Fog computing

Complex Information Systems and Vertical Applications
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What is Fog computing?

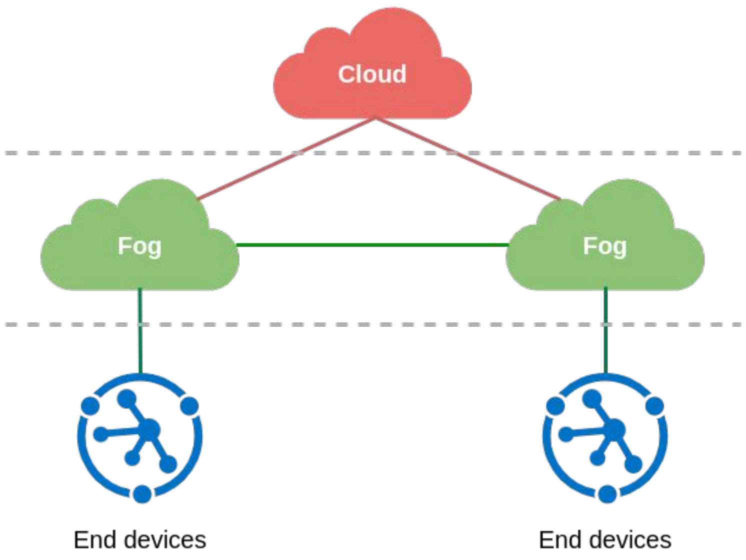
Cisco introduced Fog computing as an extension of Cloud computing: "*The Fog **extends** the Cloud to be **closer to the things** that produce and act on IoT data. These devices, called Fog Nodes, can be deployed anywhere with a network connection. **Any device** with computing, storage and network connectivity **can be a Fog Node***".

There is a fruitful ***interplay between the Cloud and the Fog***. While ***Fog Nodes provide*** localization, therefore enabling ***low latency and context awareness***, the ***Cloud provides global centralization.***

Why Fog computing?

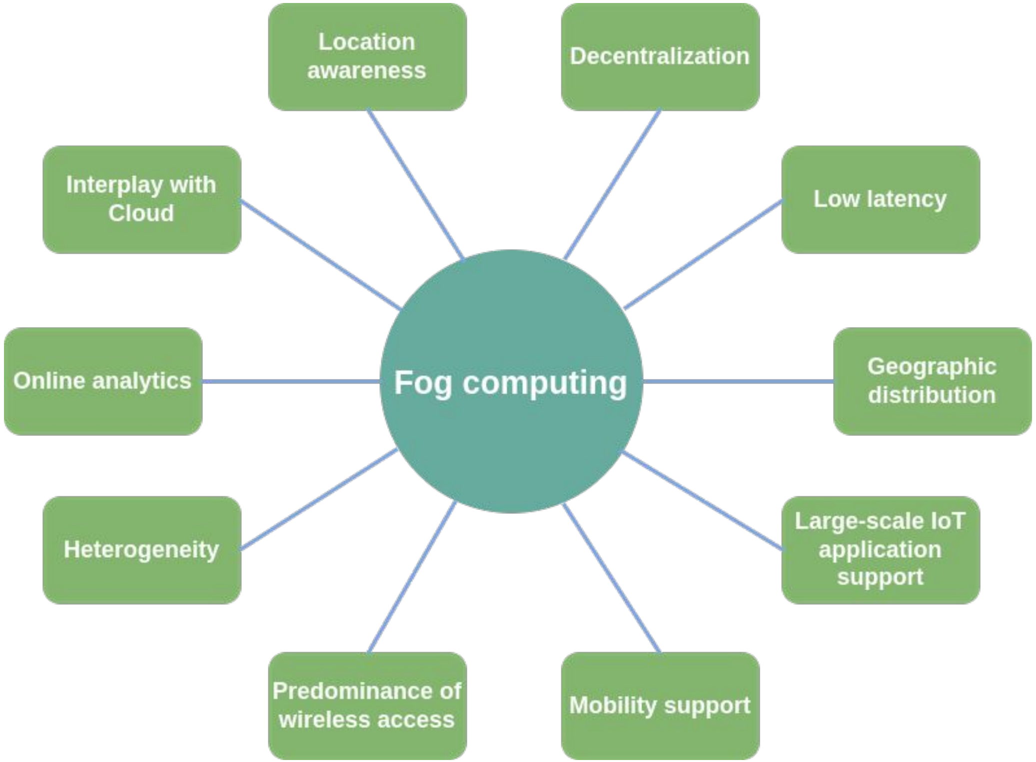
Today's ***Cloud*** models are ***not designed for*** the volume, variety, and velocity of data that the ***IoT*** generates. Analyzing IoT data close to where it is collected:

- minimizes latency
- offloads gigabytes of network traffic from the core network
- keeps sensitive data inside the "network"



Fog computing characteristics

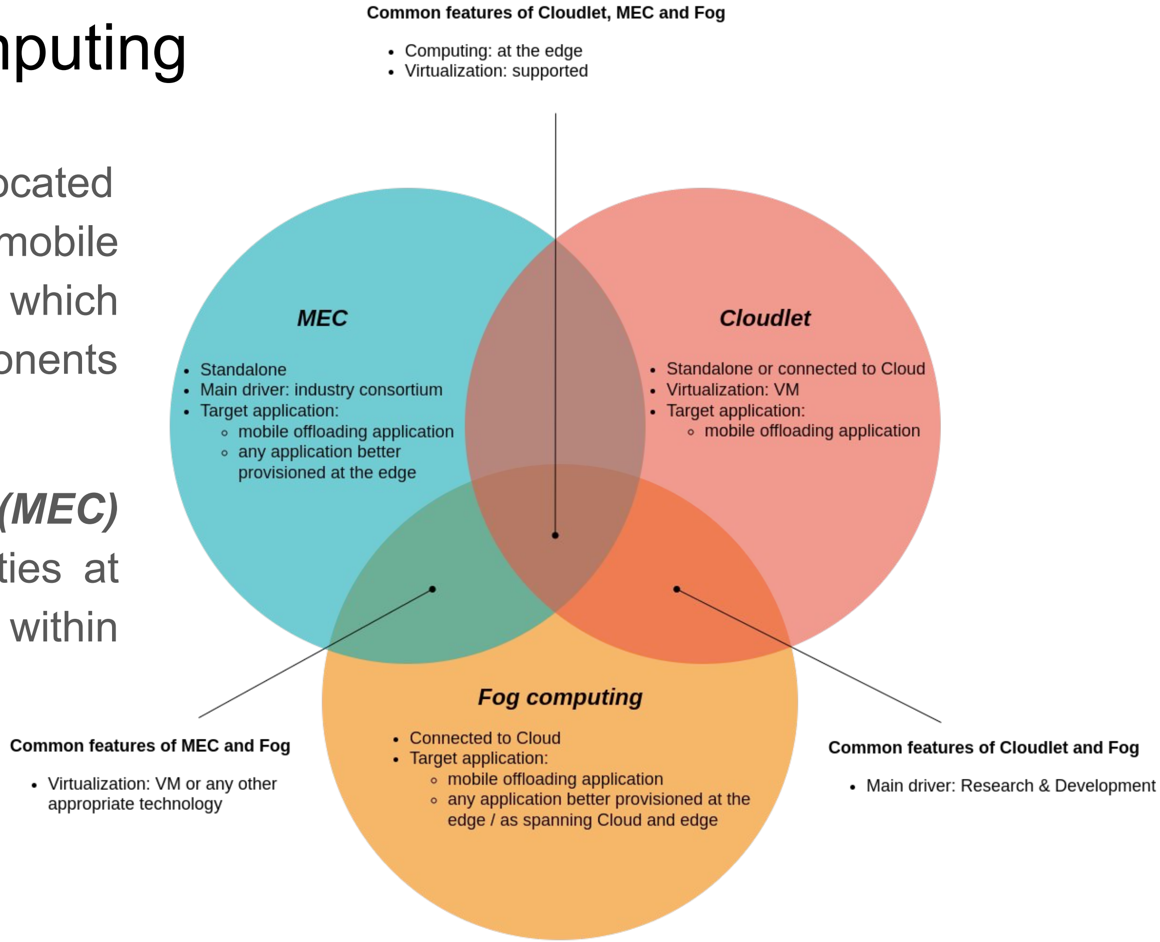
The defining characteristics of Fog computing make it ***suitable for*** application such as ***smart cities, real-time analytics and vehicular communication***. On the other hand, ***these characteristics pose significant challenges*** that need to be addressed.



Alternatives to Fog computing

Cloudlet Resource-rich servers located in a single-hop proximity of mobile devices, running multiple VMs in which mobile devices can offload components for expensive computation

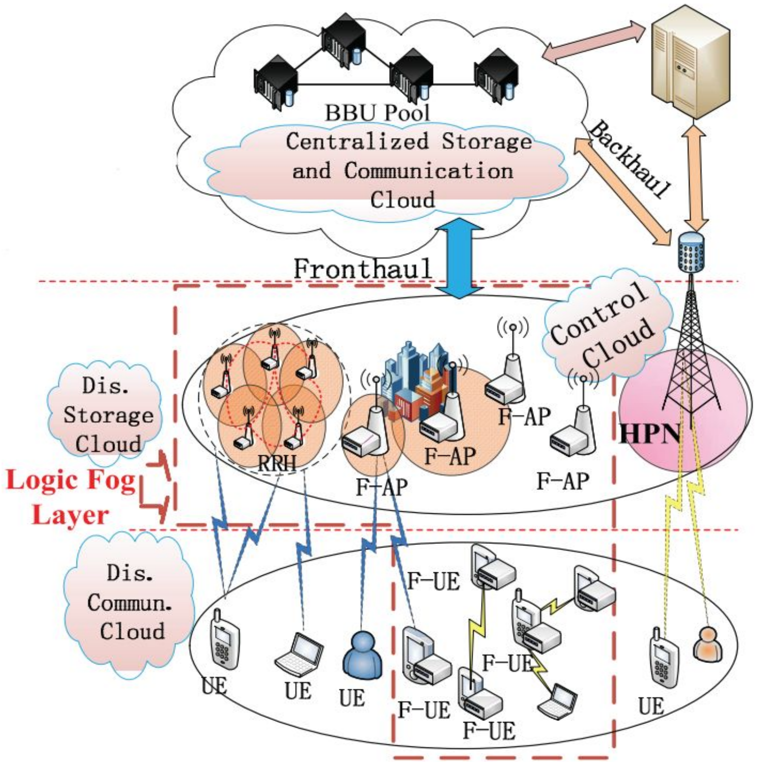
Multi-Access Edge Computing (MEC) Provide Cloud computing capabilities at the edge of mobile networks, and within the RAN



Fog computing and 5G

5G guarantees ***low latency from the end user to the base station***, but ***from the base station to the Cloud the latency is still there***. There it is where Fog computing comes into play.

F-RAN (Fog Radio Access Network) introduces a Fog computing layer at the edge of the networks (exploiting Remote Radio Heads and User Equipments, as an example), so that a part of the service requirements can be responded locally without interacting with the Cloud. The core idea is to take full advantage of ***local radio signal processing, cooperative radio resource management and distributed caching capabilities***, which can ***decrease the heavy burden on fronthaul and avoid large-scale radio signal processing*** in the centralized baseband unit pool, thus providing ***high spectral and energy efficiency***.



Application of Fog computing to Smart Factories and CPSs

The focus of the project is bringing Fog Nodes to the Shop Floor to support machines, taking into consideration the specificities of manufacturing systems.

A ***Cloud approach is not sufficient to support many IoT applications***; for example, the centralized nature of the Cloud and the stochastic behavior of the Internet is a barrier to delivering real-time services, which are fundamental in many IoT scenarios. ***Fog computing is complementary to IoT and Cloud***, offering low latency, and also keeping sensitive data on-premise and reducing bandwidth consumption.

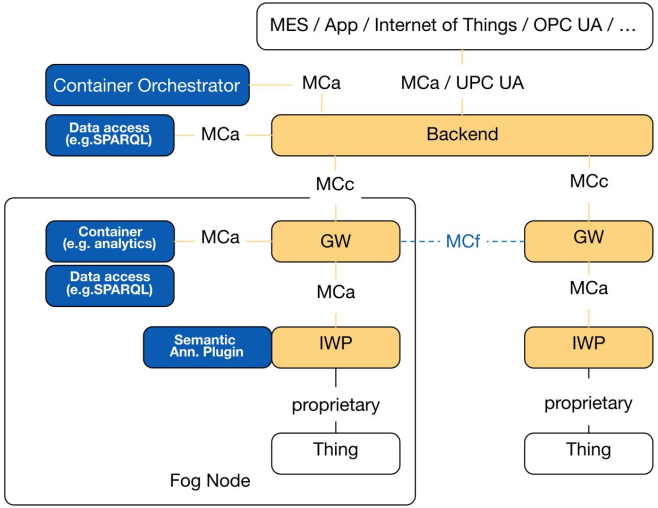
In the study, the Fog Node is implemented as an ***OpenMTC gateway (GW)***, a Middle Node in oneM2M terminology.

The authors identified three ***main goals*** for a Fog Node architecture:

- ***Ultra-low latency***: real-time information support a more efficient decision making
- ***Robustness***: fundamental in mission critical systems
- ***Node programmability:*** CPSs behavior must be able to change in an efficient way

These goals can be achieved by:

- ***P2P communication***: suitable for decentralizing and offer a higher level of auto-coordination. However oneM2M (and OPC UA) lack specifications for such an approach, allowing a MN to be connected at most either one MN or one IN. The authors proposed novelty is to release this limitation, allowing a direct communication between Fog Nodes.
- ***Hierarchical Fog, Edge and Cloud service orchestration***: a multi-tier architecture improves fault tolerance and availability, whereas orchestration allows flexibility
- ***Local filtering and analysis***: reduces latency and bandwidth consumption



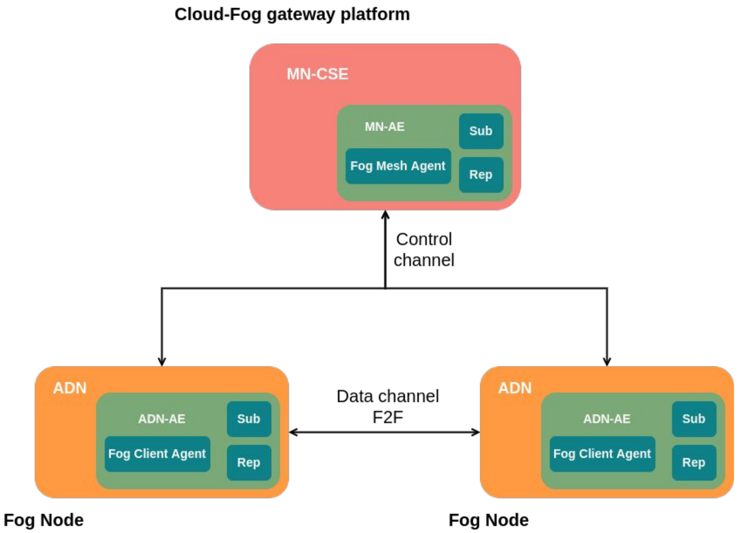
Design of oneM2M-Based Fog Computing Architecture

The F2C (Fog-to-Cloud) architecture is composed by three layers: the Device layer, the Fog layer and the Cloud layer. The Fog layer consists of ***several independent Fog entities, which relieve the load to the Cloud***, providing better service quality to IoT devices.

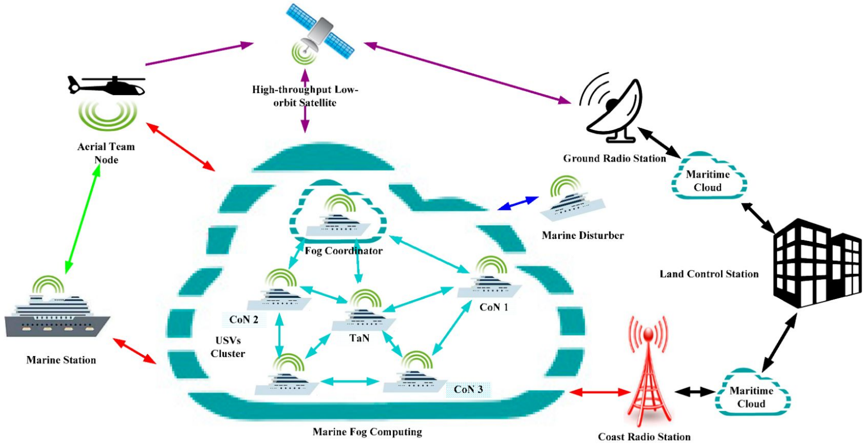
In this scenario, ***an IoT device communicates with the Fog entity*** associated with it instead of submitting the job directly to the Cloud, but this ***could cause a delay if the Fog Node can't undertake the work*** and needs to forward it to the Cloud. The delay might be reduced if the work could be forwarded to adjacent Fog Nodes.

The paper thus proposes an ***oneM2M-based Fog Computing architecture*** under which ***adjacent Fog nodes can coordinate and cooperate with each other***. Operations are no longer constrained by a node's ability to perform tasks or by the requirement of forwarding tasks to the Cloud for execution.

The study takes advantage of a ***Fog Mesh Agent responsible for the application function*** of the Fog Nodes and the ***matching of the relationships***. The communication between a Fog Node and the Fog Mesh Agent happens through the subscription and notification mechanisms of oneM2M.



Fog computing and maritime



Moving all the data generated by maritime applications to the Cloud ***over satellite links is not feasible***. ***Coastal infrastructures and large-size vessels may be turned into maritime Fog Nodes*** to process tasks generated by surrounding maritime devices, enhancing ***bandwidth saving, location-aware crowdsensing and transmission distance reduction***.

Smart ports needs efficient, capillary and smart monitoring techniques. Moving processing power and facilities close to the port location could provide several enhancements in the network architectures, such as:

- ***sensors reporting time reduction***
- ***equipment control optimization***
- ***real-time access*** to video surveillance
- ***customized applications deployment***

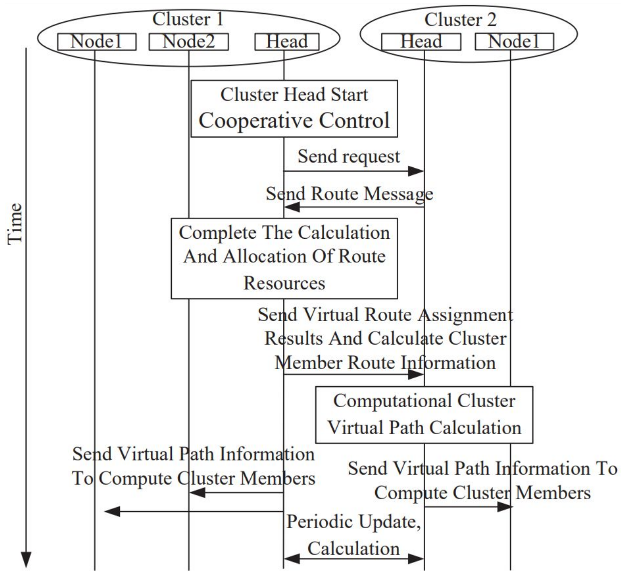
Autonomous Vessels

As an important expansion of the development of single-vehicle intelligent systems, the development of USVs (Unmanned Surface Vehicles) has moved towards ***multi-ship cooperative control***.

The ***USV's requirements*** for position perception, low delay and mobility support of heading control ***cannot be fully met by Cloud*** computing. ***Fog helps computing and storage*** between USV and Cloud services.

By dividing the path-based information and destinations, the ***USVs with similar moving models are divided into one cluster***, establishing a communication between them. This approach allows a ***navigation control information with low time delay and more intelligent selection.***

This model also ***reduces the dependency on satellite communication***, ***reducing the operational costs*** and ***improving the safety and process of USV.***



Sustainable growth

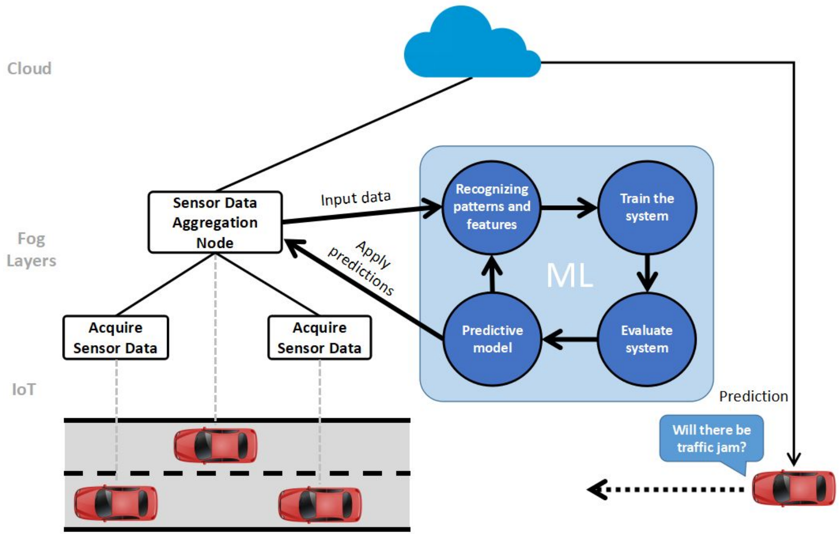
The adoption of Fog computing

- brings to ***reduced costs for data transmission*** due to its decentralized nature
- ***reduces carbon footprint*** exploiting free computational power from user equipment and other devices
- ***improves optimization*** for applications having high locality demand, such as traffic efficiency and smart grid

e-Freight

Fog computing supports ***real-time data*** sensed from the road infrastructure and other vehicles, ***enabling cooperative services*** such as road safety and traffic efficiency.

Fog computing also ***supports*** the natural multi-tier architecture of ***machine learning tasks*** useful to ***optimize the costs in the freight transport system***, where the large amount of data coming from distributed sources can be filtered at the edge.



Fog computing challenges

- ***Standardization***: lack of standards makes solutions ***non interoperable***, there are ***no clear boundaries*** of what Fog computing is
- ***Discovery / sync***: each node must be able to act as a router for its neighbours and must be ***resilient*** to node churn
- ***Management***: heavily relies on ***decentralized management*** mechanisms
- ***Security***: Fog allows to process users data in third party's software/hardware; this introduces strong concerns about ***data privacy and its visibility to*** those ***third parties***. Issues also in ***access control and intrusion detection***
- ***Accountability***: proper system of ***incentives*** need to be created
- ***Computation offloading***: how to deal with ***dynamic***
  - radio / wireless network access is highly dynamic
  - nodes in the Fog network are highly dynamic
  - resources in the Fog network are highly dynamic