Ph. D research activity in
Energetic, System, Computer and Telecommunications Engineering
XXX Cycle

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Edge Computing: challenges, solutions and architectures arising from the integration of Cloud Computing with Internet of Things

The rapid spread of the Internet of Things (IoT) is causing the exponential growth of objects connected to the network, in fact, according to estimates, in 2020 there will be about 3/4 devices per person totaling of over 20 billion connected devices. Therefore, the use of content that requires intensive bandwidth consumption is growing.

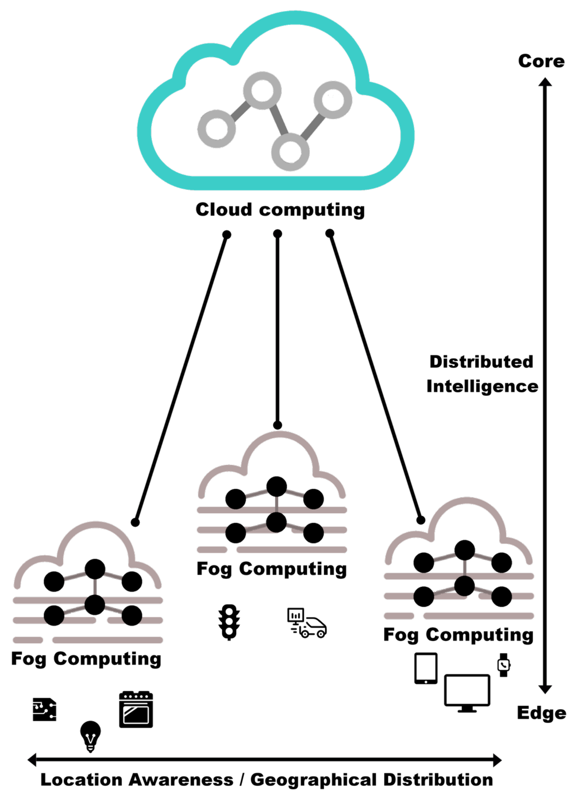
In order to meet these growing needs, the computing power and storage space are transferred to the network edge to reduce the network latency and increase the bandwidth availability. Edge computing allows to approach high-bandwidth content and sensitive apps to the user or data source and it is preferred to use it for many IoT applications respect to cloud computing. Its distributed approach addresses the needs of IoT and industrial IoT, as well as the immense amount of data smart sensors and IoT devices generate, which would be costly and time-consuming to send to the cloud for processing and analysis. Edge computing reduces the bandwidth needed and reduces the communication among sensors and the cloud, which can negatively affect IoT performance.

The goal of edge computing is to improve efficiency and reduce the amount of data transported to the cloud for processing, analysis and storage.

The research activity carried out during the three years of the Ph.D program focused on the study, design and development of architectures and prototypes based on the Edge Computing in various contexts ranging from smart cities to agriculture. Therefore, the well-known paradigms of Fog Computing and Mobile Edge Computing have been faced.

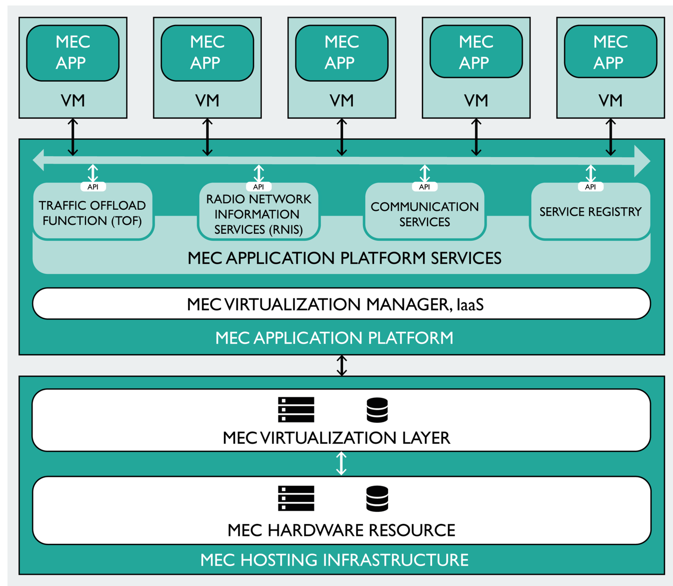
Fog Computing

- Move processing power to the edge of network.
- Reduce the amount of data to be transmitted to the Cloud
- Provide processing, analysis and networking services between end devices and data centers

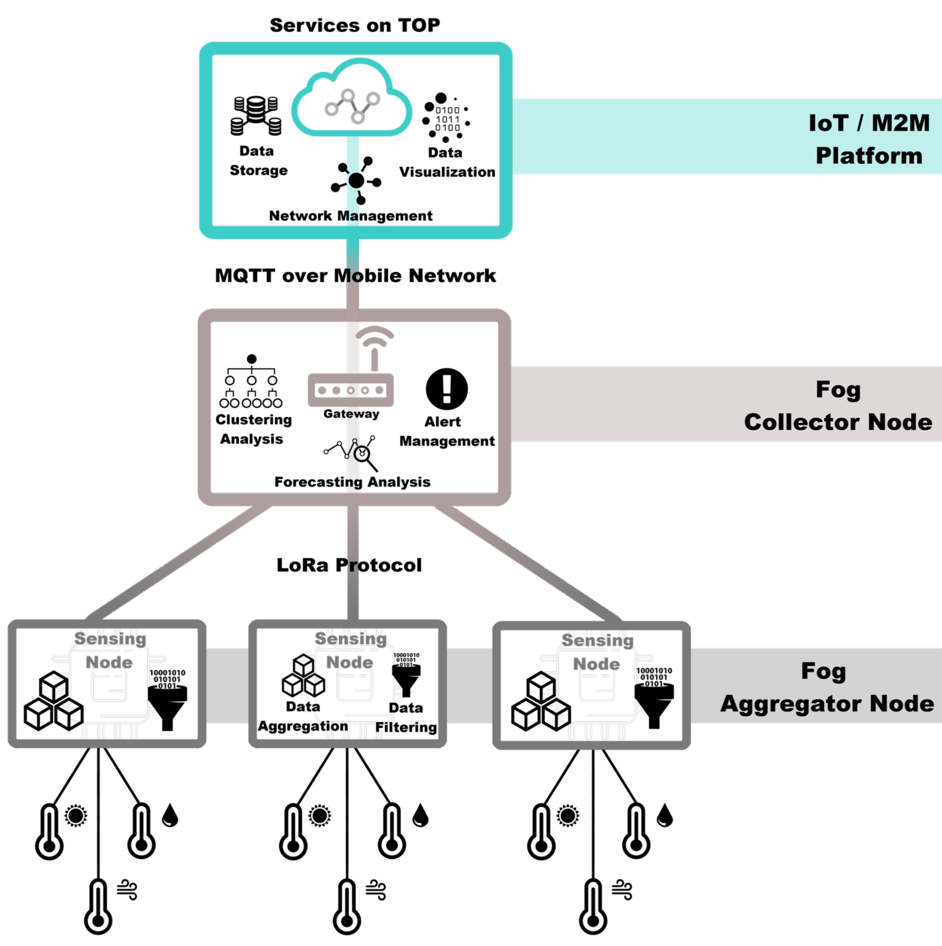


Mobile Edge Computing

- Enables cloud computing capabilities at the edge of mobile network
- Can be considered as an evolution of the RAN (Radio Access Network)
- Aims to create a standardized and open environment
- Provides IT capabilities (computational resources, storage, connectivity, access to user traffic and network information)



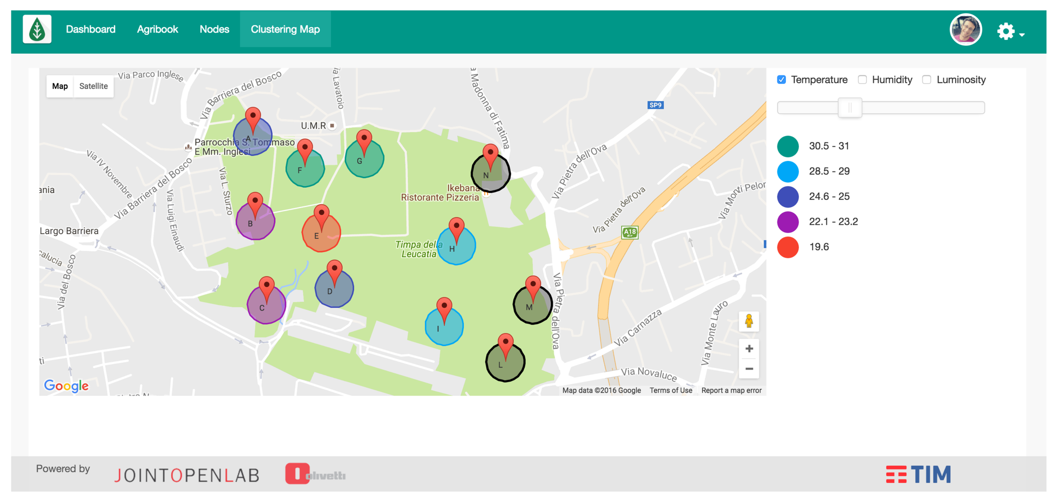
A Fog computing based architecture for precision agriculture



This solution allows to the agricultural companies to improve the agricultural harvest and increase the productivity, using IoT technology and algorithms that support an intelligent handling of the agricultural crop.

It consists of a modular system that includes:

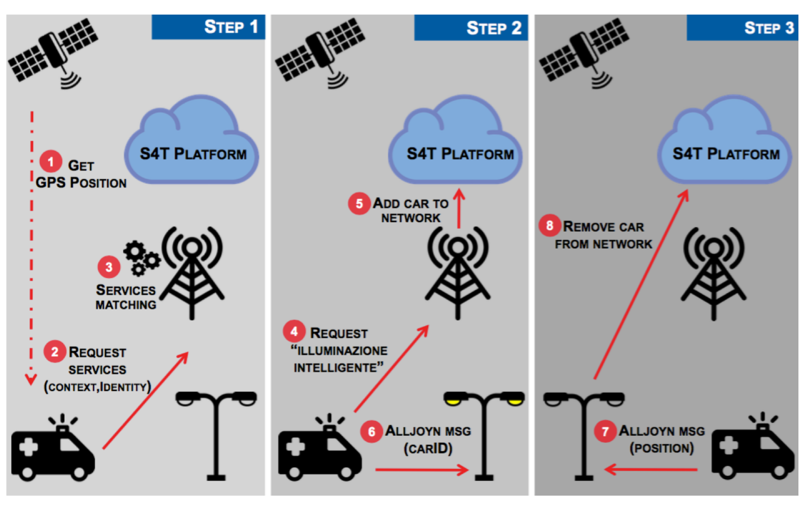
- Cloud based IoT Smart Platform
- Fog Collector Node (FCN) represented by the gateway
- Fog Aggregator Node (FAN) represented by sensor node

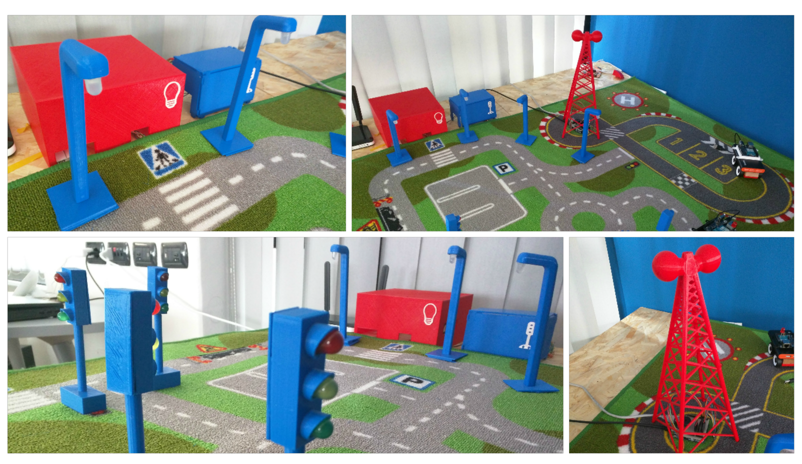


FAN is connected to sensors that monitor both the soil and the plants. It is programmed to acquire data from the sensors connected to it and sends them to the gateway via LoRa technology. Before to transmit the data, FAN implements a data filtering process in such a way that the values of the data collected by the sensors belong into an acceptable range, according to the design of the sensors. The next step is the Data Aggregation process. One per-hour value will be transmitted to the gateway as result of the average of the previous values or, if the samples present certain variability, also the min and max values of the series will be sent.

FCN implements a middleware able to receive data from FAN by LoRa technology, store the received data in local RDBMS, transmit data to the Cloud in MQTT over mobile 4G/3G network and, periodically, perform the following tasks: Cluster Analysis, Forecasting Analysis, Alert Management and Actuation.

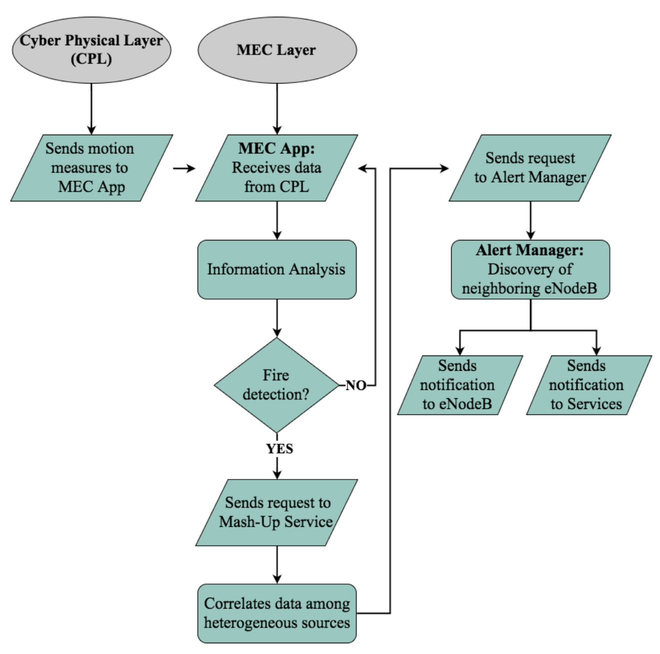
A Mobile Edge Computing solution for smart city services

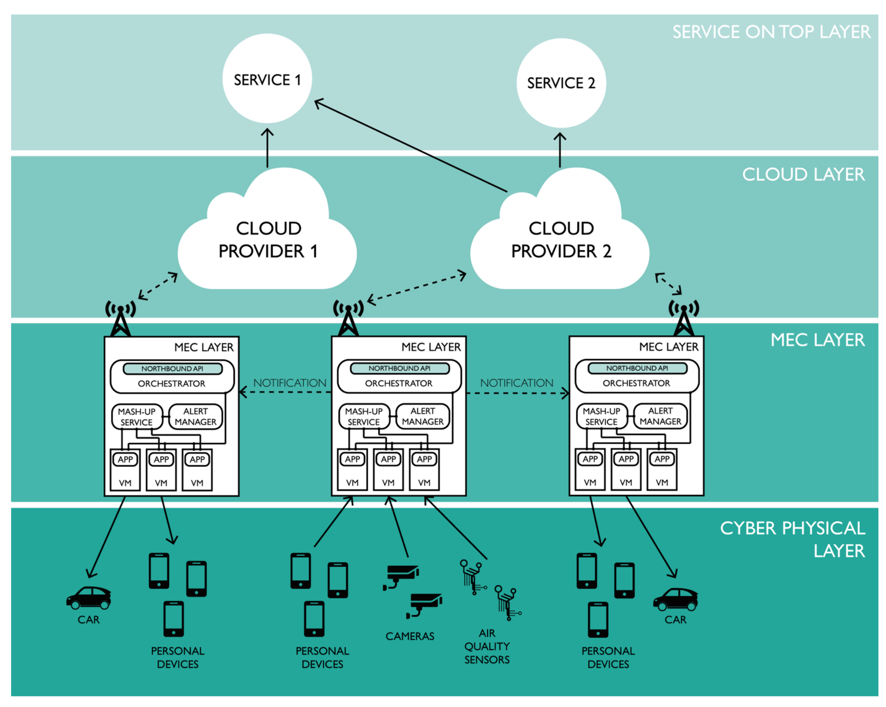




1. The vehicle gets the GPS coordinates from the satellite.
2. The vehicle demands all the services that can exploit (discovery services), sending its context and identity to the controller (BTS), in such a way that the BTS can understand which type of user is making the request (normal user, ambulances, etc.).
3. The controller makes a Services Matching returning all the services to which the user is enabled with the relative positions.
4. When the user (vehicle) realizes to be in proximity to a service, performs a specific request to the BTS.
5. The BTS adds the car to the virtual network of the service manager.
6. Exploiting the Alljoyn protocol, the nodes will communicate with each other and the car will send its id to the Service Manager/Provider to receive the custom service
7. While nodes are connected to the virtual network, the client polls its position toward the service.
8. When the vehicle moves away from the coverage area, the service manager will remove it from the virtual network and disable the service.

Proposed Architectures of MEC for critical event scenario





Four layers compose the proposed architecture

- Service on top layer, composed by services directly connected to the cloud providers;
- Cloud layer, that contains the cloud providers which exploit the information provided by a single IoT/WSN system;
- Mobile Edge Computing layer, that enables a subset of features, usually exposed at the cloud level, such as processing and analysis of data. The components deployed inside the MEC Server will be discussed below.
- Cyber-Physical Layer, composed by an heavily distributed ecosystem that cover several smart objects, mobile and fixed, such as personal devices, sensors, video surveillance systems.