Cognitive Multi-Scale Networking and Processing for Smart Cities with Edge Computing

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The integration of the personal and urban Internet of Things (IoT) has the potential for opening to a new class of applications, where data from individuals are merged with contextual data from fixed, city wide-scale, sensor data. Relevant examples of such applications are *city-wide mobile health care monitoring* and *smart transportation systems*. However, the high-volume and heterogeneous nature of the data to be processed makes centralized approaches impractical. Fog and edge computing architectures, then, are critical components of the technological transitions to these multi-scale smart systems.

However, the intense local exchange of information required to locally perform distributed computing may overload the wireless network edge. Moreover, since these architectures will use local access networks (*e.g.*, cellular networks, and private and public wi-fi) to enable interoperation, a coexistence problem arise with traditional applications. Finally, algorithms processing information in real time (*e.g.*, object tracking) may impose short-term QoS requirements to the network, which are difficult to meet in this complex, dynamic and heterogeneous environment. The design criteria for networking protocols largely remain unchanged compared to those conceived for much "simpler" times and networks, and we argue that new protocol design principles are urgently needed to support these emerging architectures and environments.

We contend that the notion of cognitive network can play an important role in the design of networking technologies capable of analyzing the surrounding network environment and dynamically adapt channel access and transmission protocols to facilitate the coexistence of concurrent applications. We propose to extend cognition to include computational aspects of distributed processing and edge computing architectures. The objective is to empower the devices with the ability to determine the critical information which needs to be forwarded, and the transmission modality, within the constraints imposed by other active data streams and applications. Interestingly, in many application examples the relevance of information is a function of the system state and application-related features such as data compression. For instance, in human activity recognition, data from a subset of sensors are typically needed to detect a specific state. In smart camera applications, interference has a different impact depending on the frame being transmitted due to differential compression, where packet loss affecting reference frames propagates forward and backward in time. Extending such concepts to larger scales will enable network traffic and computational load reduction by means of smart joint communication-processing algorithms.

Our recent contributions explore the notion of content-aware wireless protocols, where the transmission parameters are adapted to create interference patterns compatible with other concurrent applications. We are currently developing a detailed D2D/LTE simulation environment which includes video processing architectures (*e.g.*, smart camera systems for object detection and tracking) and biometric signals upload. The simulator will serve as a platform for the design of such protocols and the thorough study of the networking implications of distributed processing in the Smart City.

PI Expertise: Dr. Levorato's research activity developed at UC Irvine, Stanford and the University of Southern California, and involved both the departments of Electrical Engineering (EE) and Computer Science (CS). His research centers on fundamental modeling, analysis and control tools for a wide spectrum of systems ranging from communication to sensor, cyber-physical, and smart energy systems. He has contributed many fundamental results in a number of areas in communications and networking, including cognitive and cooperative networks, and multimedia transmission. In recent research, Dr. Levorato explored communication technologies supporting the tracking and detection of human-technology systems, where information extraction and communication are jointly optimized based on the underlying system model. He also proposed innovative frameworks for the modeling, analysis and control of smart energy systems, with particular attention devoted to online learning and control of these complex systems. His research resulted in more than 70 publications in IEEE and ACM journals and conferences, including the paper recipient of the best paper award at IEEE Globecom 2012.