

# **TUTORIAL PROPOSAL – IEEE NETSOFT 2016**

## **TUTORIAL TITLE**

Powering Internet of Things with Cloud and NFV for Cost Efficient and Agile Applications and Services Provisioning

## **INTENDED LENGTH**

Half a day (Lecture with no hands-on)

## **INSTRUCTOR**

Roch Glitho, PhD, Associate Professor and Canada Research Chair, Concordia University, Montreal, Canada

## **SHORT BIOGRAPHY**

Roch H. Glitho, PhD, (<http://users.encs.concordia.ca/~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 Geneva, Switzerland), and computer science (University of Geneva). He is an associate professor of networking and telecommunications at Concordia University, Montreal, Canada where he holds a Canada Research Chair in End-User Service Engineering for Communication Networks. In the past he has worked in industry for almost a quarter of a century and has held several senior technical positions at LM Ericsson in Sweden and Canada (e.g. expert, principal engineer, senior specialist). He has presented tutorials at several major IEEE and ACM major conferences including Globecom, ICC and Mobihoc. In the past he has served as IEEE Communications Society distinguished lecturer, Editor-In-Chief of IEEE Communications Magazine and Editor-In-Chief of IEEE Communications Surveys & Tutorials.

## **OBJECTIVES AND MOTIVATIONS**

- The main objective is to review the state of the art and discuss the research directions of a promising and emerging area, i.e. Cloud and NFV based - IoT applications and Services Provisioning
- The key motivation is that the traditional approaches to IoT applications and Services have shown their limits and the potential of cloud and NFV has not yet been unleashed in the area.

## **ABSTRACT**

The Internet of Things (IoT) exploits the ubiquity of objects such as sensors and actuators which could be networked and collaborate for meeting specific goals. The expected applications and services are numerous and cover all aspects of business and everyday life. However provisioning these applications and services in a cost efficient and agile manner remains an uphill task. The deployment of wireless sensor networks (a key building block of IoT) for instance, remains applications / services specific, precluding cost efficiency through re-use by new applications and services. The deployment of middle boxes services such as IoT gateways also remains quite cumbersome. Cloud computing and NFV, emerging paradigms for cost efficient and agile applications and services provisioning, are poised to change the current state of affairs. This tutorial in three parts reviews the state of the art and discusses the research directions. The first

part introduces the basics of applications and services provisioning, IoT, cloud computing and NFV. The second part is devoted to cloud based IoT applications and services provisioning. The approaches proposed so far for IoT virtualization to enable cost efficiency are reviewed. The works on IoT platforms as a Service (PaaS) for rapid and easy applications and services provisioning are also discussed. A concrete cloud based - IoT fire detection and fighting application we have prototyped in our lab is presented as a case study. In the last part NFV based IoT applications and service provisioning is reviewed with a focus on virtual network function (VNF) chaining and deployment issues. A concrete NFV based IoT gateway we have designed and prototyped in our lab is presented as a case study. We conclude by discussing research directions including how fog computing could complement cloud and NFV for unleashing even more powerful IoT applications and services.

#### **REFERENCES TO PRESENTER'S WORK IN THE AREA (A SAMPLE)**

- I Khan, F. Belqasmi, **R. Glitho**, N. Crespi, M. Morrow, P. Polakos, Wireless Sensor Network Virtualization: A Survey, *IEEE Communications Surveys and Tutorials* , Vol PP, Issue 99, March 2015
- I Khan, F. Belqasmi, **R. Glitho**, N. Crespi, M. Morrow, P. Polakos, Wireless Sensor Network Virtualization: Early Architecture and Research Perspectives, *IEEE Network*, May / June 2015
- C. Mouradian, S. Tonmoy, J. Sahoo, M. Abu-Lebdeh, **R. Glitho**, M. Morrow, P. Polakos, Network Functions Virtualization Architecture for Gateways for Virtualized Wireless Sensor and Actuator Networks, forthcoming, *IEEE Network*, 2016
- S. Yangui, F. Belqasmi, **R. Glitho**, M. Morrow, P. Polakos, PaaS for IoT Applications Provisioning: State of the Art and Research Directions, IEEE International Conference on Cloud Engineering 2016 (IC2E), Berlin, Germany, April 4-8, 2016

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#### **REFERENCES TO PREVIOUS ITERATIONS OF THE TUTORIAL**

- It is the very first iteration of this tutorial. However, a very embryonic version of part II (i.e. Cloud based IoT applications and Services provisioning) was included in « T02: Application Architectures for Machine to Machine Communications: State of the Art and Research Directions », a tutorial I presented at IEEE ICC 2012 and which was well attended ([http://icc2012.ieee-icc.org/2012/program/tutorials/mon\\_0830.html](http://icc2012.ieee-icc.org/2012/program/tutorials/mon_0830.html))

## DETAILED OUTLINE

### 1. Introduction

- Key definitions in a nutshell: applications and services, IoT, cloud, NFV
- Motivations
- Tutorial organization

### 2. Basics

#### a. Applications and Services

- Applications / service life cycle
- Examples of IoT applications

#### b. IoT

- Communications aspects (IEEE 802.15.)
- Networking aspects (6LowPAN)
- Higher layer protocol aspects (CoAP)

#### c. Cloud computing and Network Function Virtualization

- Virtualization
- Key facets of cloud (i.e. IaaS, PaaS, SaaS)
- Fundamental concepts of NFV (e.g. VNF, NFVI)
- Cloud vs. NFV

### 3. Cloud Based IoT applications and services provisioning

#### a. Leveraging cloud fabric storage and power

- Architectures
- Case studies
- Pros (e.g. simplicity) and cons (No efficient resource usage)

#### b. Towards true cloud based IoT applications and services provisioning

- IoT virtualization with a focus on WSN virtualization (device level virtualization, network level virtualization)
- IoT PaaS
- Case study on cloud based fire detection and fighting application including a prototype description

### 4. NFV based – IoT applications and services provisioning

#### a. Use cases

- IoT middle-box deployment (e.g. gateway)
- IoT value added services deployment

#### b. A case study on an IoT gateway

- High level architecture
- Implementation architecture
- Prototype

### 5. Conclusions

#### a. Summary

#### b. Research directions

- Examples
  1. IoT PaaS which could interact with fog layers
  2. Integrated cloud/fog for IoT applications and service provisioning