A Publish/Subscribe QoS-aware Framework for Massive IoT Traffic Orchestration

ILLUSTRATED TECHNICAL PAPER

Pedro F. Moraes, Rafael F. Reale and Joberto S. B. Martins

Abstract

This "**ILLUSTRATED TECHNICAL PAPER**" presents the presentation slides of the paper "A Publish/Subscribe QoS-aware Framework for Massive IoT Traffic Orchestration".

The talk was presented at **6th International Workshop on ADVANCEs in ICT Infrastructures and Services - ADVANCE 2018**, 11 - 12 January 2018 at Santiago, Chile.

The "illustrated technical paper format" is used with slides, complementary text and bibliographic references to subsidize and enrich paper contents lecture.

Index Terms

Internet of Things (IoT), IoT Framework, Resource Allocation, Publish/Subscribe, Information-Centric Network (ICN), Quality of Service (QoS), Bandwidth Allocation Model (BAM), Edge Computing.

✦

1 PAPER ABSTRACT

INternet of Things (IoT) application deployment requires the allocation of resources such as virtual machines, storage, and network elements that must be deployed over distinct infrastructures such as cloud computing, Cloud of Things (CoT), datacenters and backbone networks. For massive IoT data acquisition, a gateway-based data aggregation approach is commonly used featuring sensor/ actuator seamless access and providing cache/ buffering and preprocessing functionality. In this perspective , gateways acting as producers need to allocate network resources to send IoT data to consumers. In this paper, it is proposed a Publish/-Subscribe (PubSub) quality of service (QoS) aware framework (PSIoT-Orch) that orchestrates IoT traffic and allocates network resources between aggregates and consumers for massive IoT traffic. PSIoT-Orch schedules IoT data flows based on its configured QoS requirements. Additionally , the framework allocates network resources (LSP/ bandwidth) over a controlled backbone network with limited and constrained resources between IoT data users and consumers. Network resources are allocated using a Bandwidth Allocation Model (BAM) to achieve efficient network resource allocation for scheduled IoT data streams. PSIoT-Orch adopts an ICN (Information-Centric Network) PubSub architecture approach to handle IoT data transfers requests among framework components. The proposed framework aims at gathering the inherent advantages of an ICN-centric approach using a PubSub message scheme while allocating resources efficiently keeping QoS awareness and handling restricted network resources (bandwidth) for massive IoT traffic.

- *Prof. Dr. Martins, Joberto S. B. is with Salvador University - UNIFACS, Brazil.*
- *Invited Professor at HTW - Hochschule für Techknik und Wirtschaft des Saarlandes, Saarbrucken - Germany.*
  E-mail: joberto.martins@gmail.com

2 PAPER REFERENCES

Paper references are:

[1] E. E. Rachikidi. Modeling and placement optimization of compound service in a converged infrastructure of cloud computing and internet of things. Université Paris-Saclay, Evry, 2017.

[2] Eleonora Borgia. The internet of things vision: Key features, applications and open issues. Computer Communications, 54:1-31, 2014.

[3] Ling Qian, Zhiguo Luo, Yujian Du, and Leitao Guo. Cloud computing: An overview. Lecture Notes in Computer Science, pages 626-631, 2009.

[4] Ivan Stojmenovic and Sheng Wen. The fog computing paradigm: Scenarios and security issues. Proceedings of the 2014 Federated Conference on Computer Science and Information Systems, 2014.

[5] ETSI TS 102 921 v1.1.1. Machine-to-machine communications (M2M); mia, dia and mid interfaces, 2012.

[6] Glenn Daneels, Esteban Municio, Kathleen Spaey, Gilles Vandewiele, Alexander Dejonghe, Femke Ongenae, Steven Latr, and Jeroen Famaey. Real-time data dissemination and analytics platform for challenging iot environments. presented at the Global Information Infrastructure and Networking Symposium (GIIS), 10 2017.

[7] Rafael Freitas Reale, Romildo Martins da S. Bezerra, and Joberto S. B. Martins. GBAM: A Generalized Bandwidth Allocation Model for IP/MPLS/DS-TE Networks. International Journal of Computer Information Systems and Industrial Management Applications (IJCISIM), 6:635-643, 2014.

[8] Sasu Tarkoma. Publish/subscribe systems: design and principles. John Wiley Sons, 2012.

[9] Emmanuel Baccelli, Christian Mehlis, Oliver Hahm, Thomas C. Schmidt, and Matthias Whlisch. Information centric networking in the iot. Proceedings of the 1st international conference on Information-Centric networking - INC '14, 2014.

[10] Hong-Linh Truong and Nanjangud Narendra. SINC - an information-centric ap- proach for end-to-end iot cloud resource provisioning. 2016 International Confer- ence on Cloud Computing Research and Innovations (ICCCRI), 2016.

[11] Kyoungho An, Aniruddha Gokhale, Sumant Tambe, and Takayuki Kuroda. Wide area network-scale discovery and data dissemination in data-centric publish/subscribe systems. In Proceedings of the Posters and Demos Session of the 16th International Middleware Conference, page 6. ACM, 2015.

[12] Andrew Banks and Rahul Gupta. MQTT Version 3.1. 1. OASIS standard 29, 2014.

[13] Rafael Freitas Reale, Romildo Martins da S. Bezerra, and Joberto S. B. Martins. A Preliminary Evaluation of Bandwidth Allocation Model Dynamic Switching. International Journal of Computer Networks Communications (IJCNC), 6(3):131-143, May 2014.

[14] Rafael Freitas Reale, Romildo Martins da S. Bezerra, and Joberto S. B. Martins. Analysis of bandwidth allocation models reconfiguration impacts. In 3rd International Workshop on ICT Infrastructures and Services (ADVANCE), December 2014.

[15] Rafael Freitas Reale, Walter d. Costa Pinto Neto, and Joberto S. B. Martins. AllocTC-Sharing: A New Bandwidth Allocation Model for DS-TE Networks. In 7th Latin American Network Operations and Management Symposium - LANOMS, pages 1-4, Oct 2011.

[16] Bob Lantz, Nikhil Handigol, Brandon Heller, and Vimal Jeyakumar. Introduction to mininet, 2017.

3 PAPER SLIDES

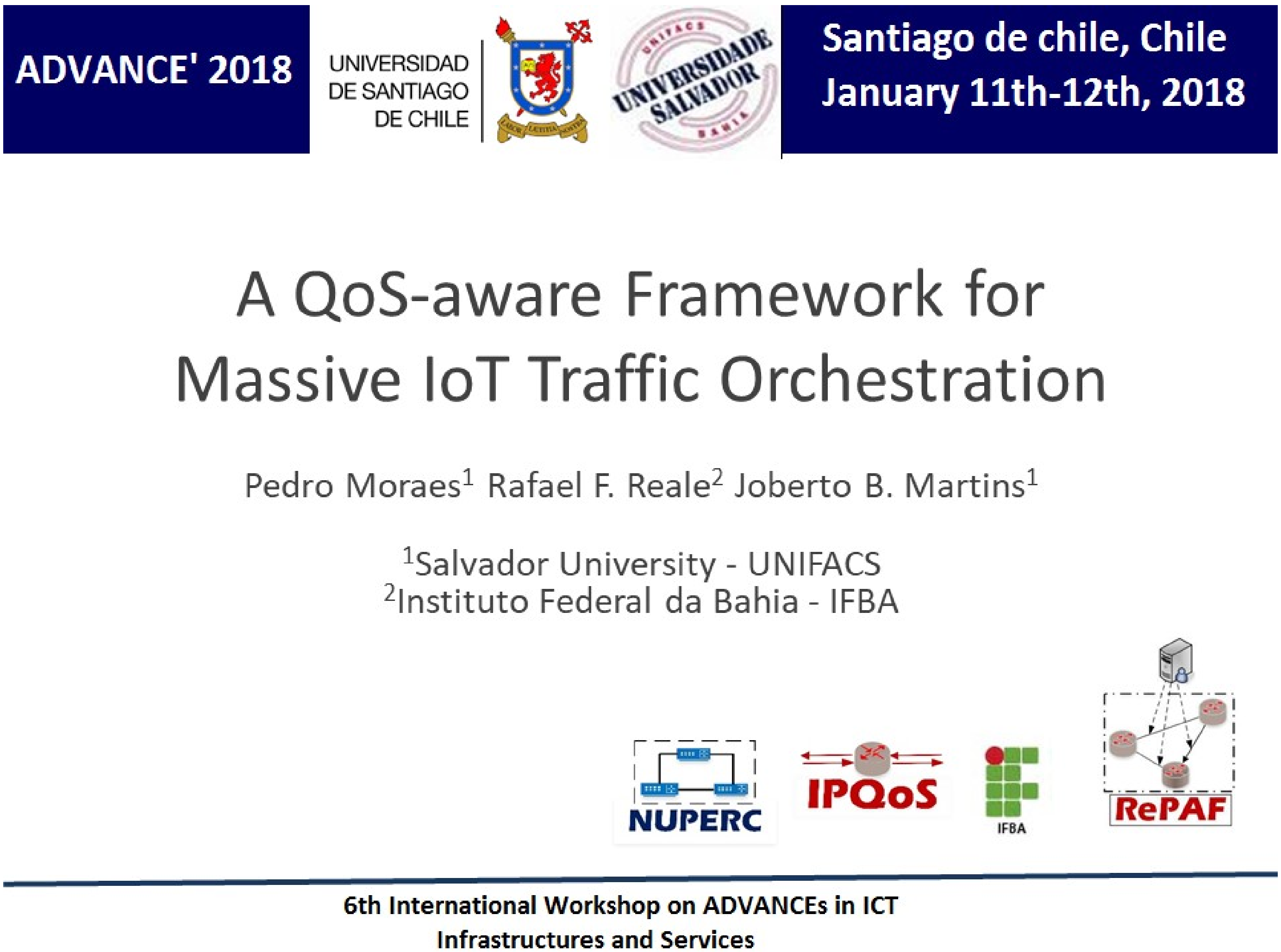


Fig. 1.

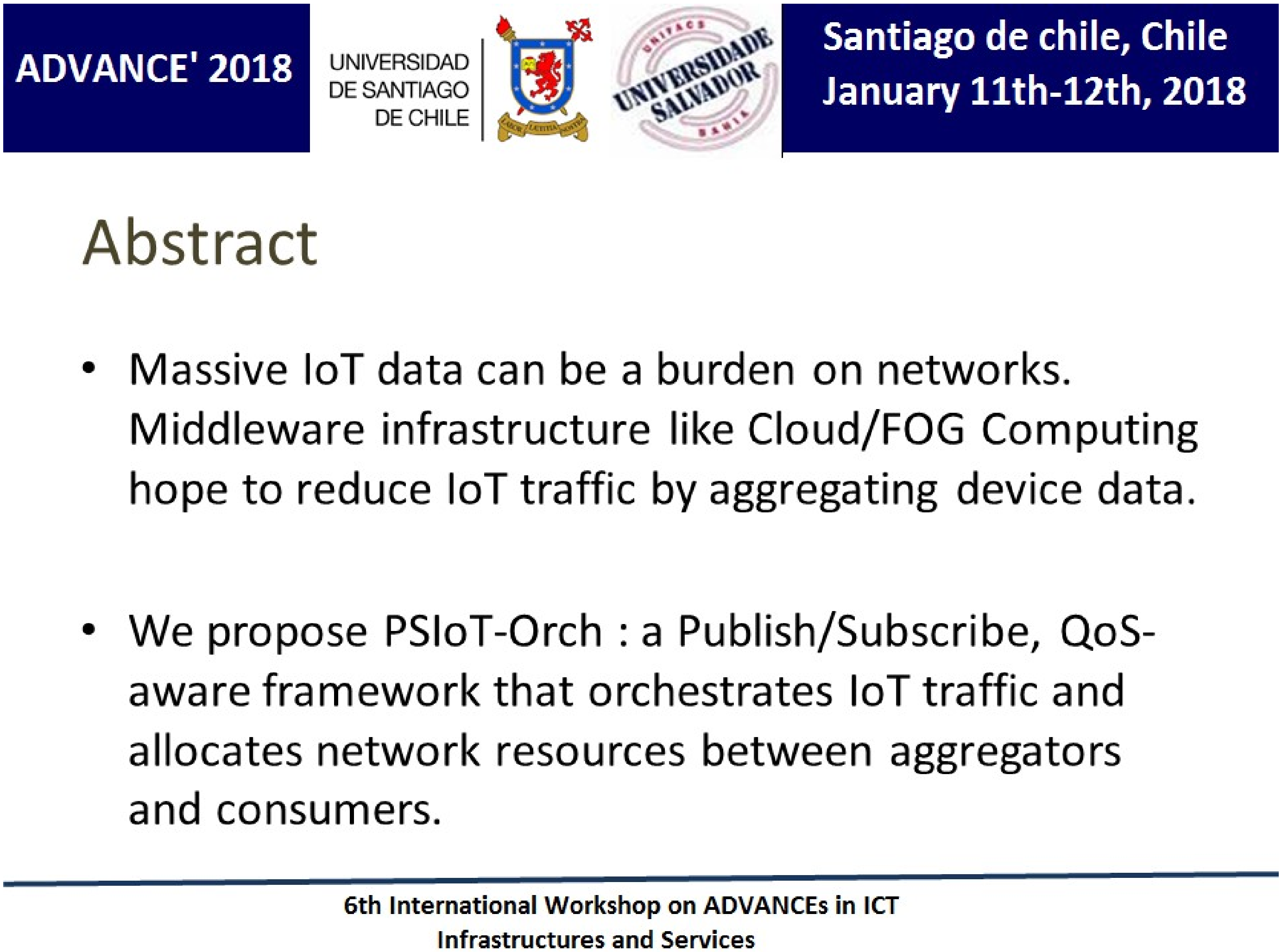


Fig. 2.

−− > **PAPER TEXT EXTRACT**:
"The Internet of Things (IoT) is considered an important trend in many areas like smart cities, smart grid, e-health, industry and future Internet [1] [2]. As such, a large effort is being undertaken to find suitable technologies, standards, middlewares and architectures to support IoT application deployment. IoT deployment typically requires the orchestration of heterogeneous resources that are allocated over distinct infrastructures such as cloud computing, cloud of things (CoT), datacenters and backbone networks [1]."

"Paradigms such as Cloud Computing [3], and more recently Fog Computing [4], arise to alleviate the weight that massive IoT data processing and traffic has on networks and devices. In particular Fog Computing relies on mostly operating on the edges of the network, to minimize the load on the whole network by serving already processed and aggregated data. However, traffic still might need to be sent across the network to interested clients, and as the amount of IoT devices increases and spreads geographically, processed IoT traffic served by IoT/ Fog-like aggregators along the edges might still heavily load the network if no specific traffic management is done."

"In an attempt to address this scenario, we present a Pub/ Sub QoS-aware framework (PSIoT-Orch) for managing massive IoT traffic aggregated into Fog-like IoT gateways along the network edge. This framework allows for IoT quality of service traffic management according to network-wide specifications, application domain and IoT characteristics. Aspects like the backbone network topology, network traffic saturation and IoT domain requirements are considered."

$-- >$ Paper to read: [17]

$-- >$ Complementary papers:[1] [2] [3] [4]

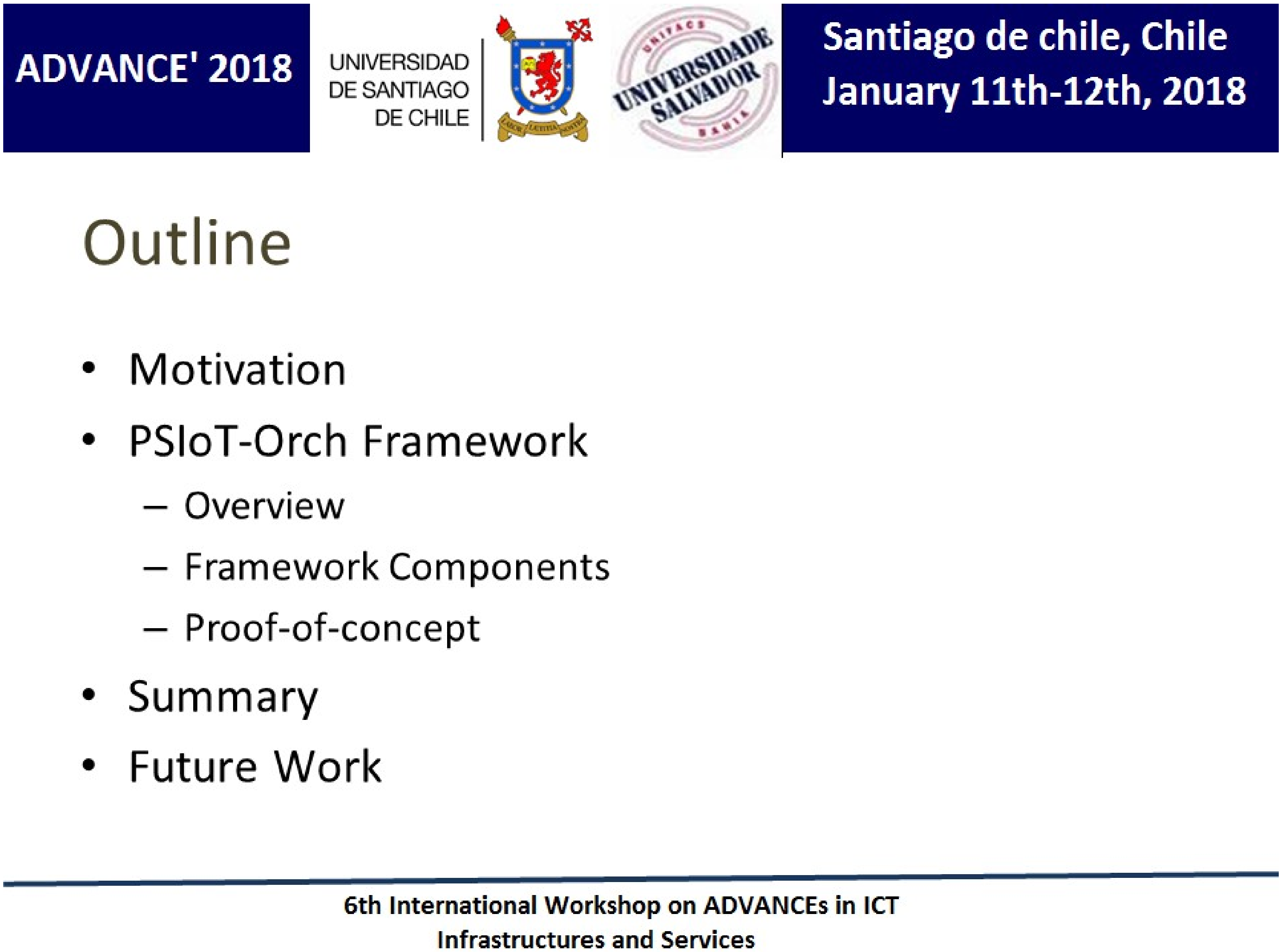

ADVANCE' 2018
UNIVERSIDAD DE SANTIAGO DE CHILE
UNIVERSIDADE SALVADOR
Santiago de chile, Chile
January 11th-12th, 2018
Outline
• Motivation
• PSIoT-Orch Framework
– Overview
– Framework Components
– Proof-of-concept
• Summary
• Future Work
6th International Workshop on ADVANCEs in ICT
Infrastructures and Services

Fig. 3.

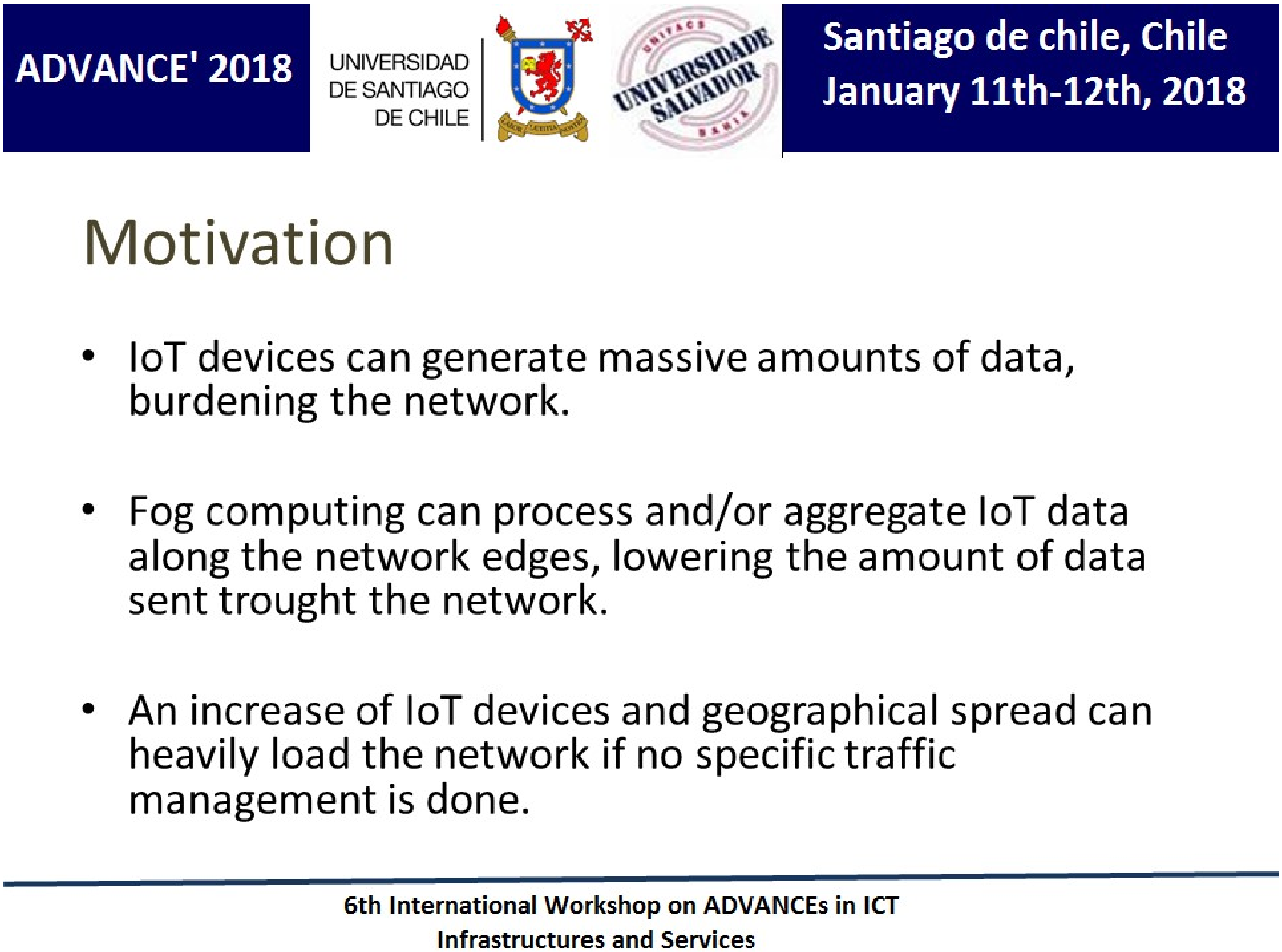


Fig. 4.

−− > **PAPER TEXT EXTRACT**:
"IoT has potential for the creation of new intelligent applications in nearly every field, with it's devices that enable local or mobile sensing and actuation services."

"The different felds of application can be organized in different ways into various domains like industrial, smart city and health among others. For every standardized or practical field, IoT devices share common features and requirements in traffic and usage. Our framework builds on dealing with distinct IoT requirements, namely heterogeneity, scalability and QoS."

−− > Papers to read:
−− > Complementary papers: [2]

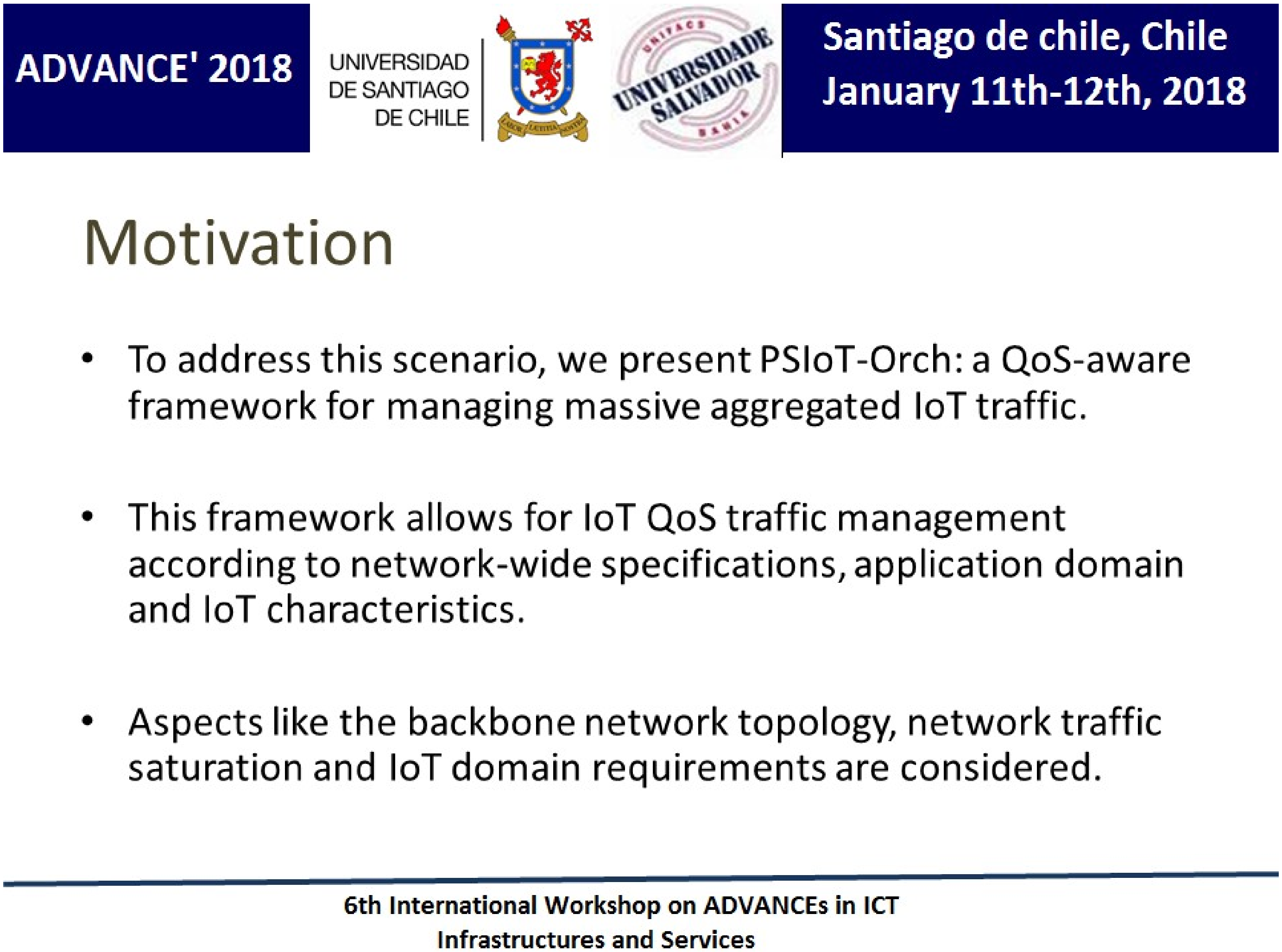


Fig. 5.

−− > **PAPER TEXT EXTRACT**:
"While IoT devices, traffic characteristics and requirements are quite well defined, architectures for IoT generally have a hard time maintaining interoperability with each other. In 2009 the ETSI Technical Committee for Machine-to-Machine communications (ETSI TC M2M) was established to develop a reference IP-based architecture relying on existing technologies [5]. This architecture has three domains: a) the Application Domain, where client and M2M applications reside; b) the Network Domain, consisting of any network between applications and device gateways; c) the Device Gateway domain, where all the devices and/or gateways are located. Our framework fits well in".

−− > Papers to read:
−− > Complementary papers: [5]

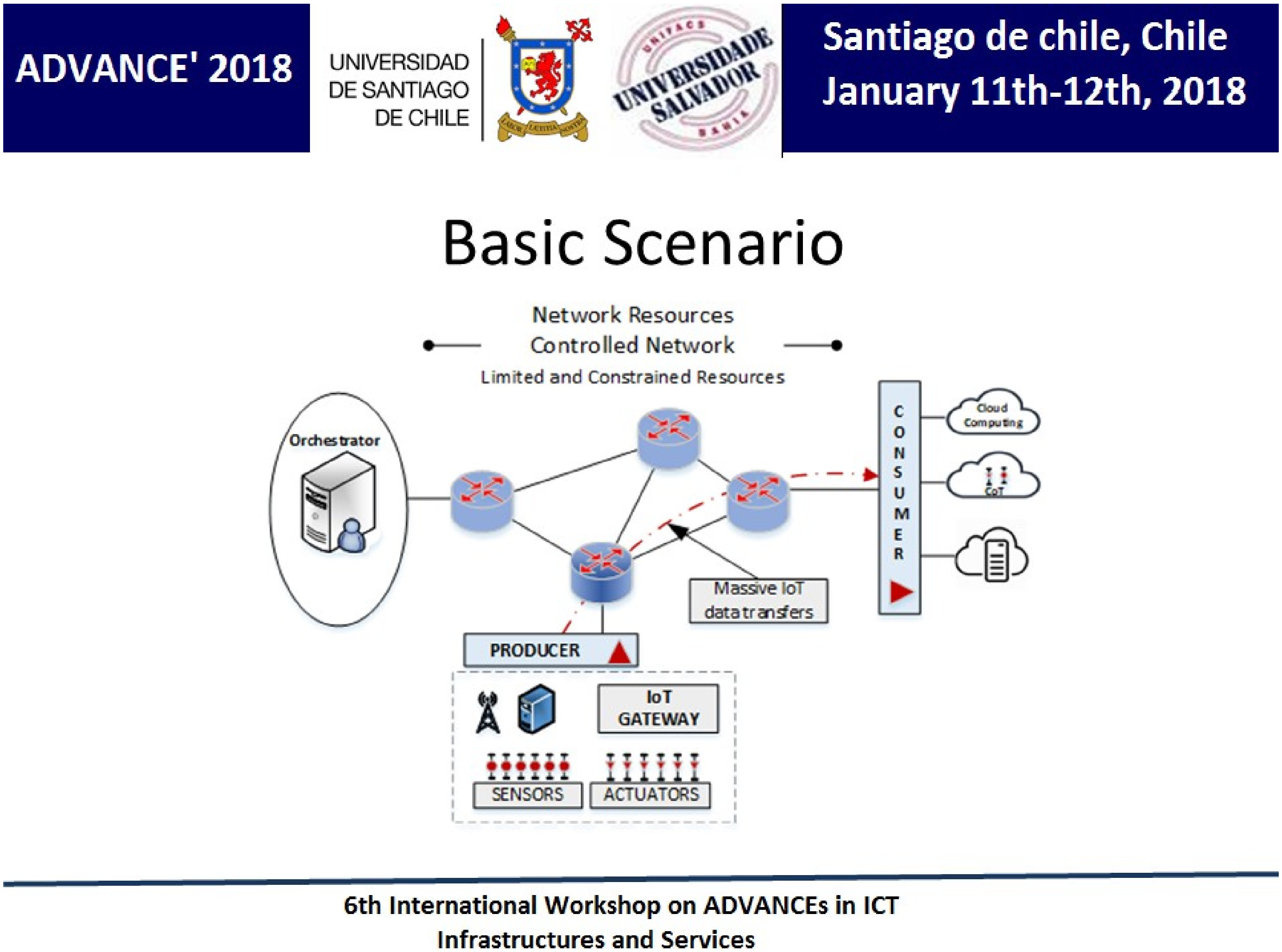


Fig. 6.

−− > **PAPER TEXT EXTRACT**:

"The overall goal of the proposed PSIoT-Orch framework is to manage the massive traffic generated by a huge number of IoT devices, aiming to handle efficiently network resources and IoT QoS requirements over the network between the IoT devices and consumer IoT applications. Consumers might be hosts over the backbone network, cloud computing infrastructures accessed by the network or any other scheme that makes use of the managed network infrastructure for communication (Figure 6)."

"IoT gateways (IoTGW-Ag) act as traffic aggregators interacting with IoT devices. IoT gateway traffic aggregators use a PubSub style architecture lined along the network edge to transmit their data to application clients (consumers), with these transmissions being mediated by a centralized orchestrator (PSIoT-Orchestrator) (Figure 6)."

−− > Papers to read:

−− > Complementary paper:

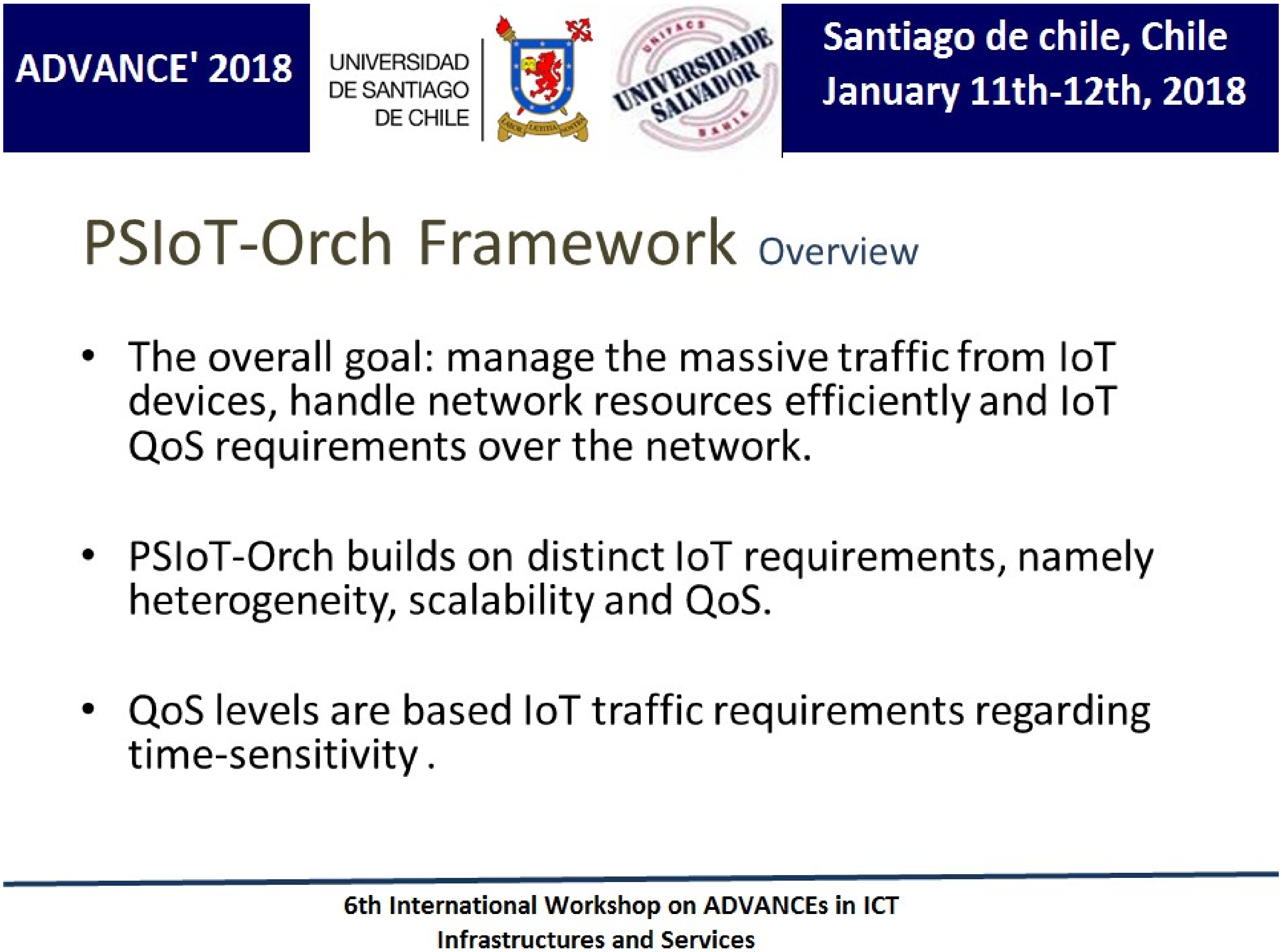


Fig. 7.

- **PAPER TEXT EXTRACT**:
  "The PSIoT-Orch framework offers a set of QoS levels based on time-sensitivity to deal with IoT traffic requirements regarding time-sensitivity for massive data transmission"

  "i) Insensitive: best-effort transmission (e.g., weather data, non-critical smart home data). ii) Sensitive: low data transmission delay (e.g., commercial data, security sensors). iii) Priority: high transmission rate and low delay (e.g., health care, critical industrial sensors)."

−− > Papers to read:

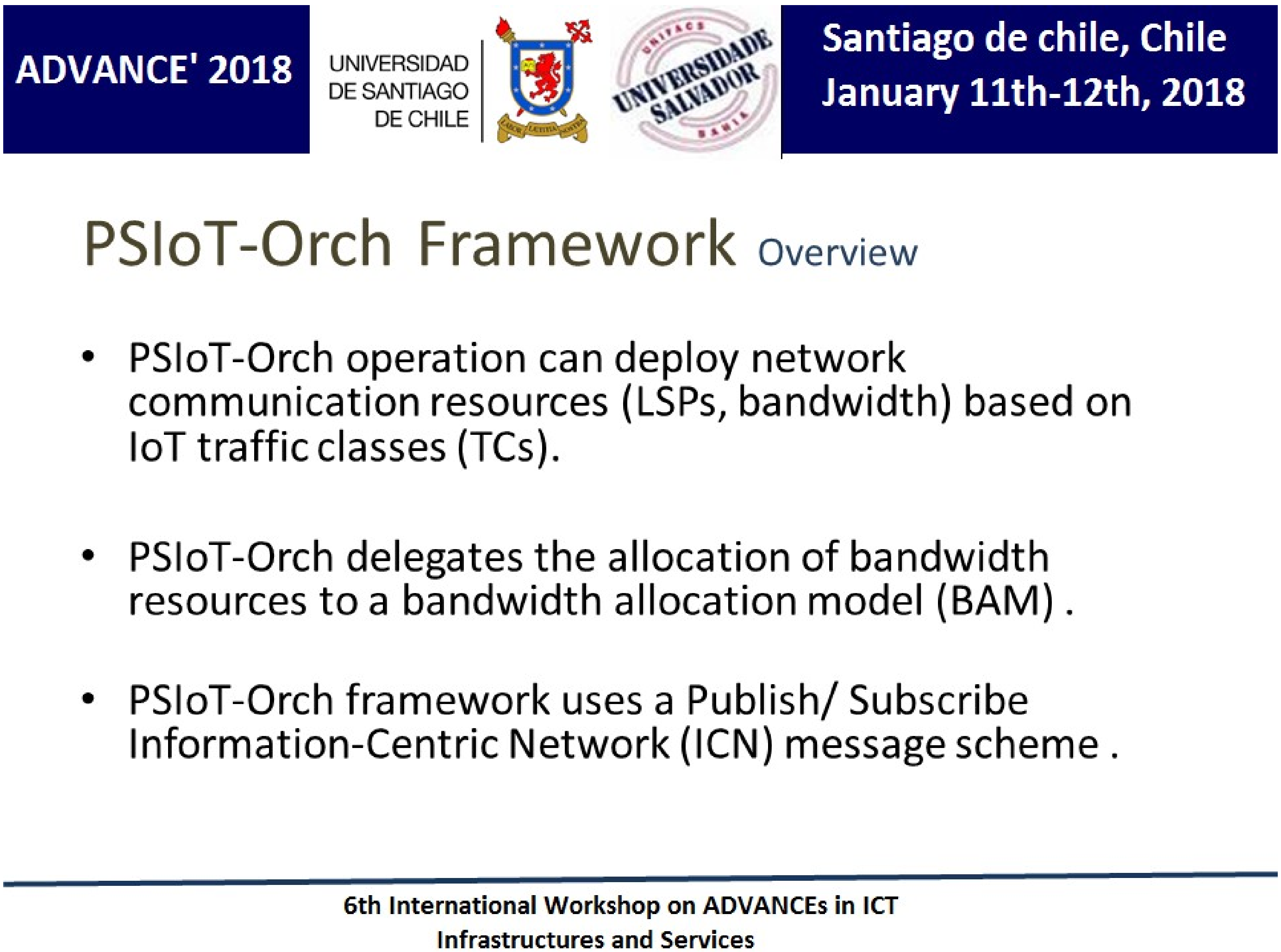


Fig. 8.

−− > **PAPER TEXT EXTRACT**:
"The PSIoT-Orch QoS levels are intended to allow the creation of IoT traffic classes (TCs) over the backbone. These time-sensitivity classes group IoT traffic having similar application requirements and allows a QoS-aware arbitration of IoT massive data ows over the backbone network. The traffic scheduling is done for these defined classes and will require the allocation of network resources."

"As indicated, subsequently and independently, PSIoT-Orch operation will deploy network communication resources (LSPs, bandwidth) based on IoT traffic classes (TCs). As such, application's IoT data ows are simultaneously prioritized by the QoS scheduler and communication resources are efficiently allocated over the network using a bandwidth allocation model based strategy (BAM-based)."

"PSIoT-Orch framework uses a Publish/ Subscribe (PubSub) Information-Centric Network (ICN) message scheme in which an information-based access model is used. As such, consumers try to access named content (IoT data) without any direct mapping to the transport mechanism used over the network that interconnect them with data producers."

−− > Papers to read: [7]

−− > Complementary papers: [8]

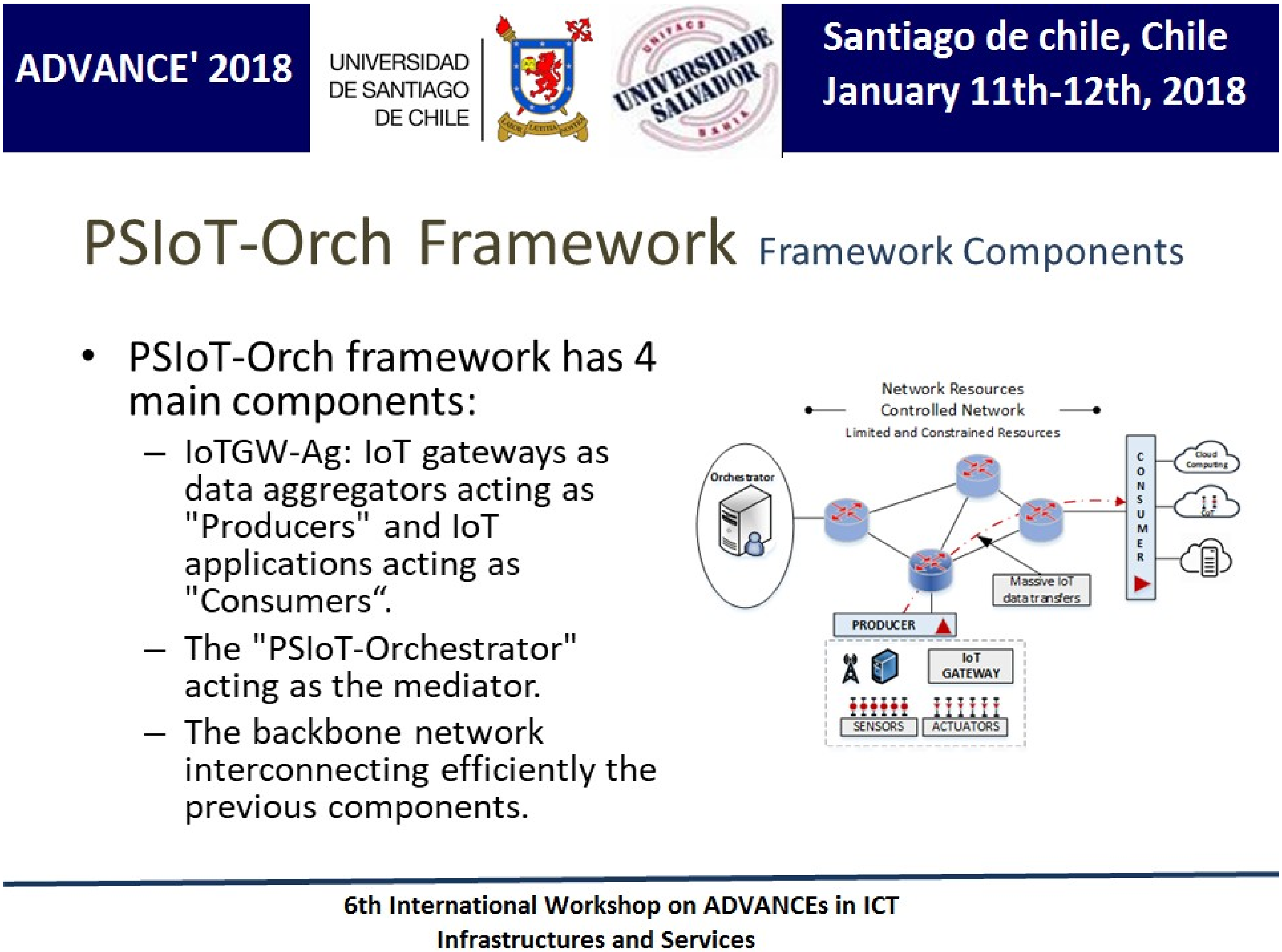


Fig. 9.

−− > **PAPER TEXT EXTRACT**:
"PSIoT-Orch framework has 4 main components that interact to provide network resource allocation with quality of service awareness (Figure 9): i) IoT gateways data aggregators (IoTGW-Ag) acting as "Producers"; ii) IoT applications acting as "Consumers"; iii) The "PSIoT-Orchestrator" acting as the mediator; and iv) The backbone network interconnecting efficiently the previous components."

−− > Papers to read:
−− > Complementary papers:

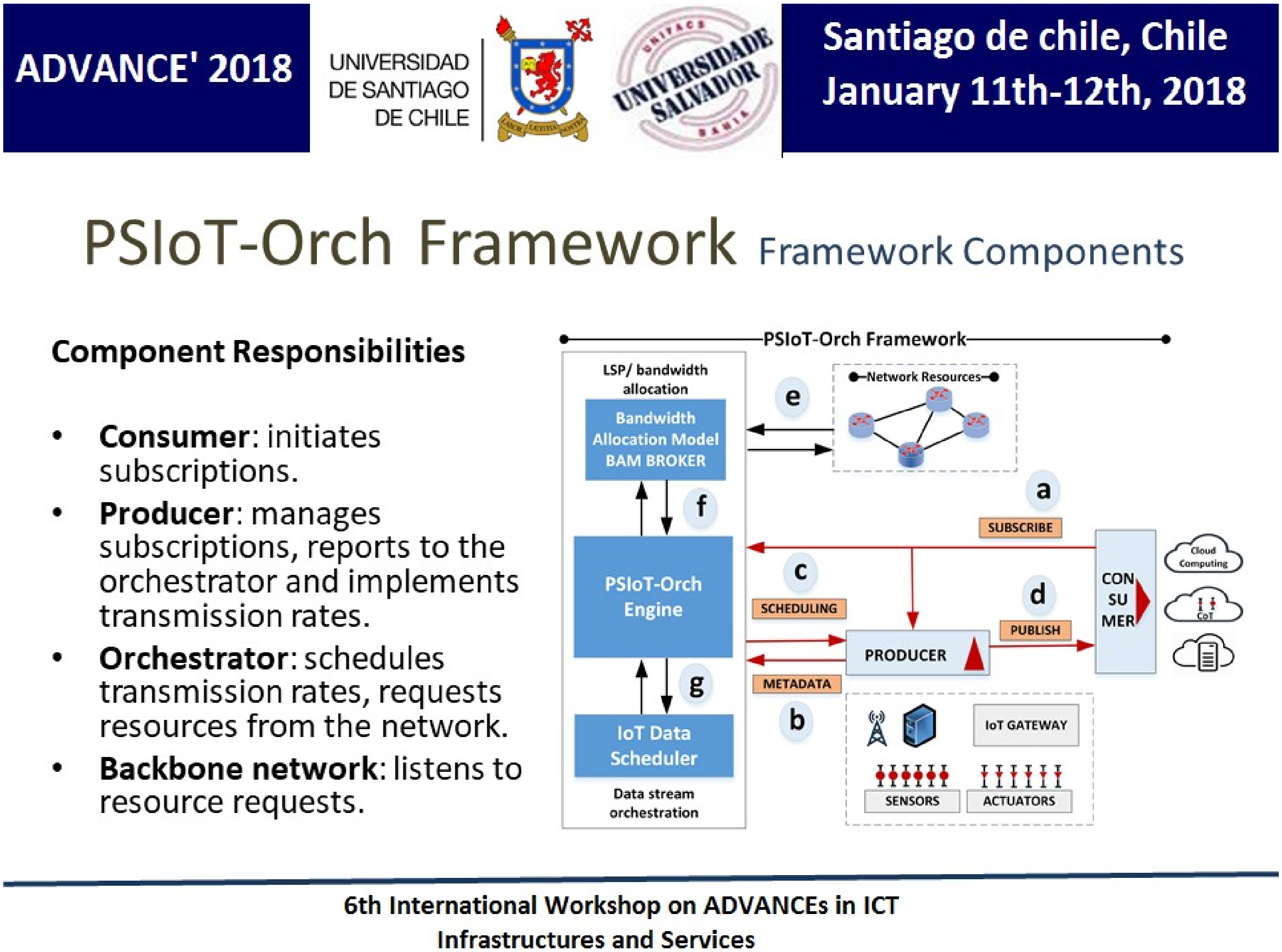


Fig. 10.

−− > **PAPER TEXT EXTRACT**:
"The PSIoT-Orch framework functional operation is composed by 2 distinct and cooperating functional entities: i) The PubSub message scheme allowing the asynchronous request of IoT data over the entire infrastructure; and ii) The quality of service (QoS) and network resource allocation police and implementation scheme provided by the "PSIoT-Orchestrator."

"The PSIoT-Orch frameworks main role is to manage and monitor the traffic output from each IoT aggregator according to the overall aggregators throughput and the underlying network resource availability and usage (saturation)."

"In PSIoT-Orch, each IoT aggregator works in a similar paradigm to Fog Computing. Each aggregator node is lined up along the network edge collecting IoT traffic from local devices and offering them to applications via a topic-based PubSub interface. While PSIoT-Orch framework only manage traffic aggregation, it can also be further extended to perform Fog-like capabilities such as IoT raw data processing and manipulation."

−− > Papers to read:

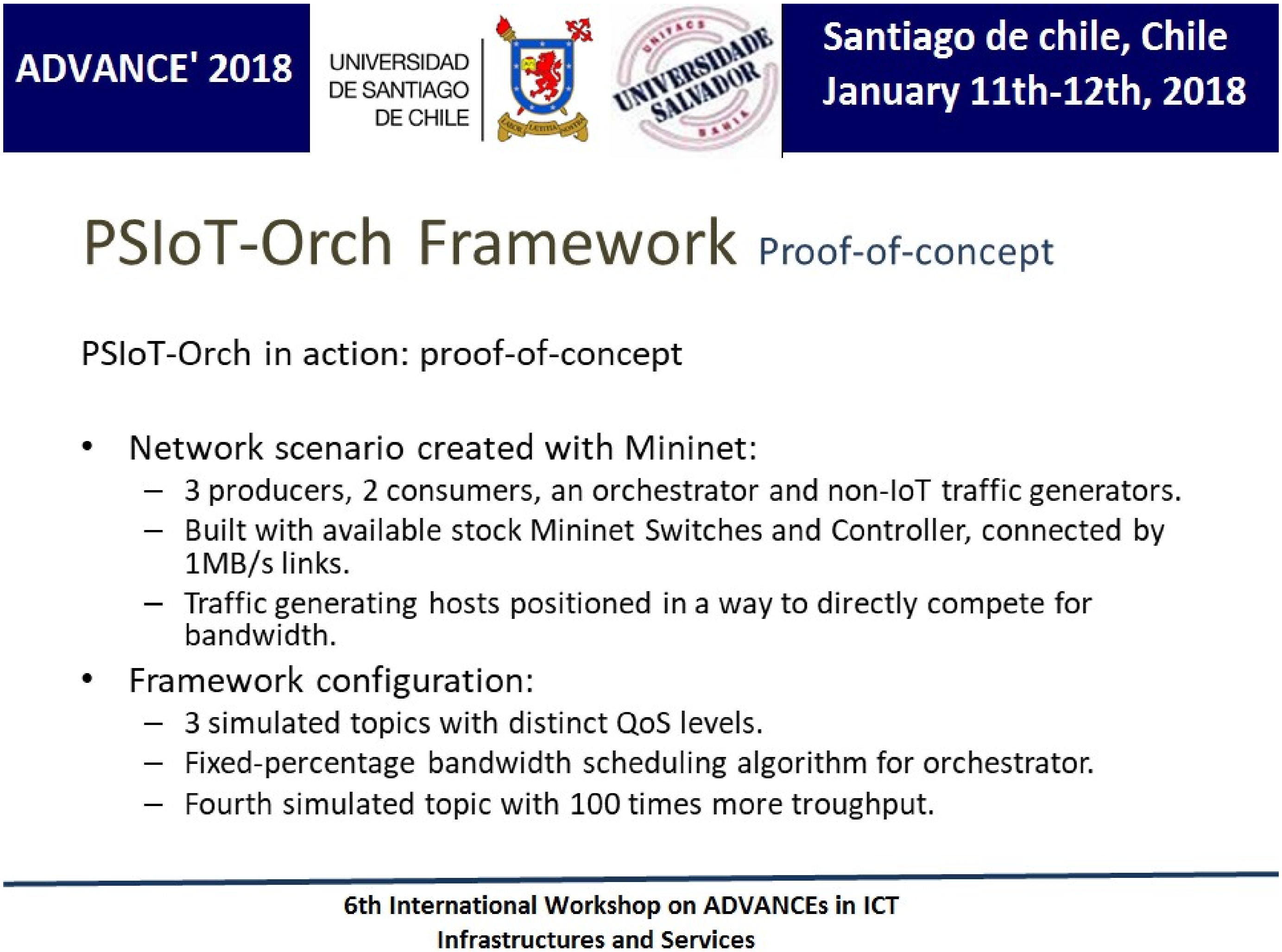


Fig. 11.

−− > **PAPER TEXT EXTRACT**:
"As a proof-of-concept we have developed the three core components of our proposed framework: an orchestrator, an aggregator (producer) and a client (consumer)."
"We have chosen the network emulator Mininet [16] for its SDN capabilities and exibility in creating network topologies. Mininet is a network emulator that uses lightweight virtualization to run many different network components in a single system. With Mininet we built a simple bandwidth-constrained network with consumers, aggregators, an orchestrator and two hosts to generate network traffic to simulate non-IoT network traffic."

The orchestrator is implemented in a multi-purpose messaging platform, with capabilities similar to PubSub systems. Each aggregator (producer) then connects itself to the orchestrator and receives the designated efforts for each QoS level."

"A simple fixed scheduler was used to determine each QoS level for all aggregators (producers). The transmission rates for each QoS level are static and proportionally divided between QoS levels, according to importance. These QoS levels are specific to our producer software and deal directly with each aggregators IoT traffic throughput."

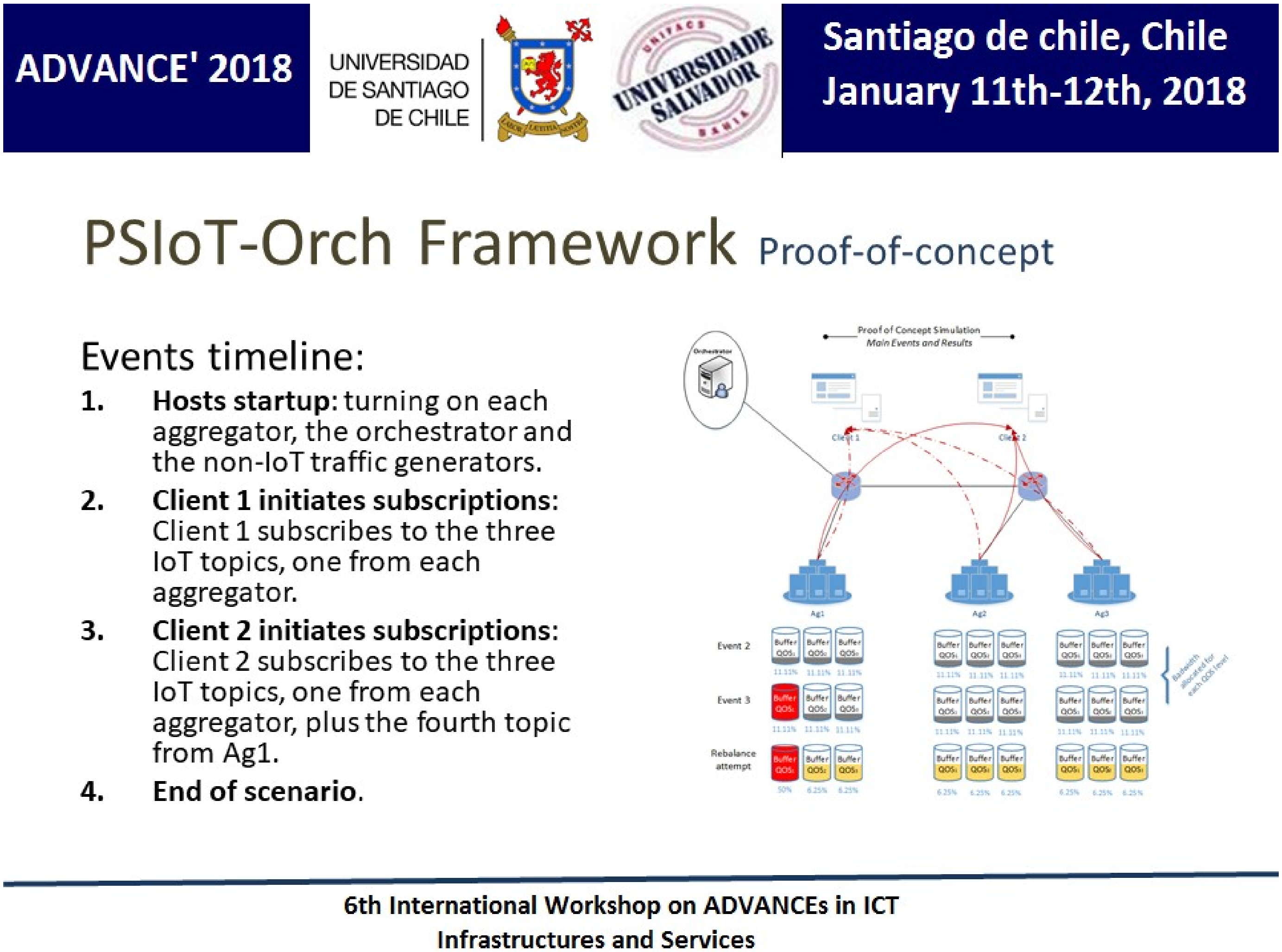


Fig. 12.

−− > **PAPER TEXT EXTRACT**:

"After running the scenario, we were able to observe the communication between consumers and producers as well as the management of each aggregator by the orchestrator. After each subscription, the aggregators would report them to the orchestrator, and continue to report their buffer state for each QoS level. Figure 12 shows the buffer states for the aggregators as well as the allocated bandwidth by the orchestrator for each QoS level, according to each of the main events. After the first subscription event, by Client 1, the buffers where constantly at near-empty levels, as the throughput was low enough that the default allocation from the orchestrator was enough. But as soon as Client 2 initiates its subscription, along with the fourth topic in Ag1, the buffer in Ag1 begins to fill rapidly. As soon as the orchestrator detects this, by means of a defined buffer size threshold, it attempts to allocate more bandwidth to Ag1. The orchestrator allocates as much bandwidth that it can without impairing the other subscriptions, but as the data generation rate from Ag1s fourth topic is much larger than the available bandwidth, we still observe Ag1s buffer growing as the orchestrator maintains its attempts to allocate enough bandwidth."

−− > Papers to read:

−− > Complementary papers:

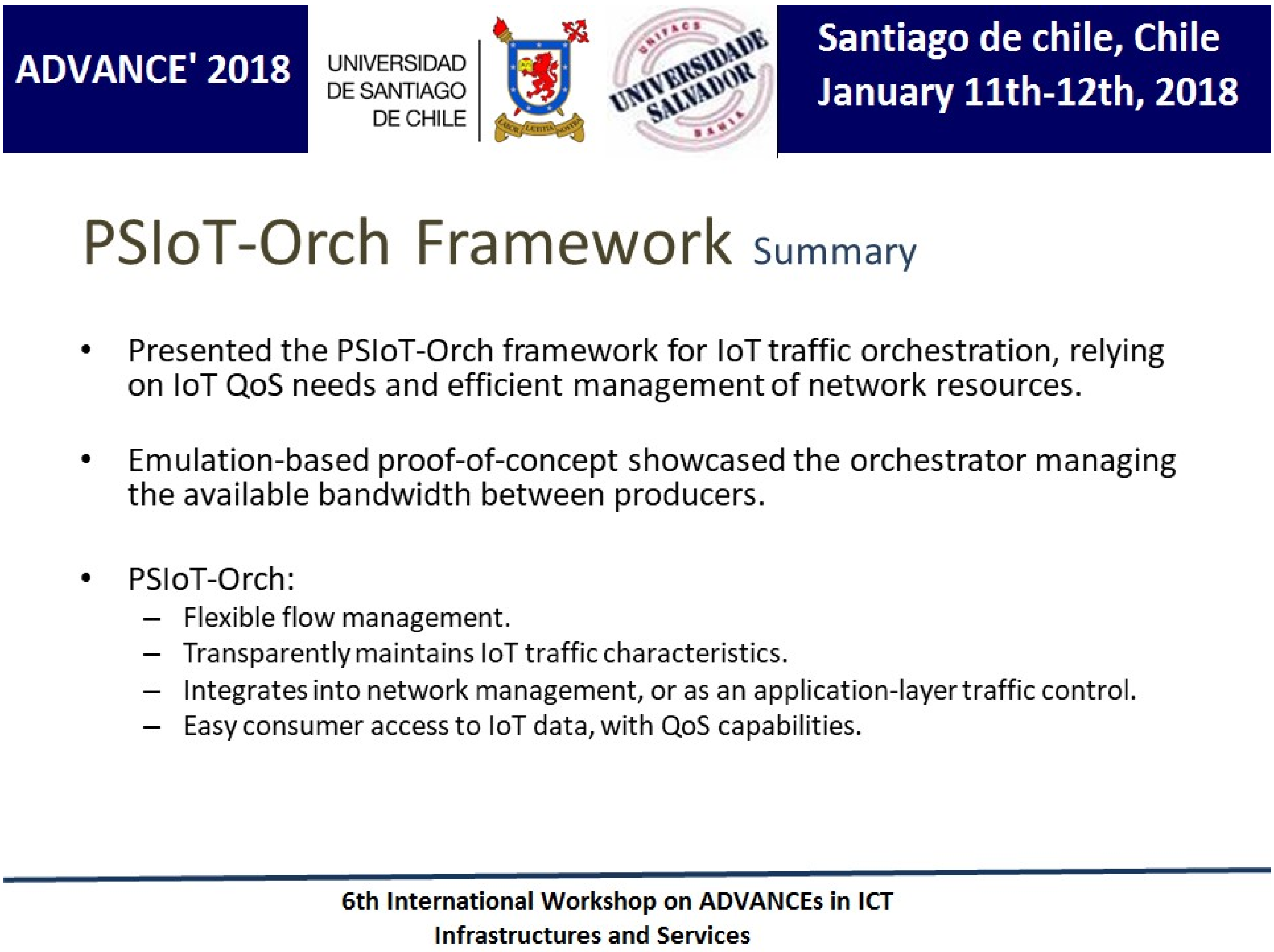


Fig. 13.

−− > **PAPER TEXT EXTRACT**: "The emulation-based proof-of-concept demonstrated the basic functionality and that our framework is a viable solution for managing the transmission of massive IoT traffic, as it predictively manages and distributes the available band- width between producers."

"The framework proved to be flexible as in both network ow management, but also in maintaining the IoT traffic characteristics by transparently offering the same topic-based IoT data from devices to consumers in the network. Furthermore, the ability to have the orchestrator work in tandem with CDN QoS functionalities, allows our framework to be used both integrated to the network, or simply as a 3rd party traffic control between IoT data producers and consumers."

"The user-centric approach adopted by the PubSub message scheme between consumers and producers presents an easy interface for data subscription by hiding the complex QoS considerations and data management from both producers and consumers. This allows for consumers to focus on receiving the data and also enables the producers to deal with their Fog-like data aggregation and/or processing."

−− > Papers to read:

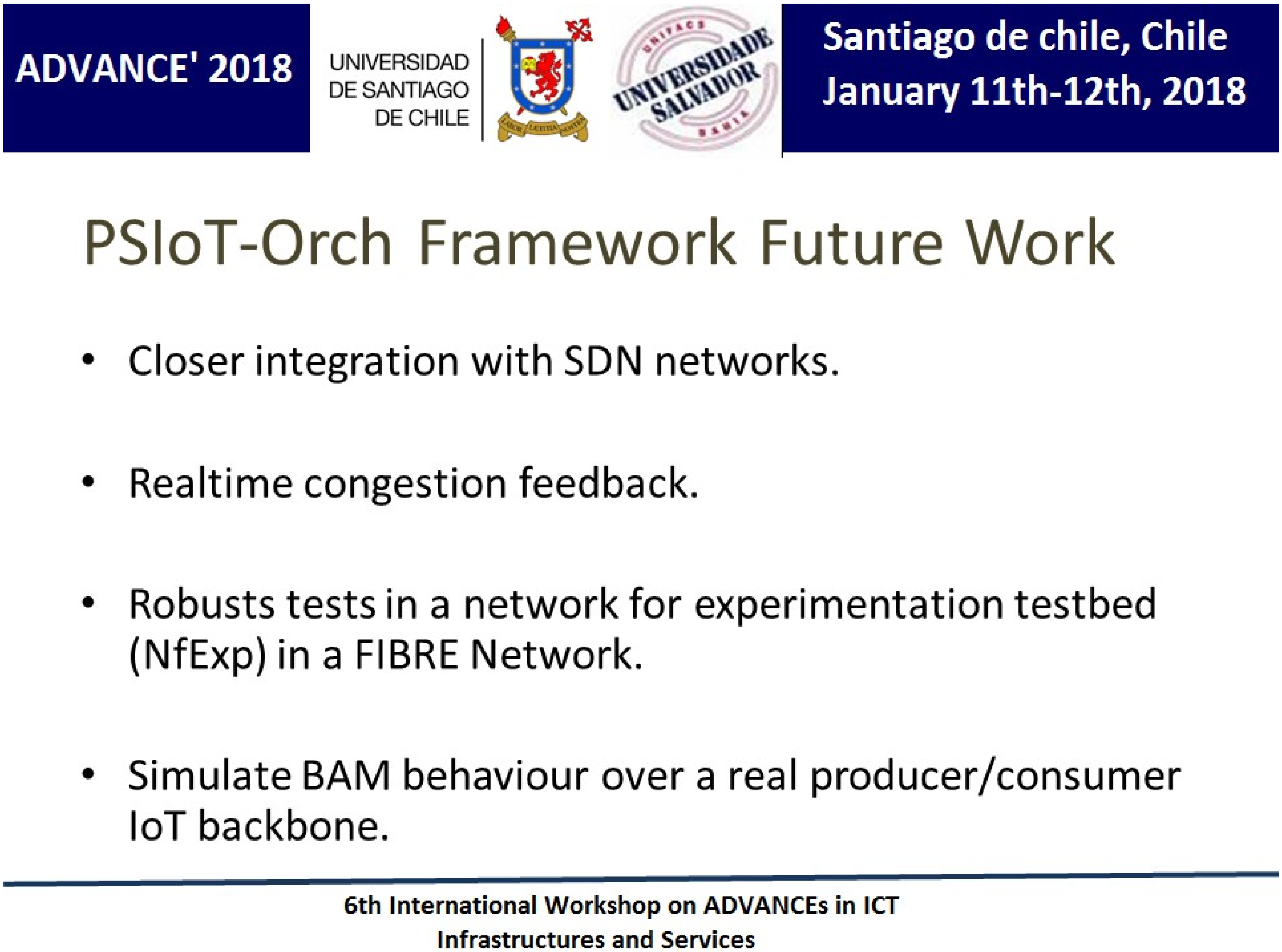

ADVANCE' 2018
UNIVERSIDAD DE SANTIAGO DE CHILE
UNIVERSIDADE SALVADOR
Santiago de chile, Chile
January 11th-12th, 2018
PSIoT-Orch Framework Future Work
• Closer integration with SDN networks.
• Realtime congestion feedback.
• Robusts tests in a network for experimentation testbed (NfExp) in a FIBRE Network.
• Simulate BAM behaviour over a real producer/consumer IoT backbone.
6th International Workshop on ADVANCEs in ICT Infrastructures and Services

Fig. 14.

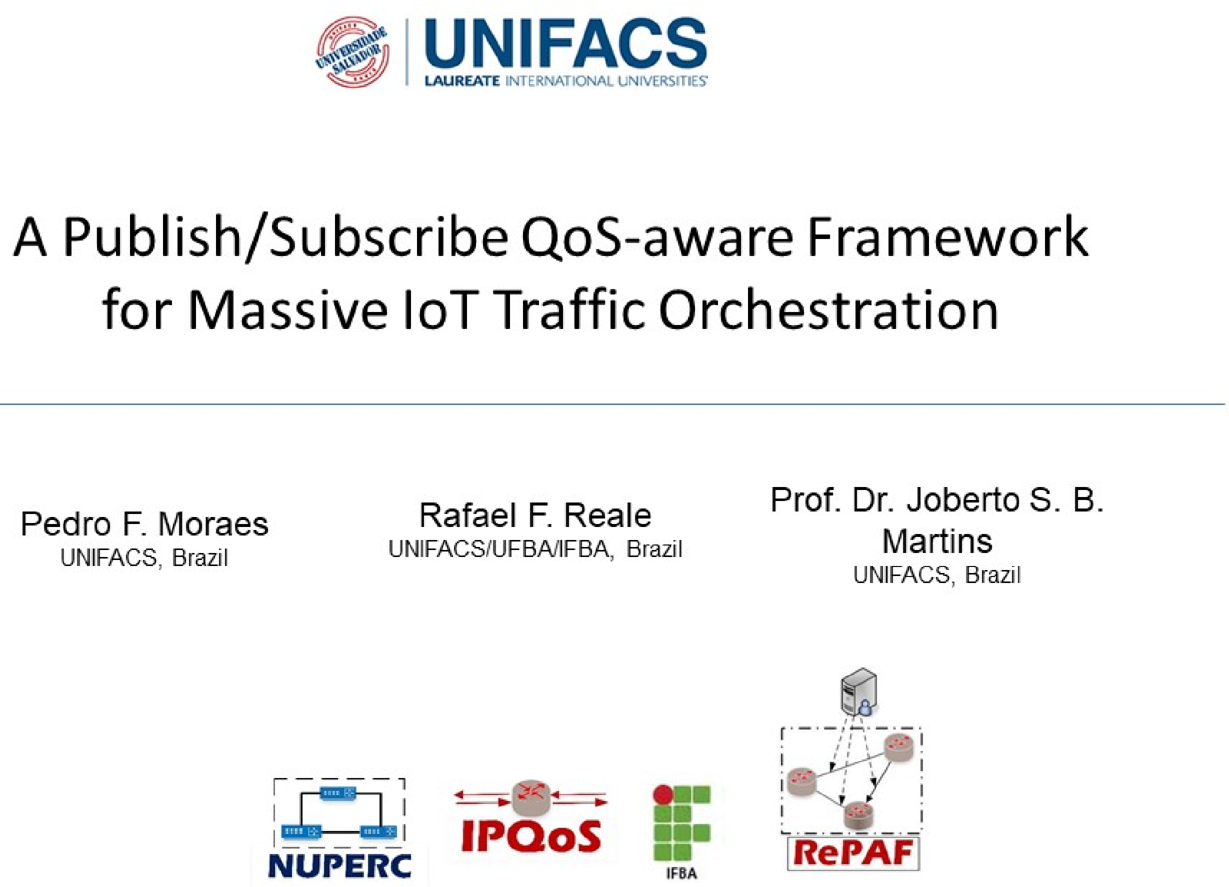
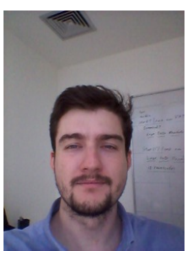

UNIFACS
LAUREATE INTERNATIONAL UNIVERSITIES
A Publish/Subscribe QoS-aware Framework for Massive IoT Traffic Orchestration
Pedro F. Moraes
UNIFACS, Brazil
Rafael F. Reale
UNIFACS/UFBA/IFBA, Brazil
Prof. Dr. Joberto S. B. Martins
UNIFACS, Brazil
NUPERC
IPQoS
IFBA
RePAF

Fig. 15.

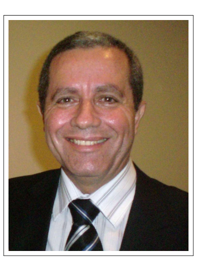
REFERENCES

[1] E. E. Rachikidi. Modeling and placement optimization of compound service in a converged infrastructure of cloud computing and internet of things. Université Paris-Saclay, Evry, 2017.
[2] Eleonora Borgia. The internet of things vision: Key features, applications and open issues. *Computer Communications*, 54:1–31, 2014.
[3] Ling Qian, Zhiguo Luo, Yujian Du, and Leitao Guo. Cloud computing: An overview. *Lecture Notes in Computer Science*, pages 626–631, 2009.
[4] Ivan Stojmenovic and Sheng Wen. The fog computing paradigm: Scenarios and security issues. *Proceedings of the 2014 Federated Conference on Computer Science and Information Systems*, 2014.
[5] ETSI TS 102 921 v1.1.1. Machine-to-machine communications (m2m); mia, dia and mid interfaces, 2012.
[6] G. Daneels, E. Municio, K. Spaey, G. Vandewiele, A. Dejonghe, F. Ongenae, s. Latré, and J. Famaey. Real-time data dissemination and analytics platform for challenging iot environments. GIIS, 10 2017.
[7] Rafael Reale, Romildo Bezerra, and Joberto Martins. G-bam: A generalized bandwidth allocation model for ip/mpls/ds-te networks. *Int. Journal of Computer Information Systems and Industrial Management Applications (IJCISIM)*, 6:635–643, 2014.
[8] Sasu Tarkoma. *Publish/subscribe systems: design and principles*. John Wiley & Sons, 2012.
[9] Emmanuel Baccelli, Christian Mehlis, Oliver Hahm, Thomas C. Schmidt, and Matthias Wählisch. Information centric networking in the iot. *Proceedings of the 1st international conference on Information-centric networking - INC '14*, 2014.
[10] Hong-Linh Truong and Nanjangud Narendra. Sinc - an information-centric approach for end-to-end iot cloud resource provisioning. *2016 International Conference on Cloud Computing Research and Innovations (ICCCRI)*, 2016.
[11] Kyoungho An, Aniruddha Gokhale, Sumant Tambe, and Takayuki Kuroda. Wide area network-scale discovery and data dissemination in data-centric publish/subscribe systems. In *Proceedings of the Posters and Demos Session of the 16th International Middleware Conference*, page 6. ACM, 2015.
[12] Andrew Banks and Rahul Gupta. *MQTT Version 3.1. 1*. OASIS standard 29, 2014.
[13] Rafael Reale, Romildo Bezerra, and Joberto S. B. Martins. A preliminary evaluation of bandwidth allocation model dynamic switchings. *Int. Journal of Computer Networks & Communications (IJCNC)*, 6(3):131–143, May 2014.
[14] Rafael Freitas Reale, Romildo Martins da S. Bezerra, and Joberto S. B. Martins. Analysis of bandwidth allocation models reconfiguration impacts. In *2014 3rd International Workshop on ICT Infrastructures and Services (ADVANCE)*, December 2014.
[15] Rafael Freitas Reale, Walter d. Costa Pinto Neto, and Joberto S. B. Martins. Alloctc-sharing: A new bandwidth allocation model for ds-te networks. In *2011 7th Latin American Network Operations and Management Symposium*, pages 1–4, Oct 2011.
[16] Bob Lantz, Nikhil Handigol, Brandon Heller, and Vimal Jeyakumar. Introduction to mininet, 2017.
[17] Pedro Moraes, Rafael Reale, and Joberto Martins. A Publish/Subscribe QoS-aware Framework for Massive IoT Traffic Orchestration. In *6th International Workshop on ADVANCEs in ICT Infrastructures and Services*, pages 1–14, Chile, January 2018.



Pedro F. Moraes - MSc. student in Computer Science at PPGCOMP/ Salvador University - UNIFACS and bachelor in Informatics by UNIFACS. Has interest in computer networks topics like Publish/ Subscribe, Network Management, Bandwidth Allocation Model and Information-Centric Networks.

Rafael F. Reale - PhD student in Computer Science with DMCC (UFBA/UNIFACS/UEFS), MSc. in Computer Systems by Salvador University - UNIFACS (2011) and bachelor in Informatics by Universidade Católica do Salvador (2005). Professor at Instituto Federal da Bahia (IFBA). Currently works in computer networks in topics like Bandwidth Allocation Model, MPLS, DS-TE, Autonomy, QoS, Future Internet and SDN.



Prof. Dr. Joberto S. B. Martins - Professor at Salvador University (UNIFACS) and PhD in Computer Science at Université Pierre et Marie Curie - UPMC, Paris (1986). Invited Professor at HTW - Hochschule für Techknik und Wirtschaft des Saarlandes (Germany) since 2003, Senior Research Period at Université of Paris-Saclay in 2016, Salvador University head and researcher at NUPERC and IPQoS research groups on Resource Allocation Models, Software Defined Networking - OpenFlow, Smart Cities, Smart Grid, Cognitive Management and AI application.Previously worked as Invited Professor at Université Paris VI and Institut National des Télécommunications (INT) in France and as key speaker, teacher and invited lecturer in various international congresses and companies in Brazil, US and Europe.