Intelligent IoT networking architecture to assess individual exposure to urban air pollution

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Context: Air pollution is one of the main challenges to urban health and environmental sustainability. Concentrations of outdoor air pollutants vary across time and geographical space depending on source characteristics, causing varying degrees of air pollutant exposure, which is defined as the contact of a person to a chemical, physical or biological agent carried by air. Most of epidemiological studies often rely on pollutant concentrations that are measured by fixed monitor stations. However, those costly monitor stations are not designed to estimate individual exposure to air pollutant. Alternatively, individual exposure levels can be measured using personal air pollution sensors. With the recent progresses of Internet of Things (IoT) technologies, low cost sensors are increasingly popular among citizens and some local collectivities. Unfortunately, these heterogeneous low cost sensors are not accurate and are generally constrained by limited energy and transmission capacities. Indeed, estimating individual exposure is significantly challenging due to temporal and spatial exposure variability, which is related to individual's behavior but also the dynamic of its surrounding environment.

Work objectives and challenges: The overall aim of this thesis is to conduct researchers on cost-effective networking architectures (i.e. protocols and mechanisms) that will allow gathering rich data needed to assess individual exposure to air pollution in urban environment. The investigated architecture relays on the participatory sensing principle of persons or groups (e.g. economical and local collectivities) accepting to federate their infrastructures and collected data, with the benefits of obtaining in return accurate assessments of urban users exposure to pollution. Few IoT architectures proposed in the literature might partially fulfill with the above requirements. However, several issues, such as privacy and scalability are still open. In addition, the intelligence is mainly put at the network border, mostly at the application level. The novel feature that we wish to integrate is to push the intelligence further inside de network. Thus, the main research direction that we seek to investigate in this thesis is to combine fog computing paradigm with recent IA technics to design an **intelligent cost-effective IoT fog computing architecture that will allow long term measurement of individual exposure to air pollution in urban environments.**

PhD research directions: Network softwarization, sustained by Software Defined Networks (SDN) and Network Function Virtualization (NFV) paradigms, is a key enabler to dynamically push the intelligence from terminals toward the network infrastructure. Yet, defining which virtualized networks mechanisms can be optimized using intelligence, where to place these mechanisms and how this intelligence is build is still an open issue.

An IoT fog architecture that aims to federate heterogeneous sensors is currently under definition at the L2TI networking team. The purpose of this thesis is to extend this architecture by adding intelligence features. The idea is to design virtualized network functions that are context-aware, thanks to observing and learning from rich data. The thesis will focus on some key network functions related to data gathering and dissemination (e.g. data sampling and aggregation, routing and transmission scheduling). AI technics shall also be used to determine where, when and how to deploy those intelligent network mechanisms. The deployment shall cover both the network border (mobile terminals and sensors) but also the backbone nodes of the fog computing infrastructure. NFV orchestration, shall take into consideration the data-context, but also the spatio-temporal variability of network/system resources capacity. Hence, dynamic dimensioning (parameterizing) of virtualized network functions can be investigated under the perspective of AI prediction technics, such as Deep Learning. For instance, sensor resources (bandwidth and energy) could be optimized using an intelligent temporal and/or spatial data aggregation mechanism that depends on predicting incoming data at a given place and at a given time as well as exploiting forecasting connectivity conditions.

Similarly, intelligent SDN routing mechanisms among the nodes composing the fog infrastructure can be investigated in order to cope with the big data scalability issue. To this purpose, we will consider using Named Data Networking (NDN) paradigm. NDN have recently emerged as an alternative to the classical TCP/IP architecture to develop data-centric networks, such as those required by IoT applications. The main concept is to provide networking functions to address data rather than hardware devices. Our choice is also motivated by the capacity of NDN networks to deal with the privacy issue.

Regarding data transmission, a first direction is to study how AI technics could be used in NDN/SDN paradigms to structure and route the flows of collected data, depending on their ontologies but also on the spatio-temporal dynamics of the surrounding cyber and physical environment. Performances of the resulting intelligent network mechanism could be assessed using a network simulator, such as NS3 or OMNET++. Finally, an operational prototype of the intelligent fog IoT architecture could be developed as a proof-of-concept.