Future Internet with Software-Defined Networking (SDN): Novel Systems, OpenFlow and Smart City Application

Course Poster

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Abstract

Internet and networks are evolving and expanding their utilization dramatically. New paradigms, new protocols, new intelligent solutions and large scale complex systems are emerging on various areas of our daily life. Researchers and engineers need to understand the current network evolution trends and to know what relevant new technologies are involved. This course discusses network evolution and presents the Software-Defined Networking programming paradigm with OpenFlow. SDN/ OpenFlow is applied to Smart City projects to allow a comprehension on how new technologies can improve system development and highlight their potential.

Index Terms

Future Internet, Software-defined Networking, OpenFlow, Smart City, Network Programmability, System Development, Resource Allocation, Network Communications, Cognitive Management, Artificial Intelligence, SDN, BAM.

1 Current networks Evolution

Current communication networks such as 5G, Cloud, IoT (Internet of Things), MPLS and evolutionary systems like Smart City, Smart Grid and Industry 4.0 are marked by a wide variety and large distribution of services, applications, equipment and users alongside with a huge volume of data exchanges with heterogeneous quality assurance requirements (Service Level Agreements - SLA, Quality of Experience - QoE, Quality of Service - QoS) [1] [2] [3].

The term "Future Internet" represents this evolution that is being fostered by different factors, aspects and technological trends like:

- The Internet/web continuous expansion and growth in diversity and complexity;
- Network requirements are diverse, ranging from miniaturized interconnect RFID tags and IoT sensor applications to large complex server farms;

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Course Synopsis prepared on July 2018

- Users are demanding more intelligent, autonomic, easy-to-use and pervasive applications; and
- Artificial intelligence techniques like Case-based Reasoning - CBR, Reinforcement Learning - RL, Machine Learning - ML and Deep Learning are being applied systematically in various areas of knowledge. This includes cognitive IoT (CIoT), 5G, big data, e-health, smart city, smart grid, industry 4.0 (Industrial Internet) and network communications (Cognitive Management) to mention some [4] [5] [6] [7] [8] [9].

2 What is the Challenge for Computer Specialists and Engineers?

Computer specialists and engineers are then challenged to develop new technical approaches in terms of network architecture, protocols and intelligent systems to adequately support this new network scenario.

Computer specialists and engineers need to understand the current network evolution trends and to know what relevant new technologies are involved. In order to be competitive in the market, it is a must to understand what is involved.

3 Course Focus

This course focuses on presenting the current network architecture and systems evolutionary trends and explores the Software-Defined Networking (SDN) new paradigm as a solution to develop new systems (Fig. 1).

In technical terms, the course elaborates on two main topics:

- Software-Defined Networks (SDN) with OpenFlow; and
- Smart City projects as an application scenario.

A typical Smart City project has most of the mentioned Future Internet requirements that engineers have to solve: heterogeneity, largely distributed, high volume of data, multiple networks involved and so on. Figure 2 presents a 3-tier framework frequently used in smart city projects [3].

This course will present firstly how to use SDN/ OpenFlow to develop a new, efficient and programmable communications solution (Communication Level) and, secondly, how new techniques like artificial intelligence can be used to allocate resources in a smart city context (Application Level).

The course will explore incrementally the following aspects of system and application development:

1) How networks can possibly evolve with SDN and without SDN;
2) How SDN supports routing, virtualization and scalability capabilities necessary on current and future systems;
3) What are the Smart City issues and requirements for system development;
4) How can SDN with resource allocation, cognitive management and artificial intelligence foster new systems development for Smart City; and
5) Presenting practical "use case" for Smart City project development.

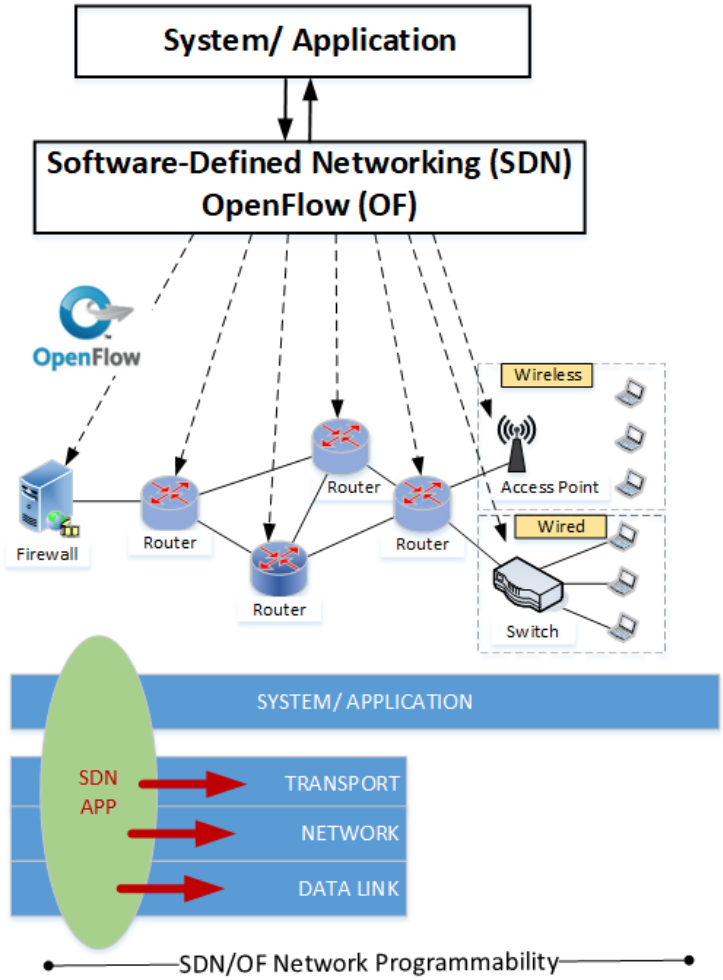

Fig. 1. Course main components view

4 Course Motivation

The motivation to follow this course comes from the fact that engineers need to understand what are the main problems that actual IP-based solutions do have, what are the current trends on system development and what are the new technologies to use.

Why to follow this course?

- To learn SDN/OpenFlow basics;
- To experiment SDN/OpenFlow network programming with MiniNet;
- To acquire expertise on Smart City project issues and requirements;
- To acquire expertise on Resource Allocation issues and network requirements; and
- To perceive the use of Artificial Intelligence (AI) techniques for cognitive management using SDN/OF as the basic network programming paradigm.

The course is intended for PhD, master and graduate students, network engineers and developers involved with network research, design and implementation. Some basic knowledge of IP and networking technologies is required.

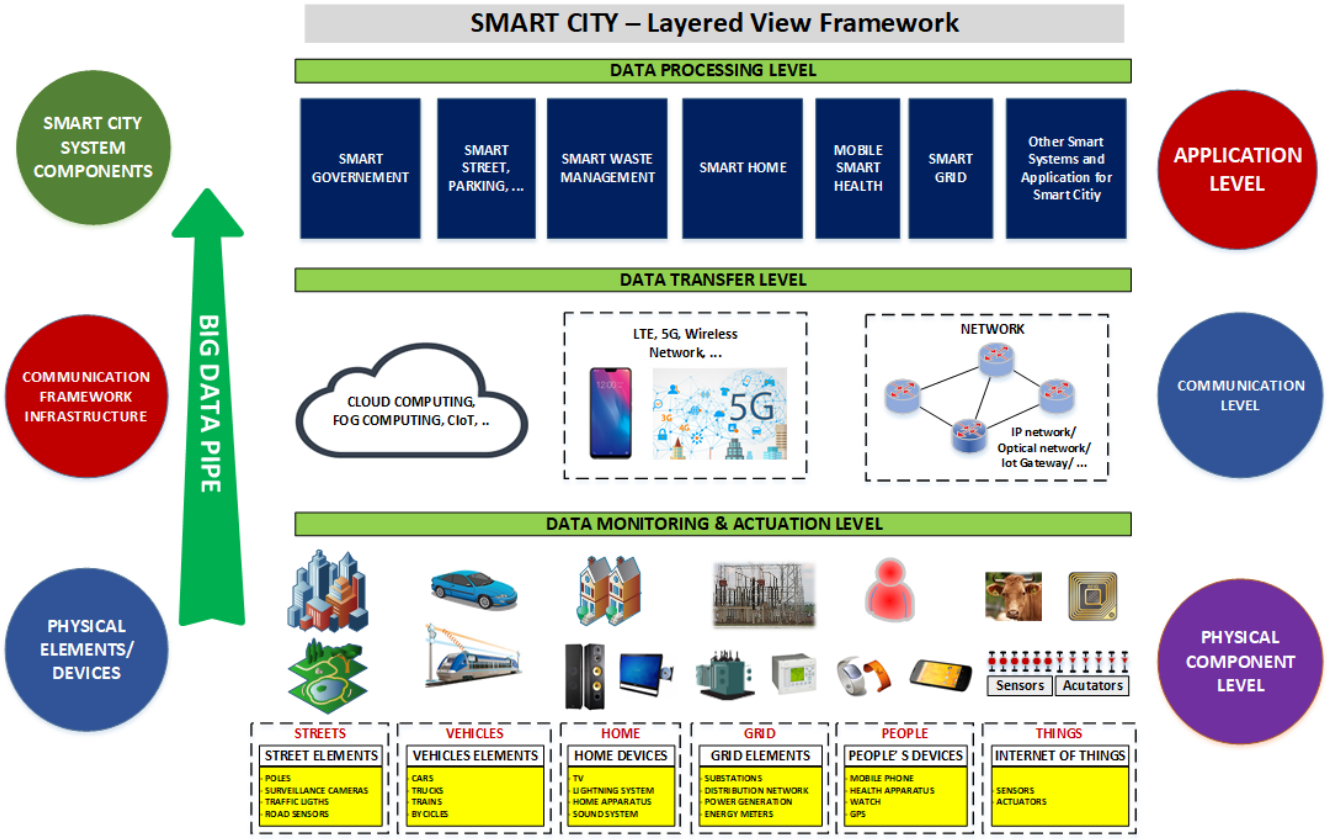

Fig. 2. Smart City Framework View

5 Course Topics

The topics presented are:

1) Evolutionary Networking Architectural approaches and SDN: (Class n^0 1)
   - Networking evolution scenario
   - Software-Defined Networking (SDN)
   - Networks evolutionary architectural issues: virtualization, cognitive management, autonomy, naming, addressing, mobility, scalability
   - SDN standardization
2) SDN/ OpenFlow Protocol Ecosystem: (Classes n^0 2 - 3)
   - OpenFlow (OF) Architecture and EcoSystem
   - OpenFlow and Virtualization
   - OpenFlow Protocol Messages and Flow Diagram
   - OpenFlow Use Cases: virtual router, level 2 virtualization, other
   - OpenFlow hands on with MiniNet:
     - MiniNet and basic OpenFlow operation
     - Virtualization with FlowVisor
3) Smart City Project - Characteristics, Requirements and Solutions (Fig. 2): (Class n^0 4)
   - Smart City – Definition, Characteristics and Requirements
   - Smart City Framework

- Smart City - Use Cases

4) Smart City Project Use Case (Fig. 3) - Communication Resource Allocation with SDN, BAM and Cognitive Management: (Class n^0 5)
   - Smart City Model for Communication Resource Allocation
   - Cognitive Management with Case-based Reasoning
   - Other Smart City Technological Approaches

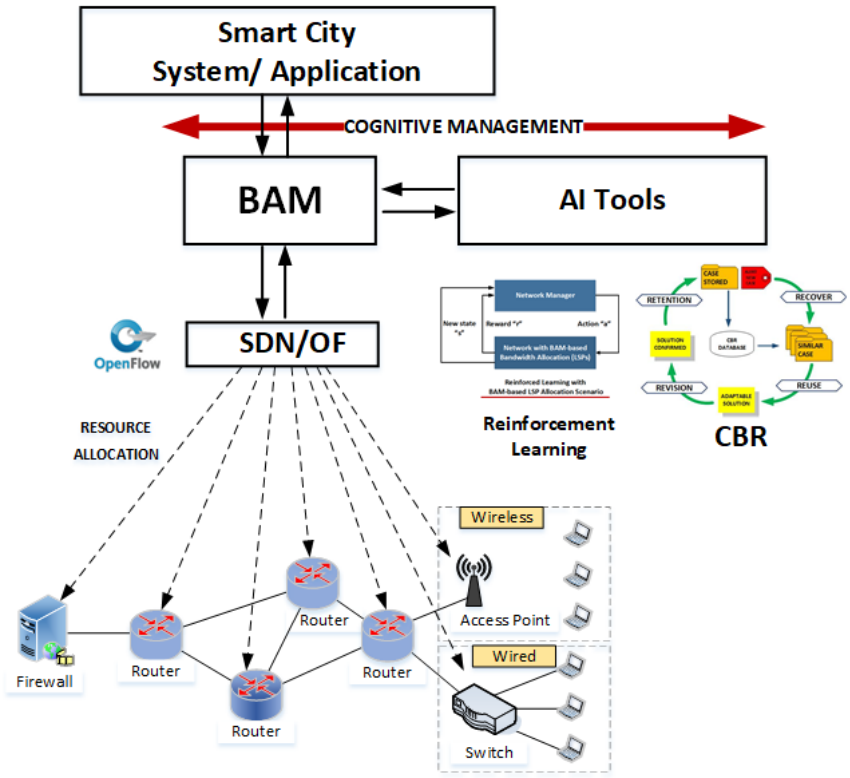

Fig. 3. Smart City - Communication Resource Allocation

REFERENCES

[1] F. Theoleyre, T. Watteyne, G. Bianchi, G. Tuna, V. Cagri Gungor, and Ai-Chun Pang. Networking and Communications for Smart Cities Special Issue Editorial. *Computer Communications*, 58:1–3, March 2015.

[2] R. Bezerra, F. Maristela, and Joberto Martins. On Computational Infraestruture Requirements to Smart and Autonomic Cities Framework. In *IEEE Int. Smart Cities Conference - ISC2-2015*, pages 1–6. IEEE, January 2015.

[3] Joberto S. B. Martins. Smart City with Innovation Perspective. JSMNet Networking and Technical Review Vol 18 - N 3, JSMNet Networking and Technical Review, September 2017.

[4] Agnar Aamodt and Enric Plaza. Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches. *Artificial Intelligence Communications*, 7(1):39–59, 1994.

[5] Richard S. Sutton and Andrew G. Barto. *Reinforcement Learning: An Introduction*. MIT Press, Massachusetts, 2nd dition edition, November 2017.

[6] Jinjiang Wang, Yulin Ma, Laibin Zhang, Robert X. Gao, and Dazhong Wu. Deep Learning for Smart Manufacturing: Methods and Applications. *Journal of Manufacturing Systems*, January 2018.

[7] J. Q. Li, F. R. Yu, G. Deng, C. Luo, Z. Ming, and Q. Yan. Industrial Internet: A Survey on the Enabling Technologies, Applications, and Challenges. *IEEE Communications Surveys Tutorials*, 19(3):1504–1526, thirdquarter 2017.

[8] Eliseu M Oliveira, Rafael F Reale, and Joberto S. B. Martins. Cognitive Management of Bandwidth Allocation Models with Case-Based Reasoning - Evidences Towards Dynamic BAM Reconfiguration. 2018.

[9] O. Rendon, M. Caicedo, F. Estrada-Solano, R. Boutaba, N. Shahriar, M. Salahuddin, N. Liman, and S. Ayoubi. Machine Learning for Cognitive Network Management. *IEEE Communications Magazine*, pages 1–9, 2018.

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