

**IEEE International Conference on Metaverse Computing, Networking and Applications**

**(IEEE MetaCom 2023)**

*26-28 June 2023 (Japan Standard Time)*

**Conference Program and Information Booklet**

**Sponsored by**



## Advanced Program Summary (Japan Standard Time Zone)

### 26 June 2023 (Monday) (Remote Presentation)

09:00-11:10	MetaCom-V-1: Metaverse Applications, Blockchain, Security
	<b>Break</b>
11:20-13:10	MetaCom-V-2: Networking and Communications (I)
	<b>Lunch Break</b>
14:00-16:30	MetaCom-V-3: [Short Paper] Metaverse Designs
	<b>Break</b>
16:40-17:40	MetaCom-V-4: Ph.D Student forum

### 26 June 2023 (Monday) (In-Person)

	Room: Hiei	Room: Kibune	Room: Kurama
09:00-10:00	MetaXP-1	Tutorial-1	Tutorial-3
10:10-12:00			
12:00-13:00	<b>Lunch Break</b>		
13:00-13:45	MetaXP-2	Tutorial-2	MANP & DORM
13:45-15:00			
15:00-15:15	<b>Break</b>		
15:15-16:00	VSM	Tutorial-2	DIM
16:00-17:00			
17:00-18:00	<b>Break</b>		
18:00-20:00	Reception & Poster Session (Gold Room)		

### 27 June 2023 (Tuesday) (In-Person)

	Room: Hiei	Room: Kibune	Room: Kurama
10:00-10:30	Opening Ceremony (Gold Room)		
10:30-11:30	Keynote Speech-1 (Gold Room)		
11:30-13:00	<b>Lunch Break</b>		
13:00-14:30	MetaCom-1: Invited Paper (I)	MetaCom-2: Metaverse Architectures and Applications (I)	MetaCom-3: Security, Privacy, and Trust (I)
14:30-14:40	<b>Break</b>		
14:40-16:10	MetaCom-4: Blockchain and Web 3.0 (I)	MetaCom-5: Theories, Experiments and Evaluations	MetaCom-6: Networking and Communications (II)
16:10-16:20	<b>Break</b>		
16:20-18:00	MetaCom-7: [Short Paper] Networking and Communications	MetaCom-8: [Short Paper] Blockchain and Web 3.0	MetaCom-9: [Short Paper] Security, Privacy, and Trust
18:00-18:30	<b>Break</b>		
18:30-20:30	<b>Banquet</b>		

### 28 June 2023 (Wednesday) (In-Person)

	Room: Hiei	Room: Kibune	Room: Kurama
--	------------	--------------	--------------

09:00-10:00	<b>Keynote Speech-2 (Gold Room)</b>		
10:00-10:10	<b>Break</b>		
10:10-11:10	<b>Panel (Gold Room)</b>		
11:00-13:00	<b>Lunch Break</b>		
13:00-14:30	MetaCom-10: Blockchain and Web 3.0 (II)	MetaCom-11: Networking and Communications (III)	MetaCom-12: Security, Privacy, and Trust (II)
14:30-14:40	<b>Break</b>		
14:40-16:00	MetaCom-13: Invited Paper (II)	MetaCom-14: Metaverse Computing	
16:00-16:10	<b>Break</b>		
16:10-18:00	MetaCom-15: [Short Paper] Metaverse Computing	MetaCom-16: [Short Paper] Theories, Experiments and Evaluations	
18:00-18:10	<b>Closing (Room: Kurama)</b>		

## Table of Contents

<i>Advanced Program Summary (Japan Standard Time Zone)</i> .....	2
<i>Keynote Speech 1</i> .....	2
<i>Keynote Speech 2</i> .....	3
<i>MetaCom-2023 Plenary Panel Session</i> .....	4
<i>MetaCom-2023 Tutorial Session 1</i> .....	8
<i>MetaCom-2023 Tutorial Session 2</i> .....	9
<i>MetaCom-2023 Tutorial Session 3</i> .....	10
<i>Technical Program - Remote Presentation (Time zone: JST)</i> .....	11
<i>Technical Program – In-Person (Time zone: JST)</i> .....	13
<i>Main Conference Day 1 – In-Person (Time zone: JST)</i> .....	18
<i>Main Conference Day 2 – In-Person (Time zone: JST)</i> .....	22

## Keynote Speech 1

### Metaverse is Taking Off?

Prof. Nirwan Ansari

*New Jersey Institute of Technology (NJIT), USA*

#### Abstract

The metaverse is often touted as the next phase of the internet, yet it is not entirely a new concept, with older iterations such as virtual and augmented reality having been around for several years. This talk traces the origins of the metaverse, explores its hype, and assesses its feasibility. We delve into existing virtual and augmented realities and examine how they can be integrated with future generation networks to create an immersive experience that blurs the line between the virtual and tangible worlds. We also review technological enablers and research approaches that have been utilized to advance the development and optimization of such enablers. To provide a more balanced view, we discuss a number of significant research challenges that must be addressed before realizing the next phase of metaverse development. Finally, we provide an overview of recent news about major tech companies suspending their metaverse research initiatives, which suggests that the metaverse hype bubble may be bursting and the market may be cooling down.

#### Biography



Nirwan Ansari, Distinguished Professor of Electrical and Computer Engineering at the New Jersey Institute of Technology (NJIT), received his Ph.D. from Purdue University, MSEE from the University of Michigan, and BSEE (summa cum laude with a perfect GPA) from NJIT. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) as well as Fellow of National Academy of Inventors (NAI).

He authored *Green Mobile Networks: A Networking Perspective* (Wiley-IEEE, 2017) with T. Han, and co-authored two other books. He has also (co-)authored more than 700 technical publications, over half published in widely cited journals/magazines. He has guest-edited numerous special issues covering various emerging topics in communications and networking. He is Editor-in-Chief of IEEE

*Wireless Communications* and has also served on the editorial/advisory board of over ten journals. His current research focuses on green communications and networking, cloud computing, drone-assisted networking, and various aspects of broadband networks.

He was elected to serve in the IEEE Communications Society (ComSoc) Board of Governors as a member-at-large, has chaired some ComSoc technical and steering committees, is current Director of ComSoc Educational Services Board, has served in many committees such as the IEEE Fellow Committee, and has been actively organizing numerous IEEE International Conferences/Symposia/Workshops. Some of his recognitions include several excellence in teaching awards, a few best paper awards, NCE Excellence in Research Award, several ComSoc TC technical recognition awards, NJ Inventors Hall of Fame Inventor of the Year Award, Thomas Alva Edison Patent Award, Purdue University Outstanding Electrical and Computer Engineering Award, NCE 100 Medal, NJIT Excellence in Research Prize and Medal, and designation as a COMSOC Distinguished Lecturer. He has also been granted more than 40 U.S. patents.

## Keynote Speech 2

### Challenges in Developing Beyond 5G Network Systems

Dr. Hiroaki Harai

*Director General of Network Research Institute, NICT, Japan*

#### Abstract

In 2030 or later, Beyond 5G network system to realize the digital transformation of advanced social systems for Society5.0 are necessary. The network systems should respond to the rapid growth in communication traffic, dynamic changes in communication quality, and various network services. In this talk, the speaker presents R&D challenges in developing the Beyond 5G Network Systems for the innovative networks. The R&D target is fundamental and system technology for optical and wireless communications and for networking enabling to fulfill essential functions of the broadband, ultra-reliable, and ultra-low latency communications desired in the Beyond 5G era. For example, we pursue

- to evolve scalability of communication networks which are terrestrial networks and non-terrestrial networks on the sea, in the sky, and in outer space in terms of numbers and of dimensions,
- to enhance resilience for supporting information distribution continuously even at disasters and network failures,
- to develop technologies for ultra-high-capacity photonic networks fundamentally supporting smooth information distribution and technologies for harmonization of bandwidths in optical and radio networks,
- to establish fundamental technologies letting network services exist simultaneously which are suitable for various information properties by controlling and managing communication, computation, storage, and sensing resources flexibly and efficiently, and
- to build system assessment technology in cyberspace to validate/verify networking technologies.

Our goal is to build Beyond 5G network systems which support society by communication and networking technologies delivering "more information quickly and extensively" with "flexibility, safety, and efficiency".

#### Biography



**Hiroaki Harai** is currently a Director General of Network Research Institute at the National Institute of Information and Communications Technology, Tokyo, where he is managing R&D on computing and AI-enabled networking technology, next-generation wireless technology, photonic network technology, optical and radio convergence technology, space communication fundamental technology, and resilient ICT technology as key technologies of innovative networks.

Prior to present position. He received the M.E. degree and the Ph.D. degree in information and computer science from Osaka University, Japan, in 1995 and 1998, respectively. After he joined NICT, he has conducted R&D on network architecture, optical networks, and mobile networks. Since April 2018 to March 2021, he managed research and development testbed construction and stable operation of networks and clouds such as JGN and StarBED, and he designed Beyond 5G Mobile and NFV Testbed that is currently in operation. From April 2021, he is in present position.

He was a recipient of the Outstanding Young Researcher at the 3rd IEEE ComSoc Asia–Pacific Young Researcher Award in 2007 (optical network topic), the Best Paper Award in ITU Kaleidoscope Academic Conference 2014 (mobile sensor network topic) and Excellent Paper Award in IEICE Communications Society in 2020 (networking topic).

## MetaCom-2023 Plenary Panel Session

### The Metaverse is Dead, Long Live the Metaverse: Distinguishing Opportunities from Hype

**Abstract:** What are the research prospects, challenges, and opportunities for Metaverse computing? Visions of immersive computing, IoT, ubiquitous computing, and augmented/extended reality have existed for some time. What has changed now to explain the recent explosion of interest in Metaverse applications? How stable is this new trend? The panel brainstorms opportunities and hype in an effort to articulate a prospective roadmap for supporting a novel application ecosystem that builds on the proliferation of pervasive “things,” the rise of machine intelligence, and the introduction of progressively more capable end-devices that facilitate immersion.

#### Panel Chair



**Tarek Abdelzaher**  
University of Illinois Urbana-  
Champaign  
USA

#### Panel Members



**Tarek Abdelzaher**  
University of Illinois  
Urbana-Champaign  
USA



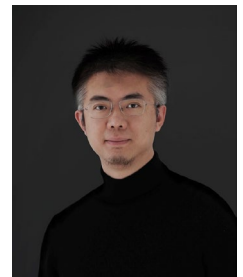
**Klara Nahrstedt**  
University of Illinois  
Urbana-Champaign  
USA



**Mani Srivastava**  
University of  
California, Los  
Angeles  
USA



**Baochun Li**  
University of Toronto  
Canada



**Max (Chong) Li**  
OORT and Columbia  
University, USA

## Panel Chair



### **Tarek Abdelzaher**

University of Illinois Urbana-Champaign  
USA

Bio: Tarek Abdelzaher is a Sohaib and Sara Abbasi Professor of Computer Science and a Willett Faculty Scholar at the University of Illinois. He received his PhD from the University of Michigan in 1999. Abdelzaher co-authored over 300 refereed publications in Real-time Computing, Distributed Systems, Sensor Networks, and IoT, with an H-index of 95. He served as Editor-in-Chief of the Journal of Real-Time Systems, and as an Associate Editor of multiple journals including IEEE TMC, IEEE TPDS, ACM ToSN, ACM TIoT, and ACM ToIT. He also chaired several top conferences in his field, including RTSS, Sensys, Infocom, ICDCS, IPSN, RTAS, DCoSS, and ICAC. Abdelzaher received the IEEE Outstanding Technical Achievement and Leadership Award in Real-time Systems (2012), a Xerox Research Award (2011), and several best paper awards. He is a fellow of IEEE and ACM.

## Panel Members



### **Klara Nahrstedt**

University of Illinois Urbana-Champaign  
USA

Bio: Klara Nahrstedt is the Grainger Chair in Engineering Professor in the Computer Science Department, and the Director of Coordinated Science Laboratory in the Grainger College of Engineering at the University of Illinois at Urbana-Champaign. Her research interests are in end-to-end QoS, teleimmersion, resource management in distributed multimedia systems, and IoT cyber-physical systems. She is the recipient of the IEEE Computer Society Technical Achievement Award, ACM SIGMM Technical Achievement Award, and other recognitions. She was the chair of ACM Special Interest Group in Multimedia (SIGMM), general and TPC co-chair of ACM Multimedia, IEEE Percom, IEEE/ACM IoTDI, IEEE SmartGridComm, IEEE SECON, and other venues. Klara Nahrstedt received her Diploma in Mathematics from Humboldt University, Berlin, Germany in 1985, and PhD from the University of Pennsylvania in the Department of Computer and Information Science in 1995. She is ACM, IEEE, AAAS Fellow, Member of the German National Academy of Sciences (Leopoldina Society), and Member of the US National Academy of Engineering.





**Mani Srivastava**

University of California, Los Angeles  
USA

Bio: Mani Srivastava is on the faculty at UCLA where he is a Distinguished Professor in the ECE Department with a joint appointment in the CS Department and is the Vice Chair for Computer Engineering. His research is broadly in the area of human-cyber-physical and IoT systems that are learning-enabled, resource-constrained, and trustworthy. It spans problems across the entire spectrum of applications, architectures, algorithms, and technologies in the context of systems and applications for mHealth, sustainable buildings, smart built environments, digital twins, and mixed-reality. He is a Fellow of both the ACM and the IEEE.



**Baochun Li**

University of Toronto  
Canada

Bio: Baochun Li is a Professor and serves as Associate Chair, Research in the Edward S. Rogers Sr. Department of Electrical and Computer Engineering at the University of Toronto. He is cross-appointed to the Department of Computer Science. He is a member of the Computer Engineering research group. Starting August 2005, he holds the Bell Canada Endowed Chair in Computer Engineering. Prof. Li's research interests include cloud computing, distributed systems such as distributed machine learning and federated learning, security and privacy, and networking. He has co-authored more than 450 research papers in major international journals and conference proceedings, with a total of over 24000 citations, an H-index of 86 and an i10-index of 319. He has also served as chair and member of organizing and technical committees of many international conferences, including IEEE INFOCOM, IEEE IWQoS, IEEE ICDCS, IEEE NETCODE, IEEE ICNP. Baochun Li received several research awards including Leonard G. Abraham Prize Paper Award in the Field of Communications Systems, University of Toronto McLean Award, the Multimedia Communications Best Paper Award from the IEEE Communications Society. He is a fellow of IEEE and Canadian Academy of Engineering.



**Max (Chong) Li**

OORT and Columbia University  
USA

Bio: Dr. Max (Chong) Li is a faculty member in the department of electrical engineering at Columbia University (in the City of New York), the founder & CEO of the Web3 data cloud company “Oort”. He had been working with Qualcomm Research on 4G LTE and 5G systems design. He is an IEEE Senior member, and also the president of Science & Technology Economic Committee at China-US Chamber of Commerce. Dr. Li is a holder of 200+ International/US patents. He has been actively publishing academic papers on top-ranking journals, including Proceedings of the IEEE, IEEE Transactions on Information Theory, IEEE Communications Magazine, Automatica, etc. His paper “Youla Coding and Computation of Gaussian Feedback Capacity” was nominated for the 2019 IEEE Information Theory Society Paper Award (one of the highest honors from the IEEE Information Theory Society). He has also served as reviewer, committee and co-chair for most prestigious journals and conferences in communications and control societies. Dr. Li is a grant review committee member of Natural Sciences and Engineering Research Council of Canada. He is the author of the book "Reinforcement Learning for Cyber-physical Systems" (Taylor & Francis CRC press). Dr. Li has broad research interests including information theory, machine learning, distributed database and computing systems (e.g., blockchain), networked control and communication, PHY/MAC systems design for advance telecommunication technologies (5G and beyond).

**MetaCom-2023 Tutorial Session 1****An Introduction to Blockchain as a Database and WEB3.0**

Instructor: Prof. Abdullah Uz Tansel

*City University of New York, USA***Abstract**

Blockchain is a foundational innovation in database technology for keeping temper proof (trusted) data in a permanent, immutable, decentralized, global, and trustless ledger. It is a relatively new field that combines distributed computing, databases, networks, cryptography, and economics, and is rapidly evolving. It allows people, organizations, and machines to digitize their current relationships as well as forming new secure digital ones since data is disclosed, secured and recorded differently in a blockchain database system. Moreover, a paradigm shift, WEB3.0 is taking place where individuals, organizations and machines are being empowered in a strong system of digital identity and trust in sharing their data and their interactions. Moreover, countless number of IoT devices, with fast and secure communication requirements, are vital for sensing their environments and securely sharing their data. Naturally, communication networks and 5G communications are significant enablers of the blockchains. The tutorial covers the blockchains as a database and its fundamentals, and its evolution to WEB3.0.

**Biography**

Abdullah Uz Tansel received his BS in management, and his MS and PhD degrees in computer science from the Middle East Technical University, in Ankara Turkey. He has also received his degree at the University of Southern California. After being a faculty member at the Middle East Technical University, Dr. Tansel joined Baruch College, the City University of New York (CUNY) where he is currently a professor of information systems and a professor of computer science at The Graduate Center of CUNY. Professor Tansel's research focus is on temporal databases, and he has made significant contributions in this field. He also headed the editorial board that published the first book on temporal databases 'Temporal Databases: Theory, Design, and Implementation' (1993). Dr. Tansel has a patent on adding temporality to RDF. His research interests are Database Management Systems, Temporal Databases, Semantic Web, and Blockchain Databases. Dr. Tansel has published many articles in the conferences and journals of the ACM, IEEE and other associations. He is a frequent speaker on time in databases and blockchain as a database. He is also a member of the ACM and the IEEE Computer Society.

**MetaCom-2023 Tutorial Session 2****The Network Infrastructure of the Metaverse: Challenges, Potential Solutions, and Research Directions**

Instructor: Prof. Roch H. Glitho

*Concordia University, Canada***Abstract**

The concept of Metaverse is getting more and more popular. However, a myriad of challenges needs to be tackled before it becomes a reality. The current network infrastructure for instance cannot fully meet the requirements imposed by applications. This tutorial focuses on the network infrastructure of the Metaverse. It introduces the challenges, discusses the potential solutions, and sketches the research directions. A plethora of applications with disparate characteristics is foreseen for the Metaverse. A very first challenge for the network infrastructure is to meet the requirements of all these applications in a cost-efficient manner. A potential solution is slicing, a technology that enables isolated virtual networks with different characteristics on top of a same physical network. It also happens that some of the applications have very stringent requirements such as ultra-high bandwidth and ultra-low latency. Holographic streaming applications for instance may require gigabits and even terabits per second, while Tactile Internet application may require latency in terms of single digit milliseconds round trip. Edge computing that stipulates computation at edge of the network (instead the cloud) is a potential solution to these very stringent requirements. Yet another emerging potential solution is In-Network-Computing (INC). It stipulates computing inside the network, instead of computing on servers outside the network. In the first part of this tutorial we introduce the metaverse, discuss use cases, and pinpoint the requirements on the network infrastructure. The second part introduces slicing and its applicability to the Metaverse network infrastructure, while the third part is devoted to edge computing and INC as potential solutions to the bandwidth and latency challenges faced by the same infrastructure. The fourth part is devoted to the research directions. It discusses architectural and algorithmic directions. We end with a summary and the perspectives.

**Biography**

Roch H. Glitho holds a Ph.D. in tele-informatics (Royal Institute of Technology, Stockholm, Sweden), and M.Sc. degrees in business economics (University of Grenoble, France), pure mathematics (University of Geneva, Switzerland), and computer science (University of Geneva). He is Full Professor of Networking and Telecommunications at Concordia University, the Ericsson/ENCQOR-5G Senior Industrial Research Chair in Cloud and Edge Computing for 5G and Beyond, and a former Canada Research Chair. He has joined academia in 2010 after an industrial career with LM Ericsson in Sweden and Canada. During his industrial career, he has held several senior technical positions (e.g. Expert, Principal Engineer, Senior Specialist). He is a former Editor-In-Chief of IEEE Communications Magazine and IEEE Communications Surveys and Tutorials journal. He is also a former IEEE Communications Society distinguished lecturer.

**MetaCom-2023 Tutorial Session 3****Point cloud video streaming: viewport prediction, semantic tiling and transmission optimization**

Instructor: Prof. Zhi Liu

*The University of Electro-Communications, Japan***Abstract**

Point cloud video can play a crucial role in the development of the metaverse, which is a virtual shared space that allows users to interact with each other and with digital objects in a seamless and immersive way. For example, point cloud video technology enables the capture and representation of 3D spatial data, which can be used to create highly realistic and interactive virtual environments. By capturing and processing real-world data, point cloud video can create detailed and accurate representations of physical spaces, objects, and people. The streaming of point cloud videos further facilitates its application in metaverse and many other applications. However, it poses significant challenges due to its distinctive characteristics such as high volume, low latency, and high encoding/decoding complexity.

This talk is a tutorial on point cloud video streaming, which enables a six-degree-of-freedom (6DoF) immersive viewing experience with a wide range of applications in entertainment and education, etc. We will present the technical challenges and possible solutions for volumetric video streaming.

**Biography**

Zhi Liu received his Ph.D. degree in Informatics in National Institute of Informatics, Japan. He is currently an associate professor with tenure at The University of Electro-Communications, Japan. His research interest is mainly on video streaming, energy efficient edge computing and wireless networks. He has published more than 60 IEEE/ACM journal papers and received six best paper. He is serving or has served as an Editor for IEEE Systems Journal, IEEE Open Journal of the Computer Society, Springer Wireless Networks. He is the recipient of IEEE ComSoc Multimedia Communications Technical Committee (MMTC) Outstanding Young Researcher Award. He is a senior member of IEEE.

# Technical Program (*Time zone: Japan Standard Time*)

Monday, 26 June 2023 (Remote Presentation)

Monday, 26 June 2023 | 9:00 – 11:10 (Tokyo Time)

Monday, 26 June 2023 | 01:00 – 03:10 (London Time)

Sunday, 25 June 2023 | 21:00 – 23:10 (New York Time)

## **Session MetaCom-V-1: Metaverse Applications, Blockchain, Security (I)**

**Session Chair:** Marco Picone (University of Modena and Reggio Emilia, Italy)

### **Digital Twin & Blockchain: Technology Enablers for Metaverse Computing**

Marco Picone, Stefano Mariani (University of Modena and Reggio Emilia, Italy), Antonio Viridis (University of Pisa, Italy) and Paolo Castagnetti (University of Modena and Reggio Emilia, Italy)

### **Layerwise Interoperability in Metaverse: Key to Next-Generation Electronic Commerce**

Shakila Zaman, Ram Dantu, Syed Badruddoja, Sirisha Madhuri Talapur and Kritagya Upadhayay (University of North Texas, USA)

### **Wi-Six: Precise Positioning in the Metaverse via Optimal Wi-Fi Router Deployment in 6G Networks**

Alireza Famili, Tolga Atalay, Angelos Stavrou and Haining Wang (Virginia Tech, USA)

### **Production Capacity Negotiation for Blockchain-enabled Collaborative Manufacturing: A Stackelberg Game Approach**

Ying Chen, Feilong Lin, Riheng Jia, Zhongyu Chen, Changbing Tang and Minglu Li (Zhejiang Normal University, China)

### **Threat Model-based Security Analysis and Mitigation Strategies for a Trustworthy Metaverse**

Md Ismail Hossain, Ragib Hasan (University of Alabama, USA)

### **Feedback-Enhanced Data Broker Routing Protocol for Multi-hop Blockchain Radio Access Network**

Qianqi Meng, Yixiao Cao, Xintong Ling, Jiaheng Wang (Southeast University, China) and Athanasios V. Vasilakos (University of Agder, Norway)

### **Inferring Private Data from AI Models in Metaverse through Black-box Model Inversion Attacks**

Zhiyi Tian, Chenhan Zhang, Keshav Sood and Shui Yu (University of Technology Sydney, Australia)

Monday, 26 June 2023 | 11:20 – 13:10 (Tokyo Time)

Monday, 26 June 2023 | 03:20 – 05:10 (London Time)

Sunday, 25 June 2023 | 23:20 – 01:10 (New York Time)

## **Session MetaCom-V-2: Networking and Communications (I)**

**Session Chair:** Sherief Hashima (RIKEN-AIP, Japan)

### **Multi-Features Fusion based Viewport Prediction with GNN for 360-Degree Video Streaming**

Xiang Xu, Xiaobin Tan, Shunyi Wang, Zhuolin Liu, Quan Zheng (University of Science and Technology of China, China)

### **Self-Sustaining Multiple Access with Continual Deep Reinforcement Learning for Dynamic Metaverse Applications**

Hamidreza Mazandarani (IEEE, Iran), Masoud Shokrnezhad, Tarik Taleb (Oulu University, Finland), Richard Li (Futurewei, USA)

### **RSU-assisted Active Perception and Edge Computing for Autonomous Driving**

Ke Shi, Wei Zhao, Cheng Wu, Runhu Zhong, Xuangou Wu, Yangzhao Yang, Xiao Zheng (Anhui University of Technology, China)

### **Instantaneous Account Settlement in Roll-Up based Layer-2 Blockchain Framework for Metaverse Applications**

Mohd Sameen Chishti and Amit Banerjee (South Asian University, India)

### **A Digital Healthcare Service Architecture for Seniors Safety Monitoring in Metaverse**

Qian Qu, Ronghua Xu, Han Sun, Yu Chen, Sumantra Sarkar (Binghamton University, USA) and Indrajit Ray (Colorado State University, USA)

### **Metaverse Cybersecurity Threats and Risks Analysis, the case of Virtual Reality Towards Security Testing and Guidance Framework**

Omega Nnamonu (University of Salford, U.K.), Mohammad Hammoudeh (University of Petroleum and Minerals Dhahran, Saudi Arabia) and Tooska Dargahi (Manchester Metropolitan University, U.K.)

**Monday, 26 June 2023 | 14:00 – 16:30 (Tokyo Time)**

**Monday, 26 June 2023 | 06:00 – 08:30 (London Time)**

**Monday, 26 June 2023 | 01:00 – 03:30 (New York Time)**

### **Session MetaCom-V-3: [Short Paper] Metaverse Designs**

**Session Chair:** Haoxiang Luo (University of Electronic Science and Technology of China, China)

### **How to design for the Metaverse? A strategic design perspective**

Martin Böckle, Flynn Booter-Stewart, Kristi Woolsey (BCGX, U.K.)

### **Performance Analysis of Non-ideal Wireless PBFT Networks with mmWave and Terahertz Signals**

Haoxiang Luo, Xiangyue Yang, Hongfang Yu, Gang Sun, Shizhong Xu and Long Luo (University of Electronic Science and Technology of China, China)

### **Exploring the data of blockchain-based metaverses**

Simone Casale Brunet (EPFL, Switzerland), Leonardo Chiariglione (CEDEO SRL, Italy), Marco Mattavelli (EPFL, Switzerland)

### **A Test-driven Action Verification Method for Intrusion Response Systems**

Pushpinder Kaur Chouhan (BT, U.K.), Bronagh Quigley (Ulster University, U.K.), Alfie Beard (BT, U.K.), Liming Chen (Ulster University, U.K.)

### **Security Risks, User Privacy Risks, and a Trust Framework for the Metaverse Space**

Prakash Kharvi (Autodesk, USA)

### **ScrapeIOC: Designing a Web-scraping Tool for Malware Detection based on Indicators of Compromise**

Katherine Cardoso Petulante Fernandes, Simon Lucas Jonker, Weizhi Meng, Brooke Elizabeth Lampe (Technical University Of Denmark, Denmark)

### **NPNL: A Non-interactive Privacy-preserving Neural Network Learning Scheme**

Dian Lei, Chenfei Hu, and Jinyang Dong (Beijing Institute of Technology, China)

### **Privacy and Ethical Concerns of Brain-Computer Interfaces**

Catherine Yue (Cherry Creek High School, USA)

### **[Poster] Exploring Domain Randomization's Effect on Synthetic Data for Activity Detection**

Megani Rajendran, Chek Tien Tan, Indriyati Atmosukarto, Aik Beng Ng, Andrew Grant, Eric Cameracci and Simon See

## **VICTOR: Video Content-aware Partially Reliable Transmission over Multipath QUIC**

Yahui Li, Biao Han, Xueqiang Han, Xiaolan Ji, Congxi Song and Guo Chen (National University of Defense Technology, China)

## **Security, Privacy and Trust for the Metaverse of Things**

Shantanu Pal (Deakin University, Australia), Anusha Vangala (International Institute of Information Technology, India), Zahra Jadidi, Zhe Hou (Griffith University, Australia) and Ashok Kumar Das (International Institute of Information Technology, India)

## **Integrating Pupilometry and Self-Assessment for Holistic Evaluation of Metaverse Experiences**

Agasthya Gangavarapu (Safety4XR, USA)

**Monday, 26 June 2023 | 16:40 – 17:40 (Tokyo Time)**

**Monday, 26 June 2023 | 08:40 – 09:40 (London Time)**

**Monday, 26 June 2023 | 03:40 – 04:40 (New York Time)**

## **Session MetaCom-V-4: Ph.D. Student forum (Room Kurama, 15:30-17:20)**

**Session Chair:** Shantanu Pal (Deakin University, Australia)

### **Invited Talk**

## **Revolutionizing Virtual Shopping Experiences: A Blockchain-Based Metaverse UAV Delivery Solution**

Chengzu Dong, Jingwen Zhou, Qi An, Frank Jiang (Deakin University, Australia), Shiping Chen (CSIRO, Australia) and Xiao Liu (Deakin University, Australia)

## **TOTPAuth: A Time-based One Time Password Authentication Proof-of-Concept against Metaverse User Identity Theft**

Pengyu Li, Lei Pan, Feifei Chen, Thuong Huang (Deakin University, Australia) and Rui Wang (CSIRO, Australia)

## **Text-to-Metaverse: Towards a Digital Twin-Enabled Multimodal Conditional Generative Metaverse**

Ahmed Elhagry and Abdulmotaleb El Saddik (MBZ University of Artificial Intelligence, UAE)

## **Applying Zero-Knowledge Proofs for Non-Fungible Tokens in the Metaverse**

Dorottya Zelenyanski, Vallipuram Muthukumarasamy, Zhe Hou (Griffith University, Australia) and Kamanashis Biswas (Australian Catholic University, Australia)

# **Technical Program (*Time zone: Japan Standard Time*)**

**Monday, 26 June 2023 (In-Person)**

**Monday, 26 June 2023 | 09:00 – 10:00 (Tokyo Time)**

**Monday, 26 June 2023 | 01:00 – 02:00 (London Time)**

**Sunday, 25 June 2023 | 20:00 – 21:00 (New York Time)**

## **The First Workshop on “Connecting Physical World to Metaverse using IoT and Digital Twin Platforms (Meta-XP)”**

### **Session 1 (Room Hiei, 9:00 – 10:00)**

**Session Chair:** JaeSeung Song (Sejong University, South Korea)

**Welcome Speech:** Jaeho Kim (Sejong University, South Korea)



**Keynote Speech:** Trung Q. Duong (Queen's University Belfast, U. K.)

**Monday, 26 June 2023 | 10:30 – 12:00 (Tokyo Time)**

**Monday, 26 June 2023 | 02:30 – 10:00 (London Time)**

**Sunday, 25 June 2023 | 21:30 – 23:00 (New York Time)**

**Session 2 (Room Hiei, 10:30 – 12:00)**

**Session Chair:** Cheolsoo Park (Kwangwoon University, South Korea)

**Crawling Method for Image-Based Space Matching in Digital Twin Smart Cities**

Hyeonji Kim, Soorim Yang and Jaeho Kim (Sejong University, South Korea)

**A Metaverse Avatar Teleport System Using an AIoT Pose Estimation Device**

Jae-won Lee, Youngwoo Lee, Hyeon-Beom Choi, Sang-woo Son, Eeksu Leem and Jeongwook Seo (Hanshin University, South Korea)

**A Metaverse Emotion Mapping System with an AIoT Facial Expression Recognition Device**

Hyemin Lee, Seung-mi Ham, Hansol Moon, Hye-min Kwon, Jae-hyun Rho and Jeongwook Seo (Hanshin University, South Korea)

**An Edge-Enabled IoT Framework for Metaverse in Smart City**

JiHo Lee, JiEun Lee and Jaeseung Song (University of Sejong, South Korea)

**Efficient Federated Digital Twin Synchronization in Edge-Cloud Collaborative System**

Ji-Wan Kim, Hong Je-Gal and Hyun-Suk Lee (Sejong University, South Korea)

**Optimal Resource Allocation for 6G UAV-enabled Mobile Edge Computing with Mission-Critical Applications**

Dang Van Huynh, Yijiu Li, Antonino Masaracchia (Queen's University Belfast, U.K.), Trang Hoang (Vietnam National University, Viet Nam) and Trung Q. Duong (Queen's University Belfast, U.K.)

**Monday, 26 June 2023 | 13:00 – 15:00 (Tokyo Time)**

**Monday, 26 June 2023 | 05:00 – 07:00 (London Time)**

**Monday, 26 June 2023 | 00:00 – 02:00 (New York Time)**

**Session 3 (Room Hiei, 13:00 – 15:00)**

**Session Chair:** Jeongwook Seo (Hanshin University, South Korea)

**Design and Implementation of Intelligent Safety Services for Personal Mobility Devices**

Taein Yong, Sohyun Lee, Hyeonji Kim, Pyeongjoo Kim and Jaeho Kim (Sejong University, South Korea)

**Mesh Deformation Scheme for High Quality 3D Model Reconstruction**

Jung Suk Park, Bong-Seok Seo and Dong Ho Kim (Seoul National University of Science and Technology, South Korea)

**Cell Partitioning Scheme for UAV Communications to Maximize Throughput**

Su Bin Hwang, Bong-Seok Seo and Dong Ho Kim (Seoul National University of Science and Technology, South Korea)

**Metaverse: Research Based Prediction Model of the Car Price view of ML Method**

Ji Seok Yang (Kwangwoon University, South Korea), Jin Seok Kim (KAFLIX, South Korea), Ji Woon Lee (Kwangwoon University, South Korea), Seong Hyuck Yeo, Yoon Ki Kim and Cheol Soo Park (KAFLIX, South Korea)

**Meta-Human Synchronization Framework for Large-Scale Digital Twin**

Donghoon Lee, Joongho Cho and Jaeho Kim (Sejong University, South Korea)

## **RID: LiDAR Range Image Descriptor for Fast and Efficient Loop Closure Detection in Dynamic Environments**

Hyeong-Jun Joo and Jaeho Kim (Sejong University, South Korea)

## **Energy Trading Framework Based on IoT and Digital Twin for Nanogrid Environment**

Dohyeun Kim, Naeem Iqbal, Faiza Qayyum, Harun Jamil (Jeju National University, South Korea), Rashid Ahmad (Comsat University, Pakistan), Atif Rizwan, Anam Nawaz Khan (Jeju National University, South Korea) and Salabat Khan (Comsat University, Pakistan)

**Monday, 26 June 2023 | 15:30 – 16:00 (Tokyo Time)**

**Monday, 26 June 2023 | 07:30 – 08:00 (London Time)**

**Monday, 26 June 2023 | 02:30 – 03:00 (New York Time)**

## **The First International Workshop on Visualization & Simulation in the Metaverse (VSM 2023)**

### **Session 2 (Room Hiei, 15:15 – 16:00)**

**Session Chair:** Peiyong Colleen Ruan (NVIDIA, Japan)

**Keynote Speech:** Exploring the Future of Digital Twins with NVIDIA Omniverse, Vincent Gong (NVIDIA, Japan)

### **DONNA: A Data Model for Enabling Extensible and Efficient Metaverse Applications**

Georgios Bouloukakis (Télécom SudParis, IP Paris, France) and Ajay Kattepur (Ericsson Research, India)

**Monday, 26 June 2023 | 13:00 – 13:45 (Tokyo Time)**

**Monday, 26 June 2023 | 05:00 – 05:45 (London Time)**

**Monday, 26 June 2023 | 00:00 – 00:45 (New York Time)**

## **IEEE MetaCom Workshop on Metaverse as a network problem: performance and enabling technologies (MANP) & Decentralized, Data-Oriented Networking for the Metaverse (DORM)**

### **Session 1 (Room Kurama, 13:00 – 13:45)**

**Session Chair:** Shuping Peng (Huawei, China)

**Keynote Speech:** Fabrizio Granelli (University of Trento, Italy)

**Monday, 26 June 2023 | 13:45 – 15:00 (Tokyo Time)**

**Monday, 26 June 2023 | 05:45 – 07:00 (London Time)**

**Monday, 26 June 2023 | 00:45 – 02:00 (New York Time)**

## **IEEE MetaCom Workshop on Metaverse as a network problem: performance and enabling technologies (MANP) & Decentralized, Data-Oriented Networking for the Metaverse (DORM)**

### **Session 2 (Room Kurama, 13:45 – 15:00)**

**Session Chair:** Shuping Peng (Huawei, China)

### **AQUA: Adding Bandwidth Allocation to QUIC for Metaverse Multi-Stream Applications**

Neta Rozen-Schiff, Amit Navon, Itzack Pechtalt, Leon Bruckman and Yu Boyuan

### **BGP Blockchain for Metaverse**

Mike McBride, Xinxin Fan and David Guzman

## **Securing the Internet of Things Network using a Hierarchical Hyperledger Fabric Model**

Mohammed Abuhaliqa, Cagatay Catal and Qingzhi Liu

## **What Happens in the Avatar Stays in the Avatar**

Fernando Beltran and David White

## **Blockchain's Role in Metaverse Trust and Transactions**

R. Can Aygun, Turan Vural and Lixia Zhang

**Monday, 26 June 2023 | 15:15 – 17:00 (Tokyo Time)**

**Monday, 26 June 2023 | 07:15 – 09:00 (London Time)**

**Monday, 26 June 2023 | 02:15 – 04:00 (New York Time)**

## **The First International Workshop on Distributed Intelligence for Metaverse (DIM)**

### **Session 1 (Room Kurama, 15:30 – 17:00)**

**Session Chair:** Peng Li (University of Aizu, Japan)

### **Rate-Aware Path Planning for Redirected Walking in 5G mmWave Networks**

Ching-Chieh Huang, Yi-Zih Chen and Wanjiun Liao (National Taiwan University, Taiwan)

### **Enabling Service Automation in Web 3.0 with a Novel Self-Sovereign Identity Paradigm**

Hao-Chen Chiu, King-Ping Tenn, Chun-Yang Chang, Hung-Yen Chen and Tsung-Nan Lin (National Taiwan University, Taiwan)

### **Advanced Learning Schemes for Metaverse Applications in B5G/6G Networks**

Sherief Hashima (RIKEN-AIP, Japan), Mostafa M. Fouda (Idaho State University, USA), Kohei Hatano and Eiji Takimoto (Kyushu University, Japan)

### **Holographic Remote Interactive Operating Technology for Controlling Networked Communication**

Tse Chuan Hsu and Jia Yu Wang (Soochow University, Taiwan)

**Monday, 26 June 2023 | 18:00 – 20:00 (Tokyo Time)**

**Monday, 26 June 2023 | 10:00 – 12:00 (London Time)**

**Monday, 26 June 2023 | 05:00 – 07:00 (New York Time)**

## **Posters**

### **Session 1 (Gold Room, 18:00 – 20:00)**

**Session Chair:** Nobuyuki Muranaka (Hitachi, Japan)

### **Zero Trust Architecture of Token Network**

Po-Han Ho, Hong-Yen Chen and Tsung-Nan Lin (National Taiwan University, Taiwan)

### **Edge-based Joint User Association and Resource Allocation for Light Field Metaverse Systems**

Chenchen Wang (BUPT, China), Xinjue Hu (Wuhan University of Technology, China) and Lin Zhang (BUPT, China)

### **Web3 Meets Behavioral Economics: An Example of Profitable Crypto Lottery Mechanism Design**

Kentaroh Toyoda (A\*STAR, Singapore)

### **Development of a Metaverse Platform for Tourism Promotion in Apulia**

Enrico Carmine Ciliberti (Polytechnic University of Milan, Italy), Marco Fiore and Marina Mongiello (Polytechnic University of Bari, Italy)

**AR Assembly Navigation with Local 5G to Improve Industrial Production Efficiency**

Nobuyuki Muranaka, Masashi Kono and Daisuke Ito (Hitachi, Japan)

**Holographic Multi-Channel QR Code based Copyright Distribution Management System**

Soonhong Kwon, Wooyoung Son and Jong-Hyouk Lee (Sejong University, South Korea)

**akaTick: Hybrid Mobile E-Ticketing System Based on Non-Fungible Tokens**

Sung Hung Ming, Chen Timothy, Tseng Hung-Chun, Prayogo Beatrice (National Taiwan University, Taiwan), Lin Jin-Yao (Tainan National University of Arts, Taiwan) and Hung Yi-Ping (National Taiwan University, Taiwan)

**UCI and EICN Integrated Model for Copyright Distribution Management**

Soonhong Kwon, Wooyoung Son and Jong-Hyouk Lee (Sejong University, South Korea)

**Copyright and License Agreement History Management Framework for Outsourced Software**

Taeyang Lee, Jinsue Lee, Seungchan Woo and Jong-Hyouk Lee (Sejong University, South Korea)

**Decentralized Identifier System for Software Copyright Transfer and License Management**

Seungchan Woo, Taeyang Lee and Jong-Hyouk Lee (Sejong University, South Korea)

# Main Conference Day 1 (Tokyo Time, UTC+9)

Tuesday, 27 June 2023 (In-Person)

Tuesday, 27 June 2023 | Gold Room, 10:00 – 10:30 (Tokyo Time)

Tuesday, 27 June 2023 | Gold Room, 02:00 – 02:30 (London Time)

Monday, 26 June 2023 | Gold Room, 21:00 – 21:30 (New York Time)

## Opening Ceremony

Tuesday, 27 June 2023 | Gold Room, 10:30 – 11:30 (Tokyo Time)

Tuesday, 27 June 2023 | Gold Room, 02:30 – 03:30 (London Time)

Monday, 26 June 2023 | Gold Room, 21:30 – 22:30 (New York Time)

## Keynote Speech 1: Metaverse is Taking Off?

- Prof. Nirwan Ansari (New Jersey Institute of Technology (NJIT), USA)

Session Chair: Enzo Mingozzi (University of Pisa, Italy)

Tuesday, 27 June 2023 | 13:00 – 14:30 (Tokyo Time)

Tuesday, 27 June 2023 | 05:00 – 06:30 (London Time)

Tuesday, 27 June 2023 | 00:00 – 01:30 (New York Time)

## Session MetaCom-1: Invited Paper (I) (Room Hiei, 13:00 – 14:30)

Session Chair: Baochun Li (University of Toronto, Canada)

### Incentive Mechanism for Throughput Enhancement in Blockchain-based Energy Trading System

Yunshu Liu, Man Hon Cheung (The Chinese University of Hong Kong, Hongkong) and Jianwei Huang (The Chinese University of Hong Kong, Shenzhen, China)

### Challenges in Metaverse Research: An Internet of Things Perspective

Tarek Abdelzaher, Matthew Caesar, Charith Mendis, Klara Nahrstedt (UIUC, USA), Mani Srivastava (UCLA, USA) and Minlan Yu (Harvard University, USA)

### Human-Centered Traffic Management Supporting Smart Cities and the Metaverse

Dinesh Cyril Selvaraj (Politecnico di Torino, Italy), Falko Dressler (Technische Universität Berlin, Germany) and Carla Fabiana Chiasserini (Politecnico di Torino, Italy)

### Fast and Atomic Cross-blockchain Asset Exchange for Metaverse Interoperability

Shan Jiang, Jiannong Cao and Hanqing Wu (The Hong Kong Polytechnic University, Hongkong)

Tuesday, 27 June 2023 | 13:00 – 14:30 (Tokyo Time)

Tuesday, 27 June 2023 | 05:00 – 06:30 (London Time)

Tuesday, 27 June 2023 | 00:00 – 01:30 (New York Time)

## Session MetaCom-2: Metaverse Architectures and Applications (I) (Room Kibune, 13:00 – 14:30)

Session Chair: Andy Neparidze (Fraunhofer FOKUS, Germany)

### Parking Lots Management and Visualization in the Smart City - Digital Twin Context

Chinmay Satish Shrivastav, Alessio Masola, Nicola Capodiecici and Roberto Cavicchioli (University of Modena and Reggio Emilia, Italy)

#### **An Interactive Platform for a High Performance Digital Twin of the Human Heart**

Yujie Gong, Fenfen Qi, Yingzhi Liu, Jing-Yuan Wang, Tianhao Ma, Zaiheng Cheng (University of Macau, China), Yi Jiang, Rongliang Chen (Chinese Academy of Sciences, China), Xinhong Wang (Zhejiang University, China), Li Luo and Xiao-Chuan Cai (University of Macau, China)

#### **MetaLung: Towards a Secure Architecture for Lung Cancer Patient Care on the Metaverse**

Michele Zanitti, Mieszko Ferens (Aalborg University, Denmark), Alberto Ferrarin, Francesco Trovò, Vanja Miskovic, Arselja Prelaj (Politecnico di Milano, Italy), Ming Shen and Sokol Kosta (Aalborg University, Denmark)

#### **A Novel Metaverse-as-a-Service Architecture from an Operator View**

Vesal Ahsani, Ali Rahimi, Mehdi Latefati and Babak Hossein Khalaj (Sharif University of Technology, Iran)

#### **Semantic Digital Twin for Interoperability and Comprehensive Management of Data Assets**

Kazuma Inokuchi, Jin Nakazato, Manabu Tsukada and Hiroshi Esaki (University of Tokyo, Japan)

**Tuesday, 27 June 2023 | 13:00 – 14:30 (Tokyo Time)**

**Tuesday, 27 June 2023 | 05:00 – 06:30 (London Time)**

**Tuesday, 27 June 2023 | 00:00 – 01:30 (New York Time)**

#### **Session MetaCom-3: Security, Privacy, and Trust (I) (Room Kurama, 13:00 – 14:30)**

**Session Chair:** Qichao Xu (Shanghai University, China)

#### **Securing Distributed Computing in the Metaverse: A Balanced TGDH Encryption Scheme**

Anway Bose, John L Nori and Li Bai (Temple University, USA)

#### **Privacy of the Metaverse: Current Issues, AI Attacks, and Possible Solutions**

Chamara Sandeepa, Shen Wang and Madhusanka Liyanage (University College Dublin, Ireland)

#### **A Blockchain based Authentication Protocol for Metaverse Environments using a Zero Knowledge Proof**

Awaneesh Kumar Yadav (Indian Institute of Technology Roorkee, India), An Braeken (Vrije Universiteit Brussel, Belgium), Madhusanka Liyanage (University College of Dublin, Ireland) and Mika Ylianttila (University of Oulu, Finland)

**Tuesday, 27 June 2023 | 14:40 – 16:10 (Tokyo Time)**

**Tuesday, 27 June 2023 | 06:40 – 08:10 (London Time)**

**Tuesday, 27 June 2023 | 01:40 – 03:30 (New York Time)**

#### **Session MetaCom-4: Blockchain and Web 3.0 (I) (Room Hiei, 14:40-16:10)**

**Session Chair:** Qinnan Zhang (Singapore University of Technology and Design, Singapore)

#### **Quantitative Analysis of Play-to-Earn Blockchain Games: A Case Study of Axie Infinity**

Yiming Lai, Sizheng Fan and Wei Cai (The Chinese University of Hong Kong, Shenzhen, China)

#### **A Distributed Asset Trading Mechanism Based on Automated Negotiation**

Jiahao Zeng (BUPT, China), Xiuhuan Zang (State Grid Economic and Technological Research Institute, China), Chang Liu (BUPT, China), Zhiyi Chen (State Grid Economic and Technological Research Institute, China), Shaoyong Guo, Feng Qi (BUPT, China), and Jianhong Pan (State Grid Jilin Electric Power, China)

## **Integration of MPC into Besu through an Extended Private Transaction Model**

Daniel Morales, Isaac Agudo (Universidad de Málaga, Spain), and Javier Lopez (UMA, Spain)

## **Complex Network Analysis on Blockchain Payment Channel Networks for Metaverse**

Bicheng Liu, Bishenghui Tao and Hong-Ning Dai (Hong Kong Baptist University, Hongkong)

**Tuesday, 27 June 2023 | 14:40 – 16:10 (Tokyo Time)**

**Tuesday, 27 June 2023 | 06:40 – 08:10 (London Time)**

**Tuesday, 27 June 2023 | 01:40 – 03:30 (New York Time)**

## **Session MetaCom-5: Theories, Experiments and Evaluations (Room Kibune, 14:40-16:10)**

**Session Chair:** Andy Neparidze (Fraunhofer FOKUS, Germany)

### **Avatar Fusion Karaoke: Research on Multi-user Music Play VR Experience in Metaverse**

Alexandre Berthault, Takuma Kato and Akihiko Shirai (REALITY Inc., Japan)

### **Grid-Metaverse: The Path From Digital Twins and Prototype Tests on DC Microgrids**

Wenxuan Ma (Zhejiang University, China), Mengxiang Liu (Imperial College London, U.K.), Guangrun Hong, Shuo Yang and Ruilong Deng (Zhejiang University, China)

### **Achieving Distributed and Privacy-Preserving Cross-Chain Transactions in Account-Model Blockchain Systems**

Chuan Zhang, Weijie Wang (Beijing Institute of Technology, China), Weiting Zhang (Beijing Jiaotong University, China), Jiangtian Nie (Nanyang Technological University, Singapore), Jinwen Liang (Hong Kong Polytechnic University, Hongkong) and Liehuang Zhu (Beijing Institute of Technology, China)

### **Ownership Tokenization and Incentive Design for Learning-based User-Generated Content in Blockchain-Driven Metaverse**

Qinnan Zhang (Central University of Finance and Economics, China), Zehui Xiong (Singapore University of Technology and Design, Singapore), Jianming Zhu (Central University of Finance and Economics, China), Wanting Yang (Jilin University, China), Dusit Niyato (Nanyang Technological University, Singapore) and Sheng Gao (Central University of Finance and Economics, China)

**Tuesday, 27 June 2023 | 14:40 – 16:10 (Tokyo Time)**

**Tuesday, 27 June 2023 | 06:40 – 08:10 (London Time)**

**Tuesday, 27 June 2023 | 01:40 – 03:30 (New York Time)**

## **Session MetaCom-6: Networking and Communications (II) (Room Kurama, 14:40-16:10)**

**Session Chair:** Xiang Su (Norwegian University of Science and Technology, Norway)

### **Enable Cross-domain QoS for Internet-Scale Metaverse**

Haoyu Song (Futurewei, USA)

### **Multi-Server Stable Rendezvous for the Metaverse**

Ningxin Su, Baochun Li (University of Toronto, Canada) and Bo Li (University of Science and Technology, Hongkong)

### **Using Stellar Consensus Protocol to Ensure the Security of Message Transmission in VANETs**

Hung-Chin Jang and Che-Wei Chang (National Chengchi University, Taiwan)

### **Task Allocation Optimization Strategy in UAV-enabled Mobile Edge Computing System**

Sanhuan Yang (Shanghai University, China), Zhou Su (Xi'an Jiaotong University, China), Qichao Xu (Shanghai University, China), Rui Xing (Xi'an Jiaotong University, China) and Dongfeng Fang (California Polytechnic State University San Luis Obispo, USA)

**Tuesday, 27 June 2023 | 16:20 – 18:00 (Tokyo Time)**

**Tuesday, 27 June 2023 | 08:20 – 10:00 (London Time)**

**Tuesday, 27 June 2023 | 03:20 – 05:00 (New York Time)**

**Session MetaCom-7: [Short Paper] Networking and Communications (Room Hiei, 16:20-18:00)**

**Session Chair:** Haihan Nan (Kanazawa University, Japan)

**Towards a Bandwidth Market for the Metaverse**

Wenjie Cao (National University of Singapore, Singapore), Felix Kottmann (Singapore-ETH Centre, Singapore) and Richard T. B. Ma (National University of Singapore, Singapore)

**Fast Detection of Cyberattacks on the Metaverse through User-plane Inference**

Beyza Bütün, Aristide Tanyi-Jong Akem, Michele Gucciardo and Marco Fiore (Universidad Carlos III de Madrid, Spain)

**Identifying Traffic Prioritization on the Internet**

Vahab Pournaghshband (University of San Francisco, USA)

**Visual Data Compression for Metaverse: Technology, Standard, and Challenges**

Chen Peilin, Chen Bolin, Wang Meng, Wang Shiqi (City University of Hong Kong, Hongkong) and Li Zhu (University of Missouri-KC, USA)

**Imperfect Digital Twin Assisted Low Cost Reinforcement Training for Multi-UAV Networks**

Xiucheng Wang, Nan Cheng, Longfei Ma, Zhisheng Yin (Xidian University, China), Tom Luan (Xi'an Jiaotong University, China) and Ning Lu (Queen's University, U.K.)

**Task Offloading for Fog-Based Meta Networks: An Energy and Delay Aware Mechanism**

Chengcheng Lv, Fei Shen (University of Chinese Academy of Sciences, China), Feng Yan (Southeast University, China), Yueyue Zhang (Shanghai Aerospace Electronic Technology Institute, China), Chao Wang (Shanghai Huace Navigation Technology, China) and Lili Cao (Shanghai Aerospace Electronic Technology Institute, China)

**Cache Replacement Based on Similarity in Mobile Crowd Photographing**

Qianyi Deng and Noriaki Kamiyama (Ritsumeikan University, Japan)

**Tuesday, 27 June 2023 | 16:20 – 18:00 (Tokyo Time)**

**Tuesday, 27 June 2023 | 08:20 – 10:00 (London Time)**

**Tuesday, 27 June 2023 | 03:20 – 05:00 (New York Time)**

**Session MetaCom-8: [Short Paper] Blockchain and Web 3.0 (Room Kibune, 16:20-18:00)**

**Session Chair:** Damiano Di Francesco Maesa (University of Pisa, Italy)

**Utilizing Latent Codes for Minting AI-Generated Digital Assets into NFTs**

Yifan Chen, Lei Li, Xinyu Hu, Jiahao Li, Junyuan Wang and Fuqiang Liu (Tongji University, China)

**Ethereum DeFi Apps in the Wild: Profiling and Implications**

Ziwei Wang, Haotian Lu and Xuetao Wei (Southern University of Science and Technology, China)



### **Non Fungible Mutable Tokens: Dynamic Assets Traceability for the Metaverse**

Damiano Di Francesco Maesa (University of Pisa, Italy), Andrea Lisi (IIT-CNR, Italy), Paolo Mori, Laura Ricci and Simone Schiavone (University of Pisa, Italy)

### **Inducing Trust in Blockchain-enabled IoT Marketplaces Through Reputation and Dispute Resolution**

Panagiotis Michalopoulos, Srisht Fateh Singh and Andreas Veneris (University of Toronto, Canada)

### **Community Detection Algorithm for Mitigating Eclipse Attacks on Blockchain-enabled Metaverse**

Fatemeh Erfan, Martine Bellaiche (Polytechnique Montreal, Canada) and Talal Halabi (Laval University, Canada)

### **ATOM : A Decentralized Task Offloading Framework for Mobile Edge Computing through Blockchain and Smart Contracts**

Roshan Singh, Debanjan Roy Chowdhury, Sukumar Nandi and Sunit Kumar Nandi (Indian Institute of Technology Guwahati, India)

**Tuesday, 27 June 2023 | 16:20 – 18:00 (Tokyo Time)**

**Tuesday, 27 June 2023 | 08:20 – 10:00 (London Time)**

**Tuesday, 27 June 2023 | 03:20 – 05:00 (New York Time)**

### **Session MetaCom-9: [Short Paper] Security, Privacy, and Trust (Room Kurama, 16:20-18:00)**

**Session Chair:** Yan Wang, Temple University, USA

### **Blockchain Enabled Architecture for Secure Authentication in the Metaverse Environment: A Student Training Use Case**

Sonali Patwe and Sunil Mane (COEP Tech University, India)

### **The Interplay Between Policy and Technology in Metaverses: Towards Seamless Avatar Interoperability Using Self-Sovereign Identity**

Romain Laborde, Afonso Ferreira, Cristian Lepore, Mohamed-Ali Kandi and Michelle Sibilla (University Paul Sabatier Toulouse III, France)

### **An Implementation and Analysis of Zero Knowledge Based E-Voting Solution With Proof of Vote on Public Ethereum Blockchain**

Roshan Singh, Sukumar Nandi and Sunit Kumar Nandi (Indian Institute of Technology Guwahati, India)

### **A Survey on the Security of the Metaverse**

Chi Zhang, Xijuan Si (University of Chinese Academy of Sciences, China), Xiaoyan Zhu (Xidian University, China) and Yuqing Zhang (University of Chinese Academy of Sciences, China)

## **Main Conference Day 2 (Time zone: Tokyo Time, UTC+9)**

**Wednesday, 28 June 2023 (In-Person)**

Tuesday, 28 June 2023 | Gold Room, 09:00 – 10:00 (Tokyo Time)  
Tuesday, 28 June 2023 | Gold Room, 01:00 – 02:00 (London Time)  
Monday, 27 June 2023 | Gold Room, 20:00 – 21:00 (New York Time)

**Keynote Speech 2: Challenges in Developing Beyond 5G Network Systems**

- Hiroaki Harai (National Institute of Information and Communications Technology (NICT), Japan)

**Session Chair:** Noriaki Kamiyama (Ritsumeikan University, Japan)

Tuesday, 28 June 2023 | Gold Room, 10:10 – 11:10 (Tokyo Time)  
Tuesday, 28 June 2023 | Gold Room, 02:10 – 03:10 (London Time)  
Monday, 27 June 2023 | Gold Room, 21:10 – 22:10 (New York Time)

**Panel:**

**Topic: The Metaverse is Dead, Long Live the Metaverse: Distinguishing Opportunities from Hype**

**Panel Chair:** Tarek Abdelzاهر, University of Illinois Urbana-Champaign, USA

**Panel Members:**

- Tarek Abdelzاهر (University of Illinois Urbana-Champaign, USA)
- Klara Nahrstedt (University of Illinois Urbana-Champaign, USA)
- Mani Srivastava (University of California, Los Angeles USA)
- Baochun Li (University of Toronto, Canada)
- Max (Chong) Li (OORT and Columbia University, USA)

Wednesday, 28 June 2023 | 13:00 – 14:30 (Tokyo Time)  
Wednesday, 28 June 2023 | 05:00 – 06:30 (London Time)  
Wednesday, 28 June 2023 | 00:00 – 01:30 (New York Time)

**Session MetaCom-10: Blockchain and Web 3.0 (II) (Room Hiei, 13:00 – 14:30)**

**Session Chair:** Kouichi Sakurai (Kyushu University, Japan)

**Blockchain for Decentralized Know Your Customer (KYC) and Customer Due Diligence (CDD) Pipelines in the Metaverse**

Valerie Huiying Tan, Wei Yang Bryan Lim, Zehui Xiong and Dusit Niyato (Nanyang Technological University, Singapore)

**CD-PBFT: Incentive-based Efficient Blockchain Consensus Mechanism for Web 3.0**

Zhipen Gao, Yifeng Wang, Yijing Lin, Yang Yang and Lanlan Rui (BUPT, China)

**First-Price Sealed-Bid Auction for Ethereum Gas Auction Under Flashbots**

Congying Jin, Taotao Wang (Shenzhen University, China), Zhe Wang (Nanjing University of Science and Technology, China), Long Shi (CUHK, Hongkong) and Shengli Zhang (Shenzhen University, China)

Wednesday, 28 June 2023 | 13:00 – 14:30 (Tokyo Time)  
Wednesday, 28 June 2023 | 05:00 – 06:30 (London Time)  
Wednesday, 28 June 2023 | 00:00 – 01:30 (New York Time)

**Session MetaCom-11: Networking and Communications (III) (Room Kibune, 13:00 – 14:30)**

**Session Chair:** Shuping Peng (Huawei, China)

**A Game Theoretic Approach for Data Asset Protection in Metaverse**

Yaqi Yang, Jinkai Zheng, Guanjie Li, Tom Luan (Xidian University, China), Zhou Su (Xi'an Jiaotong University, China) and Mianxiong Dong (Muroran Institute of Technology, Japan)

### **Range and Velocity Estimation for RadCom-Meta Network: a Fully Connected Neural Network based Mechanism**

Xiaoming Xu, Liang Tang, Fei Shen, Chao Wang, Yu Zhao and Zhiyong Bu (Shanghai Institute of Microsystem and Information Technology, China)

### **Optimizing IoT Networks Deployment Under Connectivity Constraint For Dynamic Digital Twin**

Aurélien Chambon, Abderrahim Sahli, Abderrezak Rachedi and Ahmed Merbaki (Université Gustave Eiffel, France)

### **Task Freshness-aware Incentive Mechanism for Vehicle Twin Migration in Vehicular Metaverses**

Jinbo Wen, Jiawen Kang (Guangdong University of Technology, China), Zehui Xiong (Singapore University of Technology and Design, Singapore), Yang Zhang (Nanjing University of Aeronautics and Astronautics, China), Hongyang Du (Nanyang Technological University, Singapore), Yutao Jiao (Army Engineering University of PLA, China) and Dusit Niyato (Nanyang Technological University, Singapore)

### **A Lightweight and Secure Three-Factor Access Authentication Scheme in Metaverse**

Guanjie Li, Tom H. Luan, Chengzhe Lai, Zheng Li, Nan Cheng and Lina Zhu (Xidian university, China)

[Wednesday, 28 June 2023 | 13:00 – 14:30 \(Tokyo Time\)](#)

[Wednesday, 28 June 2023 | 05:00 – 06:30 \(London Time\)](#)

[Wednesday, 28 June 2023 | 00:00 – 01:30 \(New York Time\)](#)

### **Session MetaCom-12: Security, Privacy, and Trust (II) (Room Kurama, 13:00 – 14:30)**

**Session Chair:** Pengyuan Zhou (University of Science and Technology of China, China)

### **Can We Revitalize Interventional Healthcare with AI-XR Surgical Metaverses?**

Adnan Qayyum (University of Glasgow, U.K.), Muhammad Bilal (University of the West of England, U.K.), Muhammad Hadi (Information Technology University, Pakistan), Paweł Capik (University of the West of England, U.K.), Massimo Caputo, Hunaid Vohra (University of Bristol, U.K.), Ala Al-Fuqaha (Hamad Bin Khalifa University, Qatar) and Junaid Qadir (Qatar University, Qatar)

### **Joint Beamforming and Trajectory Optimization for UAV-Assisted Double IRS Secure Transmission System: A Deep Reinforcement Learning Approach**

Yihao Qi (Shanghai University, China), Zhou Su (Xi'an Jiaotong University, China), Qichao Xu (Shanghai University, China) and Dongfeng Fang (California Polytechnic State University San Luis Obispo, USA)

### **AFNT: A Secure Data Storage Scheme Based on IOTA Tangle for Wireless Sensor Networks**

Shiyun Wang, Qiang Ye (Dalhousie University, Canada) and Kai Liu (University of PEI, Canada)

### **XVRS: Extended Vulnerability Risk Scoring based on Threat Intelligence**

Ensar Seker (CISO, USA) and Weizhi Meng (Technical University of Denmark, Denmark)

### **Detecting Smart Contract Project Anomalies in Metaverse**

Shen Su, Yuntian Tan, Yue Xue, Chao Wang, Hui Lu, Zhihong Tian (Guangzhou University, China), Chun Shan (Guangdong Polytechnic Normal University, China) and Xiaojiang Du (Stevens Institute of Technology, USA)

[Wednesday, 28 June 2023 | 13:00 – 14:30 \(Tokyo Time\)](#)

[Wednesday, 28 June 2023 | 05:00 – 06:30 \(London Time\)](#)

**Wednesday, 28 June 2023 | 00:00 – 01:30 (New York Time)**

**Session MetaCom-13: Invited Paper (II) (Room Hiei, 14:40 – 16:00)**

**Session Chair:** Juan A. Cabrera (TU Dresden, Germany)

**Cell-free massive MIMO Enabled URLLC Communication for the Green Metaverse**

Jiakang Zheng, Jiayi Zhang (Beijing Jiaotong University, China), Hongyang Du, Dusit Niyato (Nanyang Technological University, Singapore) and Bo Ai (Beijing Jiaotong University, China)

**A Survey on Metaverse: Applications, Crimes and Governance**

Kaixin Lin, Jiajing Wu, Dan Lin and Zibin Zheng (Sun Yat-Sen University, China)

**Identification Codes for Increased Reliability in Digital Twin Applications over Noisy Channels**

Caspar von Lengerke, Juan A. Cabrera and Frank H. P. Fitzek (TU Dresden, Germany)

**Unlicensed Spectrum Assisted Connection in 5G-NR Networks**

Wenbin Rao (Zhejiang University of Technology, China), Jiantao Yuan, Meng Zhou (Hangzhou City College, China), Celimuge Wu (University of Electro-Communications, Japan), Yusheng Ji (National Institute of Informatics, Japan), Weidang Lu (Zhejiang University of Technology, China) and Rui Yin (Hangzhou City College, China)

**Wednesday, 28 June 2023 | 14:40 – 16:00 (Tokyo Time)**

**Wednesday, 28 June 2023 | 06:40 – 08:00 (London Time)**

**Wednesday, 28 June 2023 | 01:40 – 03:00 (New York Time)**

**Session MetaCom-14: Metaverse Computing (Room Kibune, 14:40-16:00)**

**Session Chair:** Babak Hossein Khalaj (Sharif University of Technology, Iran)

**Multiobjective Resource Allocation Strategy for Metaverse Resource Management**

Bin Cao, Yong Chen, Xin Liu, Hua He (Hebei University of Technology, China), Houbing Song (Embry-Riddle Aeronautical University, USA) and Zhihan Lv (Uppsala University, Sweden)

**Joining Edge-Enabled Metaverse Services with Network Externality: A Stackelberg Game Approach**

Yuna Jiang, Jiawen Kang (Huazhong University of Science and Technology, China), Dusit Niyato (Nanyang Technological University, Singapore), Xiaohu Ge (Huazhong University of Science and Technology, China), Zehui Xiong (Singapore University of Technology and Design, Singapore), Minrui Xu (Nanyang Technological University, Singapore) and Ruilong Deng (Zhejiang University, China)

**Metaverse Remote Rendering Testbed**

Louay Bassbouss, Andy Neparidze, Stephan Steglich, Stefan Arbanowski, Kolja Kieslich and Peter Pogrzeba (Fraunhofer FOKUS, Germany)

**A Layered Architecture Enabling Metaverse Applications in Smart Manufacturing Environments**

Armir Bujari, Alessandro Calvio, Andrea Garbugli and Paolo Bellavista (University of Bologna, Italy)

**Device to Device Caching Delivery Using Predicted Demand on Trajectory**

Makoto Tsunekiyo (Fukuoka University, Japan) and Noriaki Kamiyama (Ritsumeikan University, Japan)

**Wednesday, 28 June 2023 | 16:10 – 18:00 (Tokyo Time)**

**Wednesday, 28 June 2023 | 08:10 – 10:00 (London Time)**

**Wednesday, 28 June 2023 | 03:10 – 05:00 (New York Time)**

**Session MetaCom-15: [Short Paper] Metaverse Computing (Room Hiei, 16:10-18:00)**

**Session Chair:** Jiayi Zhang (Beijing Jiaotong University, China)

**Towards a Frictionless Customer Relationship Management in the Metaverse: Edge-enabled Consumer Digital Twins**

Yue Han, Wei Yang Bryan Lim, Dusit Niyato (Nanyang Technological University, Singapore), Cyril Leung (The University of British Columbia, Canada) and Chunyan Miao (Nanyang Technological University, Singapore)

**Generative AI-empowered Effective Physical-Virtual Synchronization in the Vehicular Metaverse**

Minrui Xu, Dusit Niyato (Nanyang Technological University, Singapore), Hongliang Zhang (Peking University, China), Jiawen Kang (Guangdong University of Technology, China), Zehui Xiong (Singapore University of Technology and Design, Singapore), Shiwen Mao (Auburn University, USA) and Zhu Han (University of Houston, USA)

**The Metaverse for Intelligent Healthcare using XAI, Blockchain, and Immersive Technology**

Ariful Mozumder, Tagne Poupi Theodore A., Ali Athar, Shah Muhammad Imtiyaj Uddin, Hee Cheol Kim and Rashedul Islam Sumon (Inje University, South Korea)

**Federated Dynamic Match-Making for Co-opetition among Participants in Mobility-as-a-Service**

Yu-Wei Chang and Tsung-Nan Lin (National Taiwan University, Taiwan)

**Metaverse Key Technologies and Blockchains: Impacts & Considerations**

Mustaqeem M (Mohamed Bin Zayed University of Artificial Intelligence, UAE), Abdulmotaleb Elsaddik and Wail Gueaieb (MBZUAI, UAE)

**A Practical Guide to Autoscaling Solutions for Next Generation Internet Applications**

Paolo Bellavista and Nicolò Bartelucci (University of Bologna, Italy)

**Trial of Risk Assessment for Business Application of Metaverse**

Toshiya Seyama (PwC Consulting LLC, Japan) and Ryoichi Sasaki (Tokyo Denki University, Japan)

**Wednesday, 28 June 2023 | 16:10 – 18:00 (Tokyo Time)**

**Wednesday, 28 June 2023 | 08:10 – 10:00 (London Time)**

**Wednesday, 28 June 2023 | 03:10 – 05:00 (New York Time)**

**Session MetaCom-16: [Short Paper] Theories, Experiments and Evaluations (Room Kibune, 16:10-18:00)**

**Session Chair:** Akihiko Shirai (REALITY Inc., Japan)

**Efficient Kernel Design of Support Vector Machine for IoT Networks**

Haesik Kim (VTT, Finland)

**A Cloud-Edge-Terminal Collaborative System for Image-Based Crowd Counting**

Zijie Mo, Shuaifan Xia, Shuze Shen, Siyuan Du and Qingwen Liu (Tongji University, China)

**A Payment Channel Network Fee Allocation Strategy Integrating Auction Theory**

Jingjing Zhang (Guangdong University of Foreign Studies, China), Shanbin Xiao, Weigang Wu and Jieying Zhou (Sun Yat-sen University, China)

**Toward Blockchain-based Fashion Wearables in the Metaverse: the Case of Decentraland**

Amaury Trujillo and Clara Bacciu (IIT-CNR, Italy)

Wednesday, 28 June 2023 | 18:00 – 18:10 (Tokyo Time)  
Wednesday, 28 June 2023 | 10:00 – 10:10 (London Time)  
Wednesday, 28 June 2023 | 05:00 – 05:10 (New York Time)

**Closing (Room Kurama)**