE that is an application programming interface (API) for the IoT system. In [193], a face recognition system that uses an edge device such as small computer device with a camera was presented.

[198] proposed a motion artifact reduction technique to facilitate R-R interval estimation for clothing-type wearable electrocardiogram (ECG) sensors, and [200] proposed the reconstruction of maternal ECG using an autoencoder. [199] investigated the concentration of carbon dioxide in the air in a mask based on the stress index of heart rate variability, as wearing a mask for a long time often causes feelings of suffocation and stress. The fatigue of workers engaged in driving a car was focused on and a multiple regression analysis model using the fatigue feeling was proposed in [90].

For emergency rescue evacuation support systems, [98] proposed a disaster detection method that integrates sensor information and human detection, while [99] proposed a route searching method that minimizes periods of supply disruption to distribute supplies to disaster areas by vehicle.

In [189], the authors investigated the possibility of visual communications using spectrogram arts through sound media. [214] developed a data communication system with high frequency inaudible bands of sound signals, and [215] proposed a synchronization technique for inaudible sound communication systems.

## 7. Conclusions

This survey paper classified all research papers presented in ICETC2020 depending on research area and research topic. For each research area and topic, each study is introduced briefly. Many of the papers were at the cutting edge of their research areas and topics and provided stimulating content that can advance and develop their research areas. The author hopes that this survey paper will be useful for promoting research on the development of 5G and B5G networks,

future innovative network applications, and so on. Many distinguished research papers are expected to continue to be submitted and presented in ICETC.

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