27th Conference on Innovation in Clouds, Internet and Networks

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Program

	Monday March 11, 2024		Tuesday March 12, 2024		Wednesday March 13, 2024	Thursday March 14, 2024
8:30	Registration		Registration		Registration	
9:00						Registration
9:15	Workshop iNtent drivEn autonomouS neTwORks NESTOR Room November	Tutorial #1 *Setting up a Reinforcement Learning pipeline for a Telco Core Network* Room March	Tutorial #3 *Green NFV: framework and enablers for energy savings in telecom network deployments* Room November	Tutorial #4 *Enabling Networking Technologies for High Performance Computing* Room March	FPS #2 *Edge-Cloud Continuum* Room November	
9:45						FPS #4 *Network Management and Processing* Room November
10:45	Coffee Break		Coffee Break			
11:15			Opening session		Coffee Break	Coffee Break
11:45	Workshop iNtent drivEn autonomouS neTwORks NESTOR Room November	Tutorial #1 *Setting up a Reinforcement Learning pipeline for a Telco Core Network* Room March	Keynote #1 *Network and service management across the compute continuum* Room November		Keynote #2 *AI Continuum for Smart, Secure and Sustainable Network* Room November	Keynote #3 *NFV-COIN: Leveraging In-Network Computing with Network Function Virtualization* Room November
12:45	Lunch Break Room 3B-6		Lunch Break and Demos Room 3B-6		Lunch Break and Demos Room 3B-6	Lunch Break Room 3B-6
14:00	Workshop 6G Network Use Cases and Verticals 6GN Room November	Tutorial #2 *Recent advances in Container Orchestration: Network-Aware Scheduling in Container Clouds* Room March	FPS #1 *Edge Computing and IoT* Room November		FPS #3 *Security* Room November	FPS #5 *Cloud Resource Allocation and Performance Analysis* Room November
15:30	Coffee Break					Coffee Break
16:00	Workshop 6G Network Use Cases and Verticals 6GN Room November	Tutorial #2 *Recent advances in Container Orchestration: Network-Aware Scheduling in Container Clouds* Room March	Coffee Break		Coffee Break	Panel *Intelligent network service management across the compute continuum* Room November
16:30			SPS #1 *Networking and Communications* Room November		SPS #2 *Cloud Optimization and Applications* Room November	
17:15						Best Paper Award & Closing Session
18:15			Welcome Reception			
19:30					Conference Dinner	

Welcome Message from the Chairs

On behalf of the Organizing Committee of the 27th Conference on “Innovation in Clouds, Internet and Networks” (ICIN 2024), it is our great pleasure to warmly introduce you to the 2024 event of ICIN, that is taking place in Paris, France, on March 11-14, 2024. We are delighted to welcome you in Paris, a really iconic, vibrant and cosmopolitan city.

Since 1989, ICIN conferences have gathered global Internet and Telecom experts from industry, academia, and government. Renowned for identifying research challenges and industry trends, ICIN fosters interdisciplinary collaboration and idea exchange in cloud networking and Internet communities.

In the recent years, the network and computer arena has recently expanded not only in number and in type of players but also in technologies, domains, terminals and services. This expansion seeks for intelligent and efficient control, orchestration, and management platforms able to support all the challenging requirements such as dynamicity, diversity, efficiency, sovereignty, sustainability, security, reliability and openness in a timely manner and with limited operator interventions. Solutions such as AI-based or digital twin are anticipated to contribute to the solution.

Acoordingly, for the 2024 edition, ICIN will discuss about the emergence and future developments of

“Intelligent network service management across the compute continuum”

In addition to the seven technical and two demo/poster sessions, this year’s program also includes three keynote speeches from Mauro Tortonesi (University of Ferrara, Italy) on “Network and service management across the compute continuum”, Imen Grida Ben Yahia (Amazon Web Services, UK) on “AI Continuum for Smart, Secure and Sustainable Network” and Elias P. Duarte (Federal University of Paraná, Brazil) on “NFV-COIN: Leveraging In-Network Computing with Network Function Virtualization”. Apart from the keynotes, our panel moderated by Pal Varga (Budapest University of Technology and Economics, Hungary) will engage in interesting discussions between 5 distinguished experts about “Intelligent network service management across the compute continuum”.

We are also offering two workshops on engaging topics, namely NESTOR, a workshop on Intent-driven autonomous networks, and 6GN on Network Use Cases and Verticals. Finally, 4 tutorials complete the program on the following attractive topics: “Setting up a Reinforcement Learning pipeline for a Telco Core Network” by Shantanu Verma and Guillaume Fraysse (Orange Innovation Networks, India/France); “Recent advances in Container Orchestration: Network-Aware Scheduling in Container Clouds” by José Santos (Ghent University, Belgium) and Chen Wang (IBM Thomas J. Watson Research Center, USA); “Green NFV: framework and enablers for energy savings in telecom network deployments” by Hammad Zafar (NEC Laboratories Europe, Germany) and Joan Triay (DOCOMO Euro-Labs, Germany); and “Enabling Networking Technologies for High Performance Computing” by Cedric Westphal (Futurewei, USA).

We would like to thank everyone who contributed to the organization of the conference. The Organizing Committee did an outstanding job in setting technical sessions, tutorials, keynotes and panels as well as making sure the conference got the world’s attention. We are indebted to the authors who contributed to the engaging ICIN2024 program with their submissions on high-quality research works. Special thanks go to Aziza Lounis for setting up the logistics and keeping us within schedule. We are grateful to Noël Crespi for his trust in our leadership and his support of the conference in his role as Chair of the steering committee.

Last but not least, we want to acknowledge the support our sponsors: Orange whose support has been invaluable in making this conference a successful reality, as well as Gandi that is a regular partner. We are also thankful for the support of IEEE and IEEE Comsoc that have accompanied us through the years.

We hope you thoroughly enjoy the ICIN2024 event and engage in many fruitful discussions during the conference!
Again welcome to Paris!

General Co-Chairs

Barbara Martini
(Universitas Mercatorum, Italy)

Prosper Chemouil
(CNAM, France)

TPC Co-Chairs

Panagiotis Papadimitriou
(University of Macedonia, Greece)

Carmen Mas Machuca
(Bundeswehr University Munich, Germany)

ICIN 2024 Keynotes

"Network and service management across the compute continuum"

Abstract: *Fueled by impressive advances in containerization, orchestration, and network softwarization, the Compute Continuum emerged recently as a compelling concept and paradigm that aims to manage network and computation resources across the Cloud-edge spectrum in a homogeneous and holistic fashion. However, despite the promising progresses, there is still some work to do in order to reify the Compute Continuum vision.*

This keynote will introduce the Compute Continuum, illustrate the main opportunities and challenges that it opens up, and discuss some of the most promising research avenues and approaches. More specifically, we will focus on the resource allocation perspective, highlighting how digital twins, computational intelligence, and reinforcement learning can be applied to implement dynamic and proactive service fabric management solutions for the Cloud Continuum.

Finally, we will analyze some high-stakes use cases including Industry 5.0 and natural disaster rescue and recovery – where the resource continuity assumption underlying the Compute Continuum paradigm gets stretched to the point of breaking down – and analyze how researchers are attempting to address the corresponding issues.

Mauro Tortonesi
University of Ferrara, Italy

Mauro Tortonesi is the head of the Big Data and Compute Continuum research laboratory at the University of Ferrara, Italy. He received the Ph.D. degree in computer engineering from the University of Ferrara, in 2006. He was a Visiting Scientist with the Florida Institute for Human & Machine Cognition (IHMC), Pensacola, FL, USA, from 2004 to 2005 and with the United States Army Research Laboratory, Adelphi, MD, USA, in 2015. He participates / has participated with several roles in a wide number of research projects in the distributed systems area, with particular reference to Compute Continuum, IoT and Big Data solutions in industrial and military environments. He has co-authored over 100 publications and has 4 international patents.

"AI Continuum for Smart, Secure and Sustainable Network"

Abstract : *In this keynote we will define and discuss the AI Continuum pillars towards Smart, Secure and Sustainable Networks with examples from mobile networks including RAN, ORAN and CORE.*
Three pillars of AI Continuum for Smarter networks will be discussed and exemplified on real use cases:

- *Network data-centric representation: We will examine state of the art and current design patterns on Graph Modeling enriched with Graph Analytics and GNN- Graph Neural Networks for Topology discovery, RCA and proactive events analysis:*
- *Observability, Troubleshooting recommendation: We will present examples of network use cases and examine state of the art LLMs for those operations as well as which LLM AI architectures are the best fit. MoE, Mixture of Expert design pattern, will particularly be discussed.*
- *Closed loop and actuations: For thisone of the most targeted level of automation, we will examine LLM, Agents and Reinforcement Learning to discuss mature/ready to use architecture patterns and where we need more researches and innovations.*

Those pillars of AI Continuum are key to achieve the "real" Data-Driven for Networks, going beyond the costly/siloed and network segment centric Data and AI pipelines.

Imen Grida Ben Yahia
Amazon Web Services, UK

Imen Grida Ben Yahia received her PhD degree in Telecommunication Networks from Telecom SudParis, Institut Polytechnique de Paris, in 2008. She is currently, Principal AI/ML Specialist Architect for Telco in Amazon Web Services (https://aws.amazon.com). She is tech. leading and building Telco solutions with AI/ML based on AWS services with key telco players to accelerate the move towards Smarter, Greener and Cloudified Networks. Previously, Imen was a Researcher and Technical leader in Orange Innovation, in charge of building, from research to delivery, data and AI/ML pipelines for network operations; Founder of Predictive Network Maintenance use cases in Orange. She co-authored several research papers on AI for Networks (6G, 5G, Software Networks, Cloud Native Net). Imen participated to several conferences as organizer, member of several Technical Program Committee and Public speaker.

"NFV-COIN: Leveraging In-Network Computing with Network Function Virtualization"

Abstract : *In this keynote we will examine a phenomenon that is resignifying communication networks as we know them. Instead of acting just as a data transport medium, multiple technologies have made it possible to leverage networks to run and provide user-level services. This paradigm has been alternately called Computing In the Network (COIN) and In-Network Computing (INC). INC has been mostly used in the context of programmable hardware, which provides support for the implementation of services on the data-layer level. Network Functions Virtualization (NFV) is another alternative technology to deploy novel types of services within the network.*

NFV allows the implementation in software of middleboxes traditionally available as specialized hardware. Network services can be implemented as SFCs (Service Function Chains) based on virtualization technologies that run on commodity hardware. Although most virtualized functions have classic middlebox functionalities (e.g. firewalls or intrusion detectors) arbitrary COIN services can be implemented using NFV technologies, which we call NFV-COIN. An NFV-COIN architecture has been proposed that is compliant with the NFV-MANO reference model.

We present case studies of NFV-COIN services for distributed abstractions that are notoriously relevant and hard to implement and maintain, including consensus, reliable and ordered broadcast, and failure detectors.

Elias P. Duarte
Federal University of Paraná, Brazil

Elias P. Duarte Jr. is a Full Professor at Federal University of Parana, Curitiba, Brazil, where he is the leader of the Computer Networks, Distributed Systems & Security Lab (LaRSiS). He has been twice (2005 and 2009) Visiting Associate Professor at Tohoku University (Japan) and Visiting Scholar at the University of California at Irvine (1997). His research interests include Computer Networks and Distributed Systems, their Dependability, Management, and Algorithms. He has published nearly 300 peer-reviewed papers and has supervised more than 130 students both on the graduate and undergraduate levels. Prof. Duarte is currently Associate Editor of the Computing (Springer) journal and IEEE Transactions on Dependable and Secure Computing, and has served as chair of more than 25 conferences and workshops in his fields of interest, including chairing the TCPs of SRDS'18, ICDCS'21, and GLOBECOM'24.

He received a Ph.D. degree in Computer Science from Tokyo Institute of Technology, Japan, 1997, M.Sc. degree in Telecommunications from the Polytechnical University of Madrid, Spain, 1991, and both BSc and MSc degrees in Computer Science from Federal University of Minas Gerais, Brazil, 1987 and 1991, respectively. He chaired the Special Interest Group on Fault Tolerant Computing of the Brazilian Computing Society (2005-2007); the Graduate Program in Computer Science of UFPR (2006-2008); and the Brazilian National Laboratory on Computer Networks (2012-2016). He is a member of the Brazilian Computing Society and a Senior Member of the IEEE.

ICIN 2024 Panel

Title: "Intelligent network service management across the compute continuum"

As the compute landscape evolves, extending from centralized data centers to the edge of the network and into end-user devices, the complexity of managing network services across this compute continuum keeps increasing. The convergence of technologies such as Edge Computing, Fog Computing, and the Internet of Things (IoT) has led to a highly distributed computing environment where network operations and management face unprecedented challenges.

In this continuously evolving landscape, the management of network services stretches across the compute continuum, from traditional data centers to the edges of our interconnected world. This continuum is further complicated by the advent of 5G and the emerging 6G technologies, promising unprecedented speeds, lower latency, and the ability to connect a massive number of devices simultaneously. In parallel, open source technologies are playing a key role in shaping the future of network service management, offering a foundation for innovation, collaboration, and standardization across this diverse ecosystem.

Artificial Intelligence (AI) and Machine Learning (ML) emerge as cornerstone technologies, enabling intelligent network service management across this continuum. They offer the potential to automate complex decision-making processes, optimize network performance in real-time, and predict future network states to preemptively resolve issues. However, integrating AI/ML, open source, and advanced mobile networking technologies into cohesive network service management strategies presents a complex set of challenges and opportunities.

Through this panel discussion, we will uncover the various roles of AI and ML in transforming network service management across the compute continuum. The session aims to foster a special discussion on the capabilities, challenges, and future directions of intelligent network management, providing valuable insights for researchers, practitioners, and policymakers alike.

Pal Varga
Budapest University of Technology and Economics, Hungary
Moderator

Pal Varga is the Head of Department of Telecommunications and Artificial Intelligence at the Budapest University of Technology and Economics (BME). He actively promotes bridging the gap between academia and industry, especially ICT vendors, operators, and service providers together with the stakeholders of vertical industrial use cases such as Industry 4.0, smart cities, and health. His main research interests include communication systems, Cyber-Physical Systems and Industrial Internet of Things, network traffic analysis, end-to-end QoS and SLA issues – for which he is keen to apply hardware acceleration and artificial intelligence, machine learning techniques as well.
He advocates for using AI tools and methods in a both creative and responsive manner and provides practice-driven lectures worldwide for the industry. Besides being a member of HTE and Sigma Xi, he is a senior member of IEEE, where he is active both in the IEEE ComSoc (Communication Society) and IEEE IES (Industrial Electronics Society) communities. He is an Editorial Board member in many journals, Associate Editor in IEEE Transactions on Network and Service Management, and the Editor-in-Chief of the Infocommunications Journal.

Elias P. Duarte
Federal University of Paraná, Brazil

See Professor Elias P. Duarte's bio in the previous page.

Fabrice Guillemin
Orange, France

Fabrice Guillemin received the graduation degrees from Ecole Polytechnique in 1984 and from Telecom Paris in 1989, and the Ph.D. degree from the University of Rennes in 1992. He defended his “habilitation” thesis in 1999 with the University Pierre et Marie Curie (LIP6), Paris. Since 1989, he has been with Orange Innovation (formerly, Orange Labs). He is currently leading a research program on end-to-end architectures for virtualized networks. He is a member of the Orange Expert Community on “Networks of Future” and an Orange Senior Expert.

Hui Deng
Huawei, China

Hui Deng has more than 20 years of telecom experience. He was the principal staff of China Mobile for network about 10 years, and served in the board of standard and open source like OPEN-O, OPNFV, and WBA; co-chair of modeling subcommittee of ONAP, IETF MIF working group co-chair et al. Currently as the chief standard delegate, he is covering 5GC/NFV/MEC standardization and open source. He is promoting ETSI NFV standard which will benefit for telecom operators long term strategy during the transformation stage.

Sylvaine Kerboeuf
Nokia Bell Labs, France

Sylvaine Kerboeuf is a senior researcher and Distinguished Member of Technical Staff in the “Network Architecture lab” of Bell Labs Core Research, part of Nokia Bell labs. She has researched and applied breakthrough concepts in wireless network architectures, network management and automation, mobile video delivery optimization, and optoelectronics with 25+ years of experience. Since 2015 her research interests include 5G/6G network architectures, dynamic 5G network slicing and cross-slices resource allocation, future network orchestration frameworks, and intent-based network management automation. She is currently coordinating the Influence project, a French-funded project within the France 2030 framework on intent-driven exposure and automated service fulfillment and assurance. She is also leading the E2E system work package within the Hexa-X-II project, the 6G flagship project under the Smart Networks and Services Joint Undertaking (SNS JU) EC funding program. She has authored papers in international conferences and journals and holds several active patents with Alcatel-Lucent and Nokia. Sylvaine holds an M.S. degree in physics and a Ph.D. in solid state physics from Paris Sud University, Orsay France.

Mauro Tortonesi
University of Ferrara, Italy

Mauro Tortonesi is the head of the Big Data and Compute Continuum research laboratory at the University of Ferrara, Italy. He received the Ph.D. degree in computer engineering from the University of Ferrara, in 2006. He was a Visiting Scientist with the Florida Institute for Human & Machine Cognition (IHMC), Pensacola, FL, USA, from 2004 to 2005 and with the United States Army Research Laboratory, Adelphi, MD, USA, in 2015. He participates / has participated with several roles in a wide number of research projects in the distributed systems area, with particular reference to Compute Continuum, IoT and Big Data solutions in industrial and military environments. He has co-authored over 100 publications and has 4 international patents.

Tutorials 1 - *Room "March"*

Tutorial 1: "Setting up a Reinforcement Learning pipeline for a Telco Core Network"

Abstract: *This tutorial aims to describe how to implement a Reinforcement Learning (RL) pipeline using an Open Source Core Network like the Magma project as the environment. It details the steps required for such an integration: framing the problem according to RL, automating the deployment of the platform on a Cloud Infrastructure using Infrastructure-as-Code, automation of the actions on the platform, collection of the state of the environment through the monitoring tools. The tutorial will use the autoscaling of network functions as a use case for demonstration, showing how a RL algorithm can learn how to scale in or out the number of deployed instances automatically according to the traffic.*

The tutorial will show how to implement a RL algorithm such as Deep Q-Learning, how to run experiments and how to analyze the results. It will also detail lessons learned in the process.

Shantanu Verma
Orange Innovation Networks, Gurgaon, India

Shantanu Verma holds a bachelor's degree in Computer Science and started his professional career with Orange in 2020. He has worked as engineer on various AI projects with use cases focused on Telco and Cloud. Being associated with Cognitive and Predictive Network Management research project at Orange from 2021, he has contributed on engineering and designing the difference aspects of the problem of resource scaling of Network Functions (NFs) from the perspective of RL.

Guillaume Fraysse
Orange Innovation Networks, Paris, France

Guillaume Fraysse first got a Software Engineering Master's Degree in 1999 from the University of Bordeaux and worked as an engineer or architects in different capacities at Orange while getting a Master's Degree in Distributed Systems from Sorbonne University in 2003 and getting his PhD in Computer Science in 2020. He has since been managing the Cognitive and Predictive Network Management research project at Orange. One of the focus of this project is the automation of the management of Core Networks using RL.

Tutorials 2 - *Room "March"*

Tutorial 2: "Recent advances in Container Orchestration: Network-Aware Scheduling in Container Clouds"

Abstract: *Containers have revolutionized application deployment and life-cycle management in current cloud platforms.*
Applications have evolved from single monoliths to complex graphs of loosely-coupled microservices aiming to improve deployment flexibility and operational efficiency. Nonetheless, the efficient orchestration of containerized applications is still challenging due to their complex inter-dependencies. Scheduling policies in popular container orchestration platforms mainly aim to increase the resource efficiency of the infrastructure, which is insufficient for latency-sensitive applications demanding low latency between dependent microservices.

This tutorial provides an overview of application scenarios and methodologies to address the efficient orchestration of containerized applications. After that, the tutorial provides a practical vision of network-aware scheduling via the developed Diktyo framework 1,2 for the popular Kubernetes (K8s) platform. Diktyo determines the placement of dependent microservices focused on reducing the application's end-to-end latency. The tutorial includes a live-demo showing the benefits of Diktyo by deploying typical containerized applications. Diktyo is open-sourced and hosted in the K8s scheduling community as an alternative scheduler. Lastly, lessons learned alongside future trends in container scheduling are outlined.

José Santos
Ghent University - imec, IDLab, Gent, Belgium

José Santos obtained his M.Sc. degree in Electrical and Computers Engineering in July 2015 from the University of Porto, Portugal. Recently, he completed his doctoral studies at Ghent University in April 2022. He is currently a Postdoctoral Researcher in the Internet Technology and Data Science Lab (IDLab) Research Group at Ghent University – imec, Belgium. His research interests include Cloud Computing, the Internet of Things (IoT), Container Scheduling and Auto-scaling, Service Function Chaining, and Reinforcement Learning. His work has been published in more than 20 scientific publications. He received the PhD Excellence award 2022 from imec (Belgium) and the Best Dissertation Award at NOMS 2023 (Miami, USA).

Chen Wang
IBM Thomas J. Watson Research Center, USA

Chen Wang obtained her M.S.c and Ph.D. degrees in Electrical and Computer Engineering from Carnegie Mellon University (CMU) in 2014 and 2017, respectively. Since 2017, she has worked as a Research Staff Member at IBM Thomas J. Watson Research Center. Her research interests include Cloud video streaming systems, Cloud resource management, Container Cloud platforms, Serverless Computing, Machine Learning/Data Analytics systems, and data-driven cloud system management, with a special focus on machine learning approaches. She authored and coauthored 20+ papers, and served as co-chair for ACM International Workshop on Containers, ACM Middleware Industrial Track, IEEE CloudCom, etc.

Tutorials 3 - *Room "November"*

Tutorial 3: "NFV: framework and enablers for energy savings in telecom network deployments"

Abstract: *Growing number of users and ever-increasing data-intensive mobile applications are causing continuous increase in the data traffic to be handled by telecommunication networks. This growth has a direct relation with carbon footprint of telecom network deployments. To meet the goals of carbon neutrality, it becomes paramount to make the network deployments greener and energy efficient.*
Network functions virtualization (NFV) technology with its inherent properties, like virtualization, infrastructure sharing, demand-based scaling of network functions and services, can act as an enabling technology in reducing carbon footprint of large-scale telecom deployments. The sophisticated management and monitoring framework offered by the NFV Management and Orchestration (NFV- MANO) system can play a vital role in ensuring energy efficiency objectives of telecom network providers.

The goal of this tutorial is:
1. To describe NFV use cases showcasing energy saving potential in Telco deployments
2. To highlight the key issues and potential solutions related to energy consumption, energy-efficient design and management, metrics collection and monitoring
3. To explore the features and capabilities of NFV MANO system in view of energy efficiency requirements.

At the end of the proposed 90-minute tutorial, the audience is expected to have an effective understanding of energy efficiency support in NFV.

Hammad Zafar
NEC Laboratories Europe in Heidelberg, Germany

Hammad Zafar is a Standardization Researcher at NEC Laboratories Europe in Heidelberg, Germany. His current research is focused on using standard orchestration and management frameworks to achieve energy-efficiency, performance optimization, trust and privacy in communication networks. He is an active delegate at the ETSI NFV standards organization and has been involved in the development of NFV standards since 2020. He has contributed to around 6 published ETSI NFV standard documents and is Rapporteur for multiple work items. He is actively contributing to the 'Green NFV' feature in NFV and has provided several contributions to the published report on energy efficiency aspects for NFV, ETSI GR NFV-EVE 021. Besides software design, architecture and development, API design and testing, Hammad also has extensive experience in modeling, emulation and testing of standard NFV APIs for management and orchestration of virtualized network function and services. Hammad holds a Masters in Electronic Engineering (2018) and Bachelors in Electrical Engineering (2015).

Joan Triay
DOCOMO Euro-Labs, Germany

Joan Triay is a network architect and manager at DOCOMO Euro-Labs, in Munich, Germany, which he joined in 2012, and where he is currently involved in standardization and development activities spanning different areas such as network virtualization, telecom cloudification, mobile communication networks, and 5G network management and orchestration. Before joining DOCOMO Euro- Labs, Joan had been a visiting fellow at the University of Essex, UK (2009-2010) and a visiting researcher at the University of Massachusetts, Dartmouth (2010-2011) sponsored by a Fulbright fellowship. Joan served as the Technical Manager of the ETSI NFV, standardization group that he joined as a delegate from the very beginning (2013) and in which he has been participating actively in developing the NFV concepts and standards. Joan holds an M.Eng. in Telecommunications Engineering (2006), an M.Sc. and Ph.D. in Telematics Engineering (Computer Networks) (2007 and 2011, respectively) all from Universitat Politècnica de Catalunya (UPC), BarcelonaTech, Spain.

Tutorials 4 - *Room "March"*

Tutorial 4: "Enabling Networking Technologies for High Performance Computing"

Abstract: *Two converging trends motivate this tutorial: the massive amount of data center computation and the scale of these operations, as well as the deployment of reliable distributed storage systems. Indeed, with machine learning and artificial intelligence workloads becoming ubiquitous, there is a strong need for data interconnects and networking protocols that allow these workloads to be distributed over multiple processing nodes, to query databases, process the results and then the results being aggregated back to the application. This has pushed some high-performance requirements and new solutions onto the networking layer. Virtualization, softwarization and containerization impact data center networks as well.*

This tutorial provides a deep dive into the networking layer for these types of workloads. It will focus on the networking layer to support fast transport of data for time sensitive applications. We will survey the state of the art in networking technologies used for high performance computing, and will describe the most relevant ones.
The tutorial will describe the need and emerging use cases for networking technology to efficiently support RDMA, RPCs, and will describe other efforts such as DetNet for time-sensitive networking.

Cedric Westphal
Futurewei, USA

Cedric Westphal is a Principal Research Architect with Futurewei working on future network architecture, both for wired and wireless networks. His current focus is on next generation Internet.

He was an adjunct assistant, then associate professor with the University of California, Santa Cruz from 2009 to 2019. Prior to Futurewei, he was with DOCOMO Innovations from 2007 to 2011 in the Networking Architecture Group focusing on next generation network architectures. He was at Nokia Research Center (now Nokia Bell Labs) from 2000 to 2006. He has received a MSEE in 1995 from Ecole Centrale Paris, and a MS (1995) and PhD (2000) in EE from the University of California, Los Angeles. From 1997 to 2000, he was a visiting researcher at Stanford University. Cedric Westphal has authored and coauthored over a hundred journal and conference papers, including several best paper awards at conferences such as IEEE ICC'11, IEEE ICNC'18, IEEE MuSIC'16 and others.

Dr. Westphal has given tutorials at many conferences, including "High Speed Cellular Networks, architecture and protocols" (IEEE/IFIP Networking 2005); "Wireless Mesh Networks, architecture and protocols" (European Wireless 2007); "Information-Centric Networking, Current state of the Art and Future Directions" (IEEE Globecom 2013); "Information-Centric Networks: Status and Open Research Problems," (IEEE SACONET 2013); "Management of Future Networks: Issues and Opportunities in Information-Centric Networks" (IEEE IM 2015), as well as keynotes and invited talks. His most recent tutorials were "Enabling Technologies for the Softwarization of Operations and Control Networks" at IEEE NetSoft 2023 in Madrid, Spain and "Enabling Technologies for Operations and Control Network" at IEEE/IFIP NOMS 2023 in Miami, USA.

ICIN 2024 NESTOR - *Room "November"*

9:15 - 9:20 Welcome

9:20 - 9:50 NEST #1: Invited Presentation: ETSI NFV activities on Autonomous Networks

Session Chair: Bruno Chatras

Haitao Xia
Huawei, China

Haitao Xia is a senior Huawei standard expert, with professional experience of 4G/5G standardization for over 15 years, intensively involved in ETSI and 3GPP standard activities. Currently served as ETSI ISG NFV IFA working group chair, promoting release version delivery for NFV evolution towards telco cloud native.

Abstract: *ETSI ISG NFV embraces autonomous network-related work from Release 4 (2019) on, and works closely with other SDOs (either inside ETSI or outside ETSI) for promoting the improvement of automation levels for a management domain (i.e., NFV-MANO). This presentation gives an overview on applying autonomous network-related concepts, mechanisms and functionality in NFV-MANO, including NFV intent management, as well as prospects to future work in this area.*

9:50 – 10:20 NEST #1: Keynote: What can knowledge injection bring to intent-based networking?

Session Chair: Bruno Chatras

Sylvaine Kerboeuf
Nokia Bell Labs, France

Sylvaine Kerboeuf is a senior researcher and Distinguished Member of Technical Staff in the “Network Architecture lab” of Bell Labs Core Research, part of Nokia Bell labs. She has researched and applied breakthrough concepts in wireless network architectures, network management and automation, mobile video delivery optimization, and optoelectronics with 25+ years of experience. Since 2015 her research interests include 5G/6G network architectures, dynamic 5G network slicing and cross-slices resource allocation, future network orchestration frameworks, and intent-based network management automation.

She is currently coordinating the Influence project, a French-funded project within the France 2030 framework on intent-driven exposure and automated service fulfillment and assurance. She is also leading the E2E system work package within the Hexa-X-II project, the 6G flagship project under the Smart Networks and Services Joint Undertaking (SNS JU) EC funding program. She has authored papers in international conferences and journals and holds several active patents with Alcatel-Lucent and Nokia. Sylvaine holds an M.S. degree in physics and a Ph.D. in solid state physics from Paris Sud University, Orsay France.

10:20 - 10:45 NEST #1: Knowledge Driven Policy Management for Autonomous Networks

Lingli Deng (China Mobile, China)
Session Chair: Bruno Chatras

10:45 - 11:15 Coffee Break

11:15 - 12:30 NEST #2: Session 2

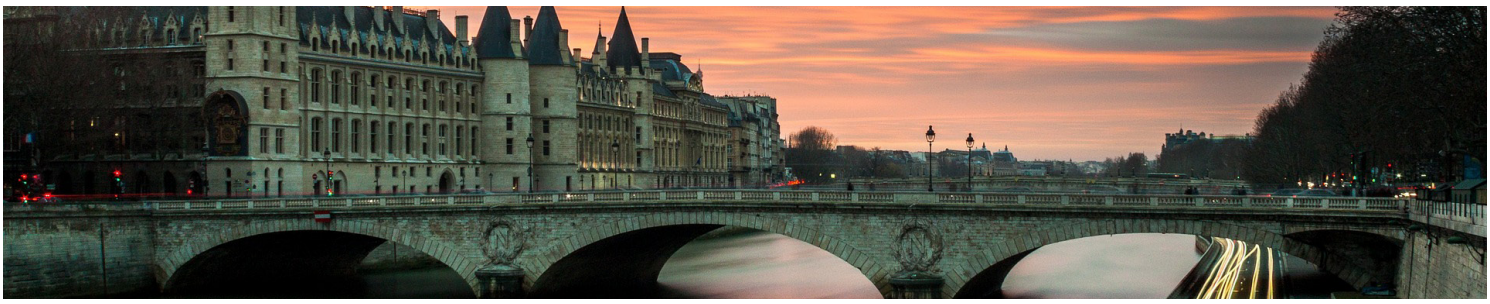
Session Chair: Kostas Katsalis

Intent Negotiation Empowers Advanced Operations for the Intent-Driven Autonomous Network
Jinguo Zhu (ZTE, China); Pengxiang Xie and Manchang Ju (ZTE Corporation, China); Lingli Deng, Keguang He and Kaixi Liu (China Mobile, China)

Towards Intent-Based Scheduling for Performance and Security in Edge-To-Cloud Networks
José Santos (Ghent University – Imec, Belgium); Eddy Truyen (KU Leuven, Belgium); Christoph Baumann (Ericsson AB, Sweden); Filip De Turck (Ghent University – imec, Belgium); Gerald Budigiri and Wouter Joosen (KU Leuven, Belgium)

A Declarative Reasoning Approach to Conflict Management in Intent-Based Networking
Jacopo Massa, Stefano Forti, Federica Paganelli, Patrizio Dazzi and Antonio Brogi (University of Pisa, Italy)

12:30 - 12:45 Conclusion/Closing



ICIN 2024 6GN - *Room "November"*

14:00 - 14:05 Opening session

14:05 - 14:50 6GN #1: Keynote: Pan-European Trials and Pilots: the story so far in the 5G-PPP, and the long way ahead towards 6G in the SNS-JU
Carles Antón-Haro (6G Industry Association (6G-IA))
Session Chair: Hamzeh Khalili

14:50 - 15:30 6GN #2: Control and Orchestration
Session Chair: Hamzeh Khalili

Dual Timescale Orchestration System for Elastic Control of NextG Cloud-Integrated Networks
Quirino Pagliuca (TIM, Italy); Luciano Jerez Chaves (Universidade Federal de Juiz de Fora, Brazil); Pasquale Imputato (University of Naples Federico II, Italy); Antonia Tulino (Università degli studi di Napoli, Italy); Jaime Llorca (New York University, USA)

Resilient Cloud Control System: Dynamic Frequency Adaptation via Q-Learning
Fatemeh Akbarian, William Tärneberg, Emma Fitzgerald and Maria Kihl (Lund University, Sweden)

15:30 - 16:00 Coffee Break

16:00 - 17:20 6GN #3: Media Vertical
Session Chair: Hamzeh Khalili

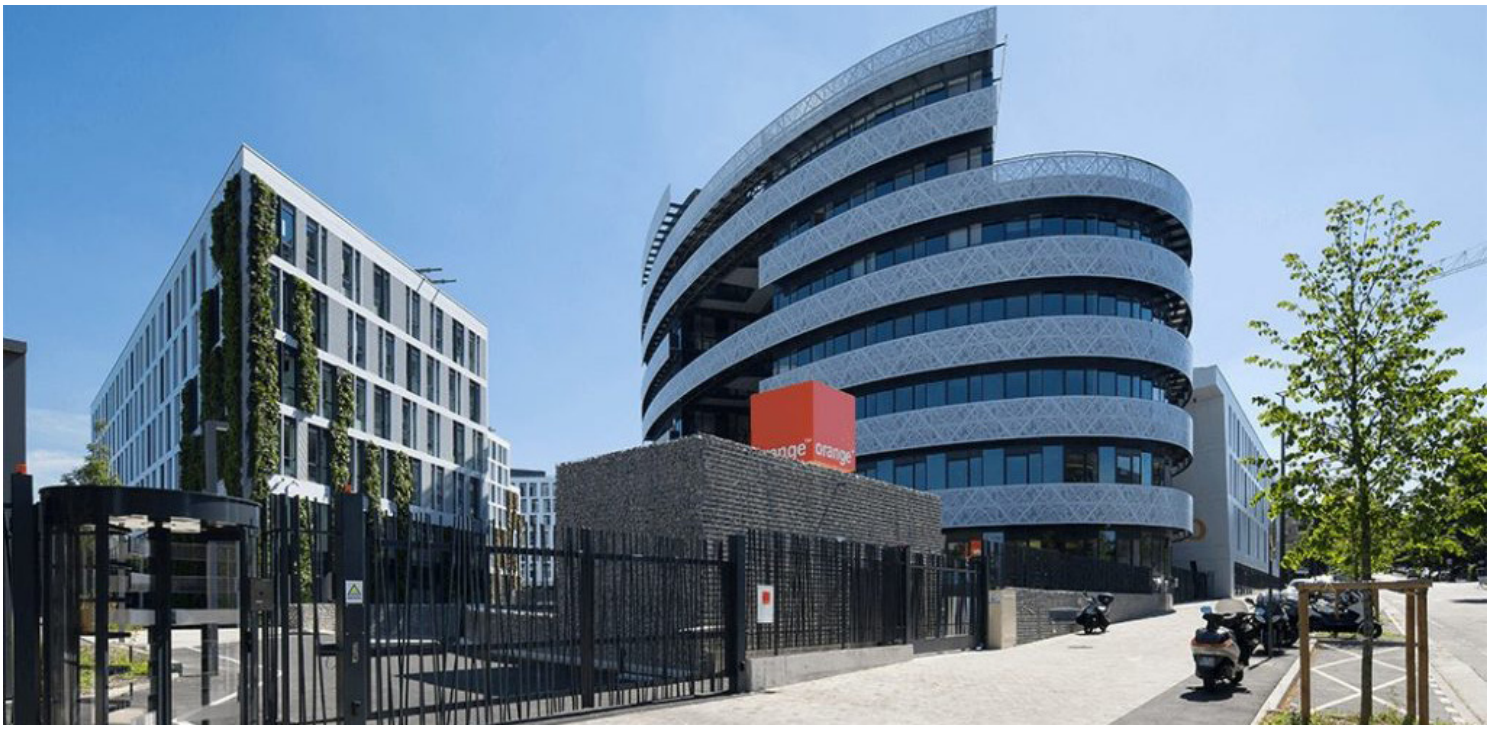
A QoE-Guaranteed Routing Scheme for VR Video Streaming Using Monte Carlo Tree Search in SDNs
Mingchun Xu , Yu Chen and Yingjie Zhou (Beijing University of Posts and Telecommunications, China)

Genetic Algorithm With Gene Regulatory Networks Based Optimization Method for Distributed Video Analysis System
Seishiro Inoue, Masaaki Yamauchi, Daichi Kominami, Hideyuki Shimonishi and Masayuki Murata (Osaka University, Japan)

A Simulation of Energy Optimized Distributed Video Processing on 28 GHz Network
Nattaon Techasarntikul, Hideyuki Shimonishi and Masayuki Murata (Osaka University, Japan)

Multimodal Object Recognition Using Bayesian Attractor Model for 2D and 3D Data
Haruhito Ando, Daichi Kominami, Ryoga Seki, Hideyuki Shimonishi and Masayuki Murata (Osaka University, Japan)

17:20 - 17:25 Conclusion/Closing



ICIN 2024 - March 11

8:30 - 9:15 Registration

9:15 - 10:45 Workshop on iNtent drivEn autonomouS neTwORks NESTOR

9:15 - 10:45 Tutorial #1: Setting up a Reinforcement Learning pipeline for a Telco Core Network
Shantanu Verma (Orange Innovation Networks, Gurgaon, India) & Guillaume Fraysse (Orange Innovation Networks, Paris, France)

10:45 - 11:15 Coffee Break

11:15 - 12:45 Workshop on iNtent drivEn autonomouS neTwORks NESTOR

11:15 - 12:45 Tutorial #1: Setting up a Reinforcement Learning pipeline for a Telco Core Network
Shantanu Verma (Orange Innovation Networks, Gurgaon, India) & Guillaume Fraysse (Orange Innovation Networks, Paris, France)

12:45 - 14:00 Lunch Break - *Room "3B-6"*

14:00 - 15:30 Workshop on 6G Network Use Cases and Verticals 6GN

14:00 - 15:30 Tutorial #2: Tutorial Recent advances in Container Orchestration: Network-Aware Scheduling in Container Clouds
José Santos (Ghent University - imec, IDLab, Gent, Belgium) & Chen Wang (IBM Thomas J. Watson Research Center, USA)

15:30 - 16:00 Coffee Break

16:00 - 17:15 Workshop on 6G Network Use Cases and Verticals 6GN

16:00 - 17:15 Tutorial #2: Tutorial Recent advances in Container Orchestration: Network-Aware Scheduling in Container Clouds
José Santos (Ghent University - imec, IDLab, Gent, Belgium) & Chen Wang (IBM Thomas J. Watson Research Center, USA)

ICIN 2024 - March 12 - *Room "November"*

8:30 - 9:15 Registration

9:15 - 10:45 Tutorial #3: Tutorial Green NFV: framework and enablers for energy savings in telecom network deployments
Hammad Zafar (NEC Laboratories Europe in Heidelberg, Germany) & Joan Triay (DOCOMO Euro-Labs, Germany)

9:15 - 10:45 Tutorial #4: Enabling Networking Technologies for High Performance Computing - *Room "March"*
Cedric Westphal (Futurewei, USA)

10:45 - 11:15 Coffee Break

11:15 - 11:45 Opening Ceremony

11:45 - 12:45 Keynote #1: Network and service management across the compute continuum
Mauro Tortonesi (University of Ferrara, Italy)
Session Chair : Carmen Mas Machuca (Bundeswehr University Munich, Germany)

12:45 - 14:00 Lunch Break & Demos - *Room "3B-6"*

14:00 - 16:00 FPS #1: Edge Computing and IoT
Session Chair : Andreas Kassler (TH Degegndorf, Germany)

Dynamic Schedule Computation for Time-Aware Shaper in Converged IoT-Cloud Environments
Georgios Papathanail, Ilias Sakellariou, Lefteris Mamatas and Panagiotis Papadimitriou (University of Macedonia, Greece)

Investigation of Container Network Function Deployment Costs in the Edge Cloud
Kien Nguyen (University of Wuerzburg, Germany); Filip Simonovski (University of Augsburg, Germany); Frank Loh (University of Wuerzburg, Germany); Nguyen Huu Thanh (Hanoi University of Science and Technology, Vietnam); Tobias Hoßfeld (University of Würzburg, Germany)

In-depth analysis of Kubernetes manifest verification tools for robust CNF deployment
Boubacar Diarra (Orange Labs & Inria Lille, France); Karine Guillouard and Meryem Ouzzif (Orange Labs, France); Philippe Merle (Inria Lille - Nord Europe, France); Jean-Bernard Stefani (INRIA, France)

DAXiot: A Decentralized Authentication and Authorization Scheme for Dynamic IoT Networks
Artur Philipp and Axel Küpper (TU Berlin, Germany); Philip Raschke (Technische Universität Berlin, Germany)

16:00 - 16:30 Coffee Break

16:30 - 18:00 SPS #1: Networking and Communications
Session Chair : Davide Borsatti (University of Bologna, Italy)

Secure and Trustful Cross-domain Communication with Decentralized Identifiers in 5G and Beyond
Hai Dinh-Tuan (Technische Universität Berlin, Germany); Sandro Rodriguez Garzon, Jianeng Fu (Technische Universität Berlin, Germany)

On cross-layer optimization for real-time remote communication in 5G and beyond
Toni Dimitrovski (TNO, The Netherlands); Evangelos Alexiou (Xiaomi Technology, The Netherlands); Lucia D'Acunto, Tim Bergman, Rick Hindriks and Belma Turkovic (TNO, The Netherlands)

Round Trip Times (RTTs): Comparing Terrestrial and LEO Satellite Networks
Javier Conde (Universidad Politécnica de Madrid, Spain); Gonzalo Martínez (Universidad Carlos III de Madrid, Spain); Pedro Reviriego (Universidad Politécnica de Madrid, Spain); Jose Alberto Hernandez (Universidad Carlos III de Madrid, Spain)

Shortcuts: A Simple Mechanism for Reducing the Data Path Delay in Beyond 5G and 6G Networks
Marius Corici (Fraunhofer FOKUS, Germany); Hemant Zope (Fraunhofer Fokus, Germany); Hauke Buhr and Christian Scheich (Fraunhofer FOKUS, Germany); Thomas Magedanz (Fraunhofer Institute FOKUS / TU Berlin, Germany)

XDQ: Enhancing XDP with Queuing and Packet Scheduling
Freysteinn Alfredsson (Karlstads Universitet, Sweden); Per Hurtig and Anna Brunstrom (Karlstad University, Sweden); Toke Høiland-Jørgensen (Red Hat, Denmark); Jesper Dangaard Brouer (Cloudflare, Denmark)

18:15 - 19:00 Welcome Reception

Demos Session at Lunch Breaks (12,13 March) - *Room "3B-6"*

Multi-Objective Microservice Orchestration: Balancing Security and Performance in CCAM
Stefano Berlato, Silvio Cretti, Domenico Siracusa and Silvio Ranise (Fondazione Bruno Kessler, Italy)

From a business intent to a network deployment with user-friendly interfaces and natural language processing
Barbara Orlandi (Nokia Bell Labs, France), Sandrine Lataste (Orange Labs, France), Sylvaine Kerboeuf, Frederic Faucheux, Bruno Mongazon and Olivier Marce (Nokia Bell Labs, France), Marc Bouillon, Xiaofeng Huang, Sihem Cherrared and Pascal Delvallet (Orange Labs, France)

A Platform for Time-Sensitive Networking in Converged IoT-Cloud Environments
Georgios Papathanail, Ilias Sakellariou, Lefteris Mamatas and Panagiotis Papadimitriou (University of Macedonia, Greece)

Experiments with Digital Security Processes over SDN-based Cloud-native 5G Core Networks
Sarantis Kalafatidis, Georgios Agrafiotis, Konstantinos Glapantzis, Antonios Lalas and Konstantinos Votis (Centre for Research and Technology - Hellas (CERTH), Greece)

ClusterSlice: A Zero-touch Deployment Platform for the Edge Cloud Continuum
Lefteris Mamatas, Sotiris Skaperas and Ilias Sakellariou (University of Macedonia, Greece)

Demonstrating Runtime Microservice Rescheduling in Hybrid Clouds for Cost Minimization
Silvio Cretti, Marco Zambianco and Domenico Siracusa (Fondazione Bruno Kessler, Italy)

ICIN 2024 - March 13 - *Room "November"*

8:30 - 9:15 Registration

9:15 - 11:15 FPS #2: Edge-Cloud Continuum
Session Chair : Mauro Tortonesi (University of Ferrara, Italy)

FORK: A Kubernetes-compatible Federated Orchestrator of Fog-native applications over multi-domain edge-to-cloud ecosystems
Shahmir Ejaz and Mays F AL-Naday (University of Essex, United Kingdom (Great Britain))

Cost Minimization in Multi-cloud Systems with Runtime Microservice Re-orchestration
Marco Zambianco, Silvio Cretti and Domenico Siracusa (Fondazione Bruno Kessler, Italy)

VOICE: Value-of-Information for Compute Continuum Ecosystems
Mattia Zaccarini and Benedetta Cantelli (University of Ferrara, Italy); Maria Fazio (University of Messina, Italy); William Fornaciari (Politecnico di Milano, Italy); Filippo Poltronieri, Cesare Stefanelli and Mauro Tortonesi (University of Ferrara, Italy)

LLRS: A Low latency Resource Scheduling in Cloud Continuum orchestration
David Kule Mukuhi (University Gustave Eiffel, CNRS, LIGM, France & CNRS, SNCF, France); Abdelkader Outtagarts (Nokia Bell Labs, France)

11:15 - 11:45 Coffee Break

11:45 - 12:45 Keynote #2: AI Continuum for Smart, Secure and Sustainable Network
Imen Grida Ben Yahia (Amazon Web Services, UK)
Session Chair : Pal Varga (Budapest University of Technology and Economics, Hungary)

12:45 - 14:00 Lunch Break & Demos - *Room "3B-6"*

14:00 - 16:00 FPS #3: Security
Session Chair : Paul Veitch (BT, United Kingdom)

Revealing the Threat Landscape of Intent-based Management in O-RAN
Filippo Rebecchi (Ericsson France, France); Daniel Cho and Loay Abdelrazek (Ericsson, Sweden); Henrik Forssell (Ericsson AB, Sweden); Jonathan Olsson (Ericsson, Sweden)

SEAL: Secure and Efficient Authentication using Linkage for Blockchain Network
Hsiang-Jen Hong (Western Washington University, USA); Sang-Yoon Chang (University of Colorado Colorado Springs, USA); Wenjun Fan (Xi'an Jiaotong-Liverpool University, China); Simeon Wuthier (University of Colorado Colorado Springs, USA); Xiaobo Zhou (University of Colorado, Colorado Springs, USA)

Secure and authorized data sharing among different IoT network domains using Beez Blockchain
Enrico Zanardo (Universitas Mercatorum, Italy & University of Nicosia, Italy); Barbara Martini (Universitas Mercatorum, Italy)

Moving Target Defense for Cloud-Native Applications
Ali Awarkeh (University of CNAM, France); Rim El Malki (Ericsson, R&D, France); Filippo Rebecchi (Ericsson France, France)

16:00 - 16:30 Coffee Break

16:30 - 18:00 SPS #2: Cloud Optimization and Applications
Session Chair : Ilhem Fajjari (Orange Innovation, France)

Assessing supervised machine learning in detecting GPS spoofing attacks on UAV application use-cases
Dimitrios-Evangelos Gkogkos, Lefteris Mamatas and Sophia Petridou (University of Macedonia, Greece)

Edge AI framework for Large Scale Smart Agriculture
Seung Woo Kum (Korea Elecronics Technology Institute, Korea (South)); Seungtaek Oh and Jaewon Moon (Korea Electronics Technology Institute, Korea (South))

Memory Bandwidth Throttling to Maximise Performance and Reduce Power Consumption
Paul Veitch (BT & Bt, United Kingdom (Great Britain)); Chris MacNamara and John J Browne (Intel Corporation, Ireland)

Optimizing TSN Routing, Scheduling, and Task Placement in Virtualized Edge-Compute Platforms
Hamza Chahed (Karlstad University, Sweden); Andreas J. Kassler (Deggendorf Institute of Technology (DIT) & Karlstad University, Sweden)

Network Planning for the Future Railway Communications
Cristian Bermudez Serna (Technical University of Munich, Germany); Peng Lin Huang (Technical University of Catalonia, Spain); Anna Prado (Technical University of Munich, Germany); Carmen Mas-Machuca (University of the Bundeswehr Munich (UniBW), Germany)

19:30 Conference Dinner

ICIN 2024 - March 14 - *Room "November"*

9:00 - 9:45 Registration

9:45 - 11:15 FPS #4: Network Management and Processing
Session Chair : Tim Wauters (Ghent University - imec, Belgium)

Intent-based network management with user-friendly interfaces and natural language processing
Barbara Orlandi (Nokia Bell Labs, France); Sandrine Lataste (Orange, France); Sylvaine Kerboeuf (Nokia Bell Labs, France); Marc Bouillon (Orange Labs, France); Xiaofeng Huang (Orange, France); Frederic Faucheux (Nokia Bell Labs, France); Arzhang Shahbazi and Pascal Delvallet (Orange, France)

Segment Routing for Chaining Micro-Services at Different Programmable Network Levels
Bertrand Mathieu (Orange Innovation, France); Olivier D Dugeon (Orange Labs & France Telecom, France); Joël Roman Ky (Orange Innovation, France); Philippe Graff and Thibault Cholez (Universite de Lorraine, CNRS, Inria, LORIA, France)

E-Commerce Bot Traffic: In-Network Impact, Detection, and Mitigation
Masoud Hemmatpour (Arctic University of Norway & Simula Research Laboratory (SRL), Norway); Changgang Zheng and Noa Zilberman (University of Oxford, United Kingdom (Great Britain))

11:15 - 11:45 Coffee Break

11:45 - 12:45 Keynote #3: NFV-COIN: Leveraging In-Network Computing with Network Function Virtualization
Elias P. Duarte (Federal University of Paraná, Brazil)
Session Chair : Bruno Chatras (Independent Expert)

12:45 - 14:00 Lunch Break

14:00 - 15:30 FPS #5: Cloud Resource Allocation and Performance Analysis
Session Chair : Abdelkader Outtagarts (Nokia Networks, France)

Multi-cloud Containerized Service Scheduling Optimizing Computation and Communication
Weifan Zhang, Sokol Kosta and Preben Mogensen (Aalborg University, Denmark)

gPerfIsol: GNN-based Rate-Limits Allocation for Performance Isolation in Multi-tenant Cloud
Benoit Nougnanke (IIJ Research Laboratory, Japan & JFLI CNRS, Japan); Justin Loye (IIJ Research Lab, Japan); Jean-François Baffier (National Institute of Informatics & Tohoku University, Japan); Simone Ferlin (Red Hat and Karlstad University, Sweden); Marc Bruyere (IIJ Innovation Institute & The University of Tokyo, Japan); Yann Labit (LAAS-CNRS, Université de Toulouse, France)

Empowering ISPs with Cloud Gaming User Experience Modeling: A NVIDIA GeForce NOW Use-Case
Gergely Dobreff and Dániel Frey (Budapest University of Technology and Economics, Hungary); Attila Bader (Ericsson, Hungary); Alija Pašić (Budapest University of Technology and Economics, Hungary)

15:30 - 16:00 Coffee Break

16:00 - 17:15 Panel: Intelligent network service management across the compute continuum

Moderator :
Pal Varga (Budapest University of Technology and Economics, Hungary)

Panel Members :
Elias P. Duarte (Federal University of Paraná, Brazil)
Fabrice Guillemin (Orange, France)
Hui Deng (Huawei, China)
Sylvaine Kerboeuf (Nokia Bell Labs, France)
Mauro Tortonesi (University of Ferrara, Italy)

17:15 Best Paper Award and Closing Session

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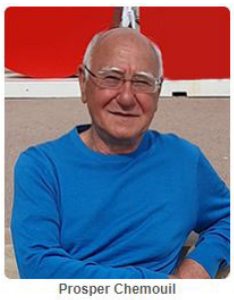

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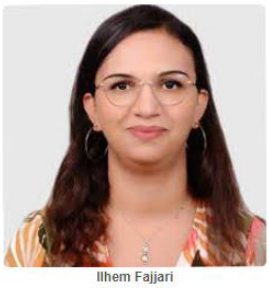

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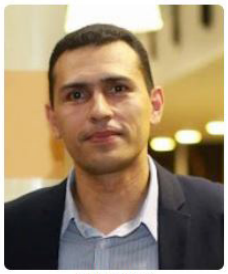

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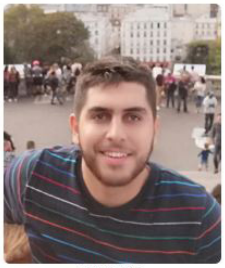

Elia Kallas
(DNAC, France)

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ICIN 2024 Venue

ICIN 2024 will be taking place at Orange Gardens, the recent Research and Innovation Campus of the Orange Group.

Orange Gardens
44 avenue de la République
92320, Châtillon

About 2 miles away south from Paris, Châtillon is a small town which can be easily reached by metro and bus.
See the map hereafter to locate Orange Gardens in Paris and Châtillon area.

Welcome to Orange Gardens

44, Avenue de la République - 92320 Châtillon

Arriving by public transport

Visitor entrance: 44, Avenue de la République

From Central Paris: Métro Line 13 + Orange Gardens shuttles

Two electric shuttles serve the main Orange Gardens entrance in the morning and at the end of the day. One serves the Châtillon Centre T6 tram stop, the other one starts at the crossroad Rue André Gide / Avenue de la République, 50 meters from the Métro Line 13 terminus.

Shuttle times:
- Tram circuit, from 8 am to 9:45 am, and 5:15 pm to 7:15 pm
- Métro circuit, from 8 am to 9:55 am, and 5:15 pm to 7:15 pm

Three bus routes serve Orange Gardens from the Métro Line 13 terminus: the 388, 294, and 195.

Arriving by car

Visitor car park entrance: 71, Boulevard de la Liberté

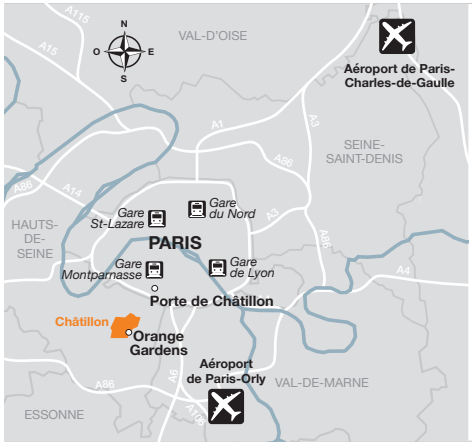
To access the visitor car park, you need to show ID, and give the name of the person you have come to see or the event you will be taking part in.

- Allocated visitor spaces are at the far end of Level -1, by the lifts.

160 allocated electric vehicle spaces.

3% of spaces are reserved for visitors with disabilities

GPS Coordinates:
Longitude: 2.292701 / **Latitude:** 8-48.801601



Getting to Orange Gardens

From Paris-CDG airport

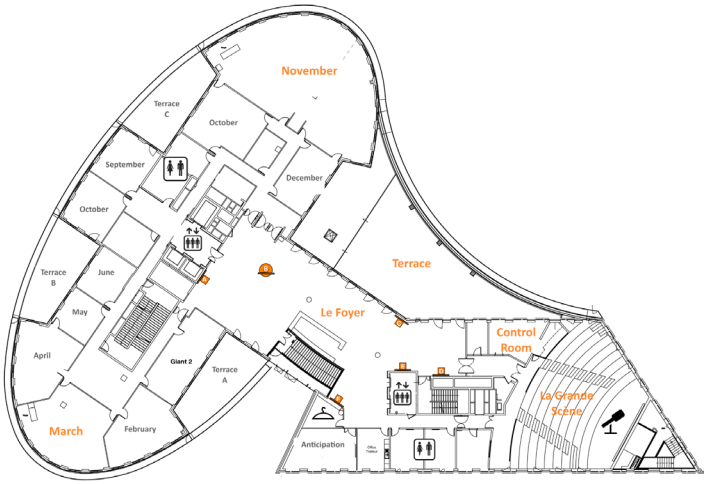
- RER Line B to Arcueil-Cachan, then Bus 162 (approx. 1h20)
- By car via A1 and Périphérique to Porte de Châtillon (approx: 1hr)

From Orly airport

- Orlybus or Orlyval + RER Line B to Bourg-la-Reine + Bus 388 (approx: 1hr)
- By car via A106 and D906 towards Avenue de la République, Châtillon (approx. 25 mins)

From Châtelet

- Métro Line 4 + Line 13 + shuttle (approx. 40 mins)
- By car via Rue Saint-Jacques to traffic circle on Avenue Jean Moulin, then D906 towards Avenue de la République, Châtillon (approx. 40 mins)



Plan du 11 septembre 2017

Orange Gardens Site Map

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