



Edge Computing

(Cloudlet, Multi-access Edge Computing - MEC, and Fog Computing)

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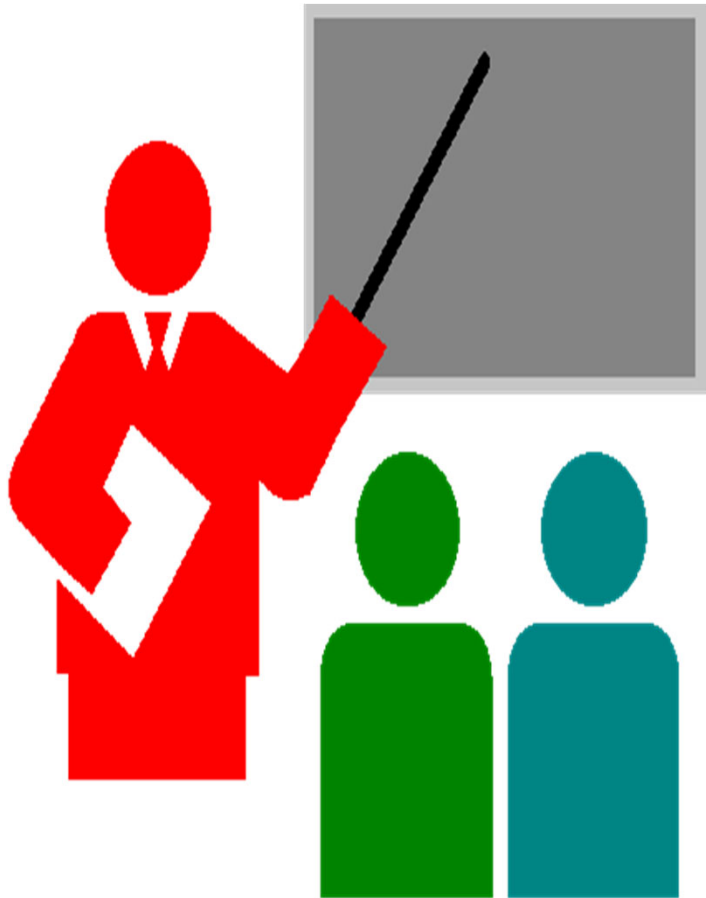
My URL - <http://users.encs.concordia.ca/~glitho/>

References

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2. S Yangui, P Ravindran, O Bibani, R Glitho, N B Hadj Alouane, M Morrow, P Polakos, A Platform as-a-Service for Hybrid Cloud/Fog Environments, The 22nd IEEE International Symposium on Local and Metropolitan Area Networks, IEEE LANMAN 2016, June 2016, Rome, Italy
3. S Satyanayanan, P. Bahl, R. Caceres, N. Davies, The Case for VM-Based Cloudlets in Mobile Computing, IEEE Pervasive Computing. 2009
4. H. Liu et al, Mobile Edge Cloud System: Architectures. Challenges and Approaches, IEEE Systems Journal. Forthcoming (available as pre-print)
5. ETSI Location API, <http://www.etsi.org/technologies-clusters/technologies/multi-access-edge-computing>



Edge Computing



- Motivation
- Clouplet
- Multi-access Edge Computing (MEC)
- Fog Computing
- Summary





Motivation



Motivation

Address some challenges faced by cloud computing:

1. Cloud might be far from end-users / devices
 - Issues for latency sensitive applications, e.g.
 - Disaster management
2. Legal requirements for processing data at given location
 - Cloud owner might not have any data centre at the location



Motivation

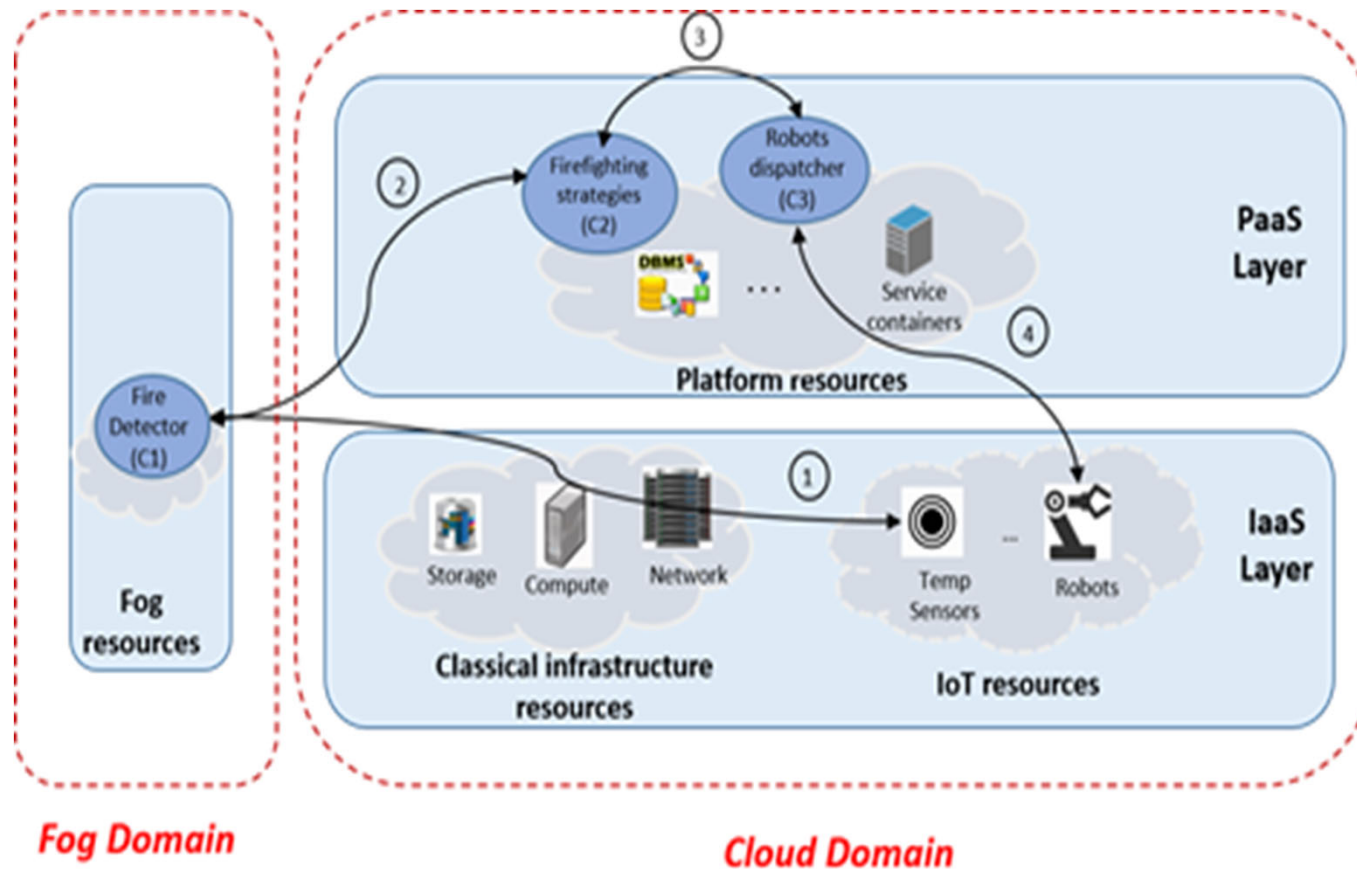
Illustration: Disaster management scenario (cloud in Paris, IoT devices at Concordia, Edge computing done at Concordia) – Ref 2

- Very simple scenario
 - Sensors detect fire at given location
 - Robots are automatically dispatched to extinguish the fire



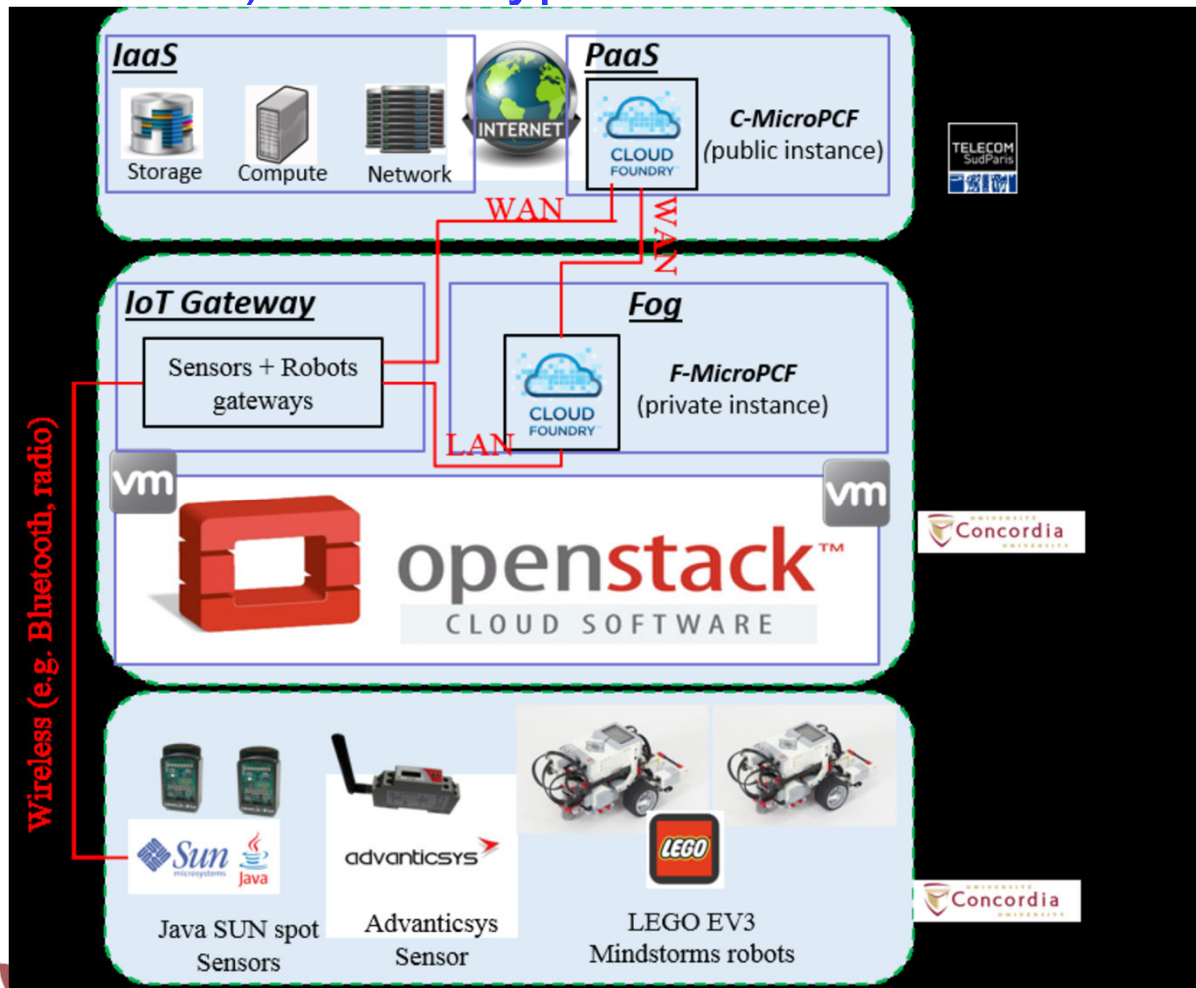
Motivation

Illustration: Disaster management scenario (cloud in Paris, IoT devices at Concordia, Edge computing done at Concordia) – Prototype - Ref. 2



Motivation

Illustration: Disaster management scenario (cloud in Paris, IoT devices at Concordia, Edge computing done at Concordia) – Prototype - Ref. 2



Motivation

Illustration: Disaster management scenario prototype
(cloud in Paris, IoT devices at Concordia, Edge computing
done at Concordia) – Potential gains - Ref. 2

C1: Fire detection component

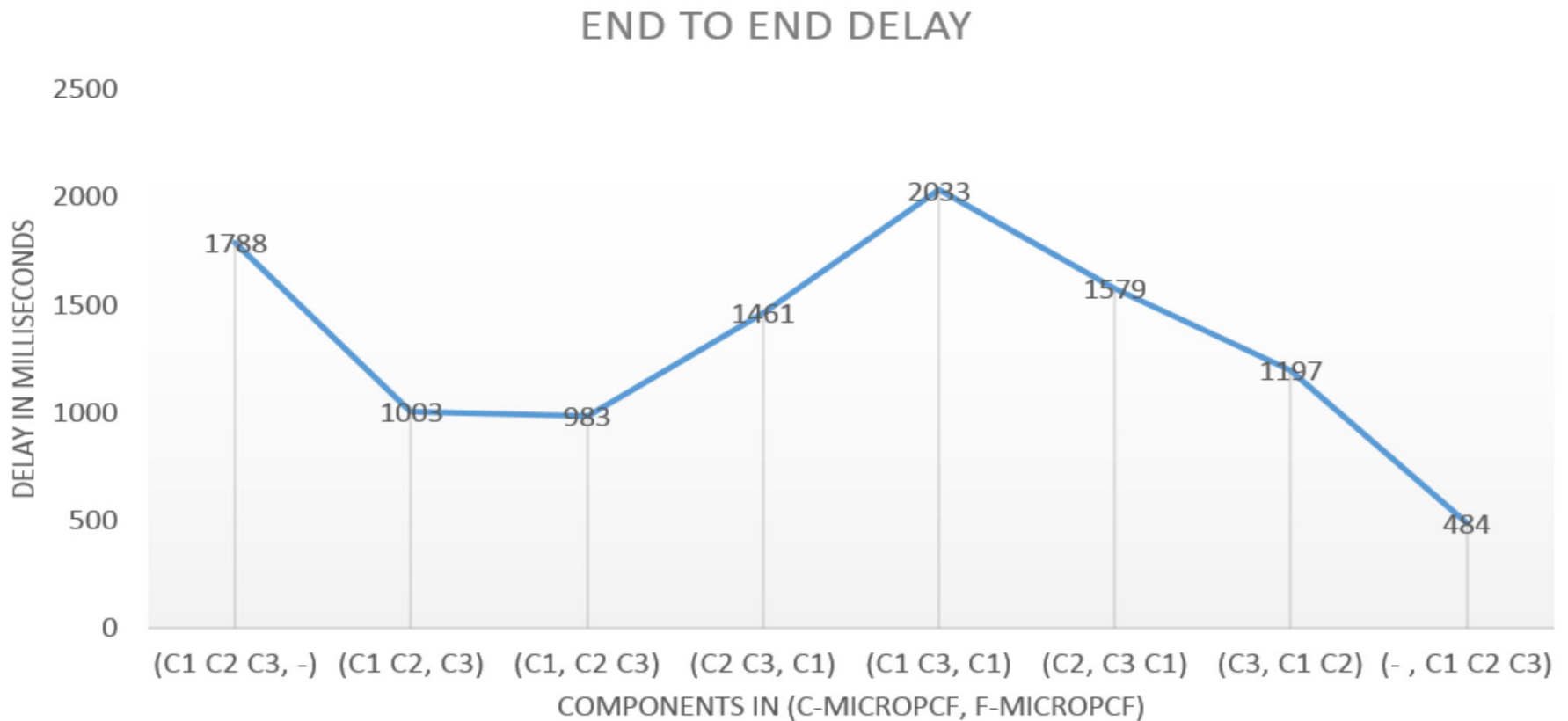
C2: Fire fighting strategy component

C3: Robot dispatcher component



Motivation

Illustration: Disaster management scenario prototype (cloud in Paris, IoT devices at Concordia, Edge computing done at Concordia) – Potential gains - Ref. 2



Motivation

Processing at the edge may help in addressing the challenges. 3 paradigms so far:

1. Cloudlet
2. Multi-access Edge Computing (MEC)
3. Fog computing





Cloudlets



Introduction

Cloudlets

- Result of research projects initiated 2008/2009
 - Did not get as widely deployed as initially thought
 - Might end in niche markets such as vehicular ad hoc networks (VANETs)
 - Deployment in road side units.



Target Applications

Mobile off-loading applications

- Applications for mobile devices which:
 - cannot run on the devices due to the poor resources on the devices
 - cannot run in the cloud due to the distance to the cloud



Target Applications

Mobile off-loading applications

- Augmented reality applications
 - Face recognition application for individuals suffering from Alzheimer disease
 - Mobile eye track wearable computer (i.e. glasses)
 - Individuals who can use sign languages but cannot talk



Target Applications (Ref. 3)



	Cloudlet	Cloud
State	Only soft state	Hard and soft state
Management	Self-managed; little to no professional attention	Professionally administered, 24/7 operator
Environment	"Datacenter in a box" at business premises	Machine room with power conditioning and cooling
Ownership	Decentralized ownership by local business	Centralized ownership by Amazon, Yahoo, etc.
Network	LAN latency/bandwidth	Internet latency/bandwidth
Sharing	Few users at a time	Hundreds to thousands of users at a time

(b)

Figure 4. What is a cloudlet? (a) The cloudlet concept involves proximate computing infrastructure that can be leveraged by mobile devices; it has (b) some key differences with the basic cloud computing concept.

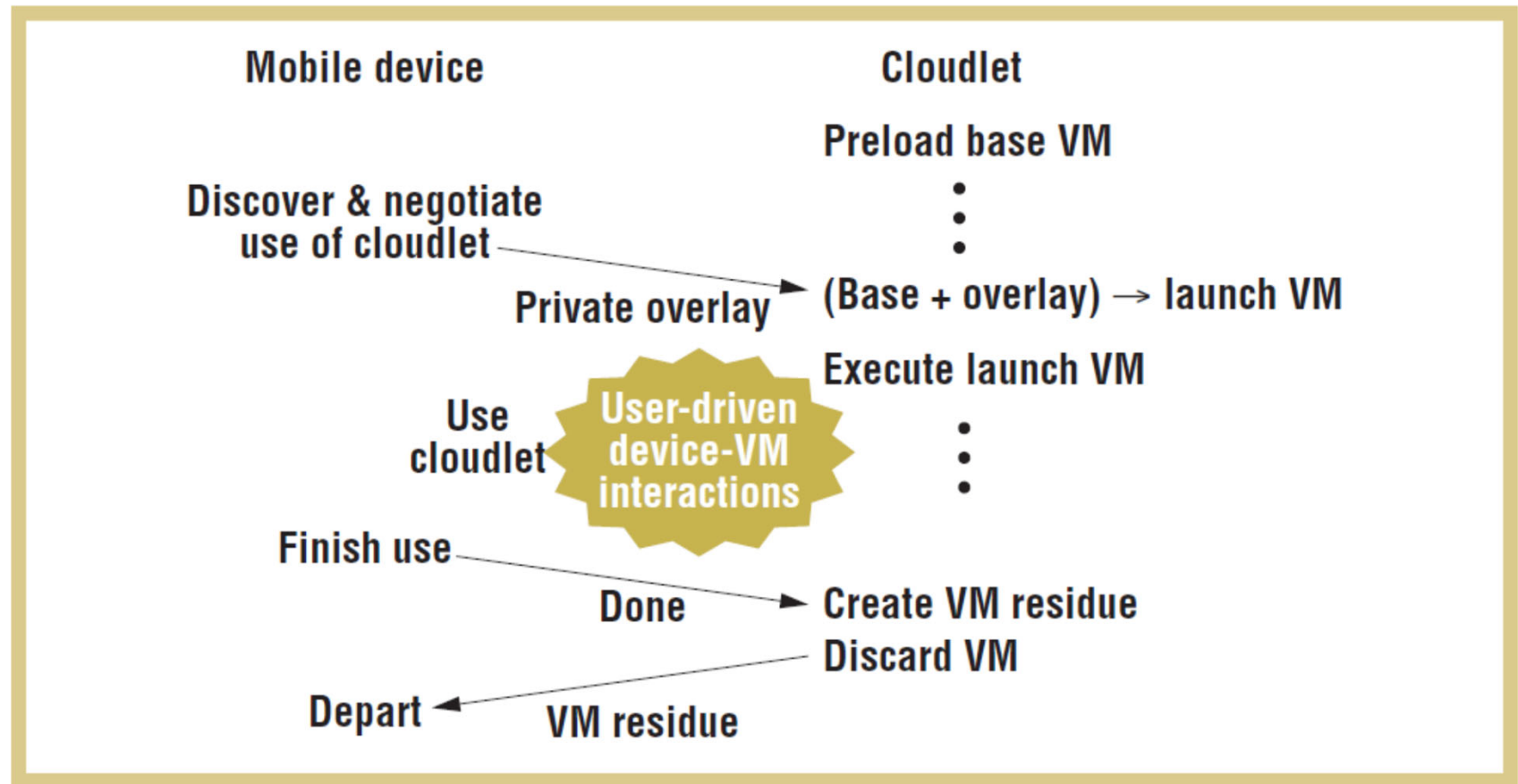
Characteristics

Cloudlet vs. Cloud

- Management
- Environment
- Ownership
- Network
- Sharing



Technology – Virtual Machine (Exclusively) – Ref. 3





Multi-access Mobile Edge Computing - MEC

(ETSI: An industry consortium
Work started in 2014)



Introduction

Work started in 2014

- Industry forum
 - European Telecommunications Standards Institute (ETSI)
 - Many major equipment suppliers and network operators
 - Focus:
 - How to use information provided by mobile networks (e.g. radio signal strength, user equipment location) to build powerful applications that rely on virtualization technologies



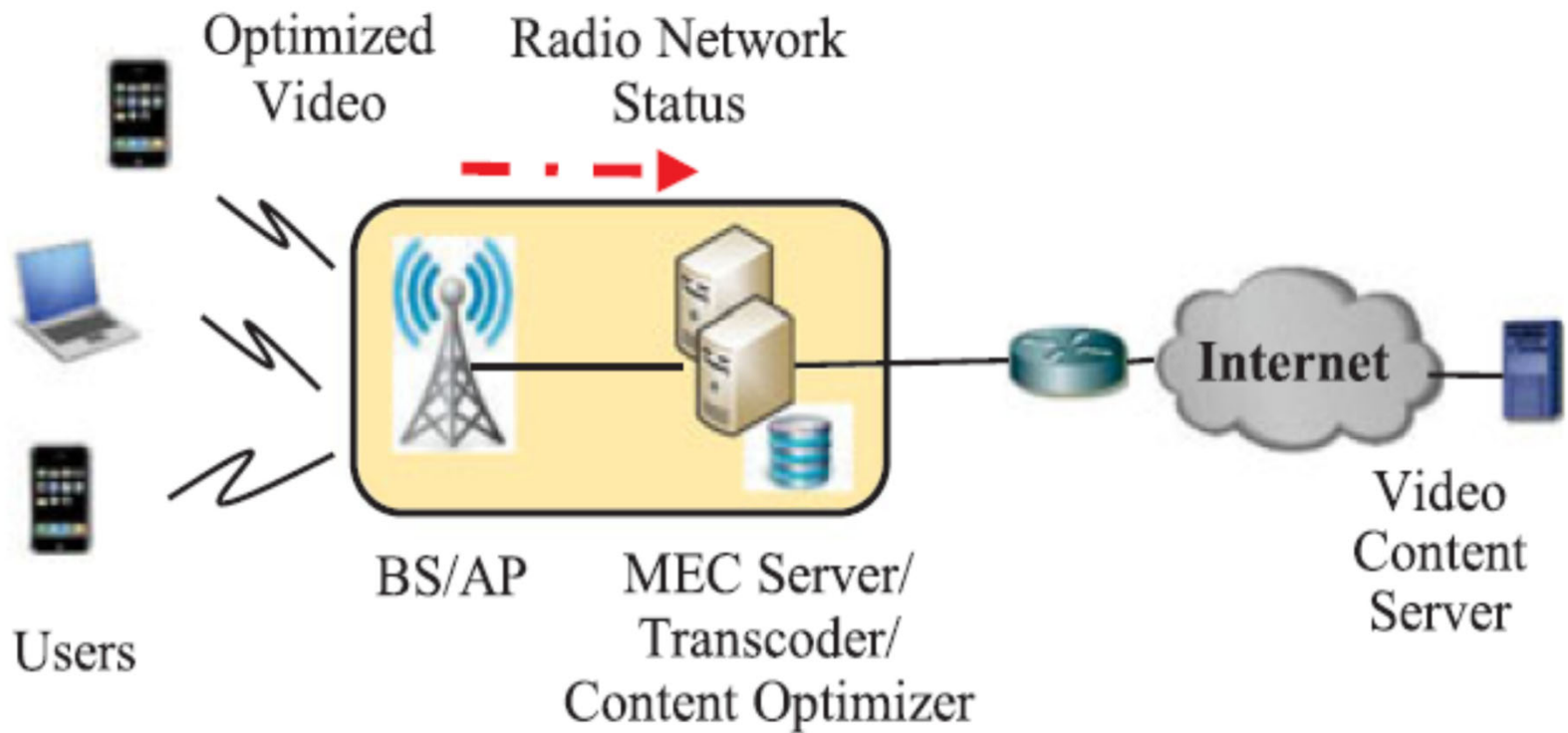
Target Applications

Any application that can run on the edge including mobile offloading applications.

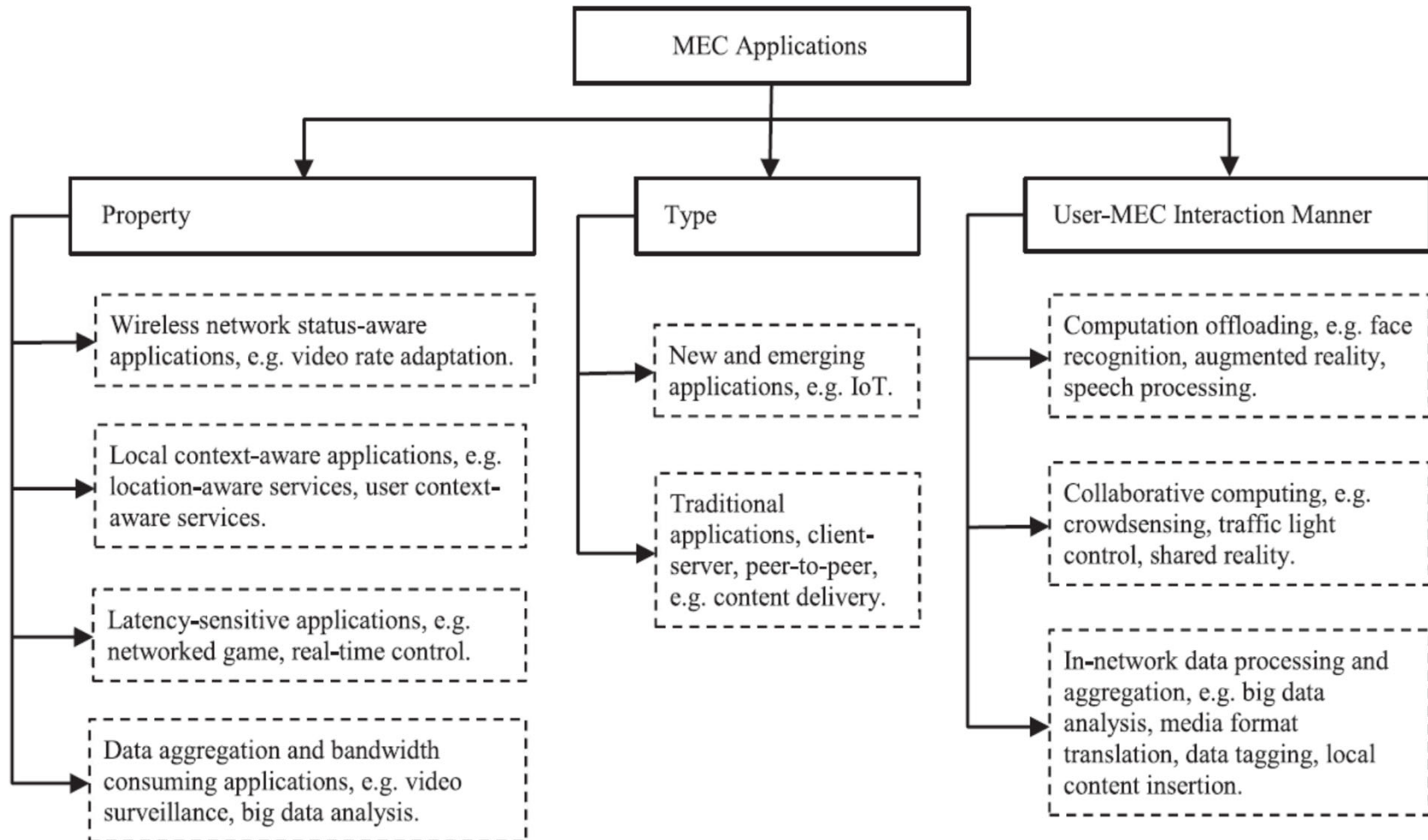
- Example and potential categorization (Ref. 4)



Target Applications (Ref. 4)



Target Applications (Ref. 4)



Characteristics (Ref. 4)

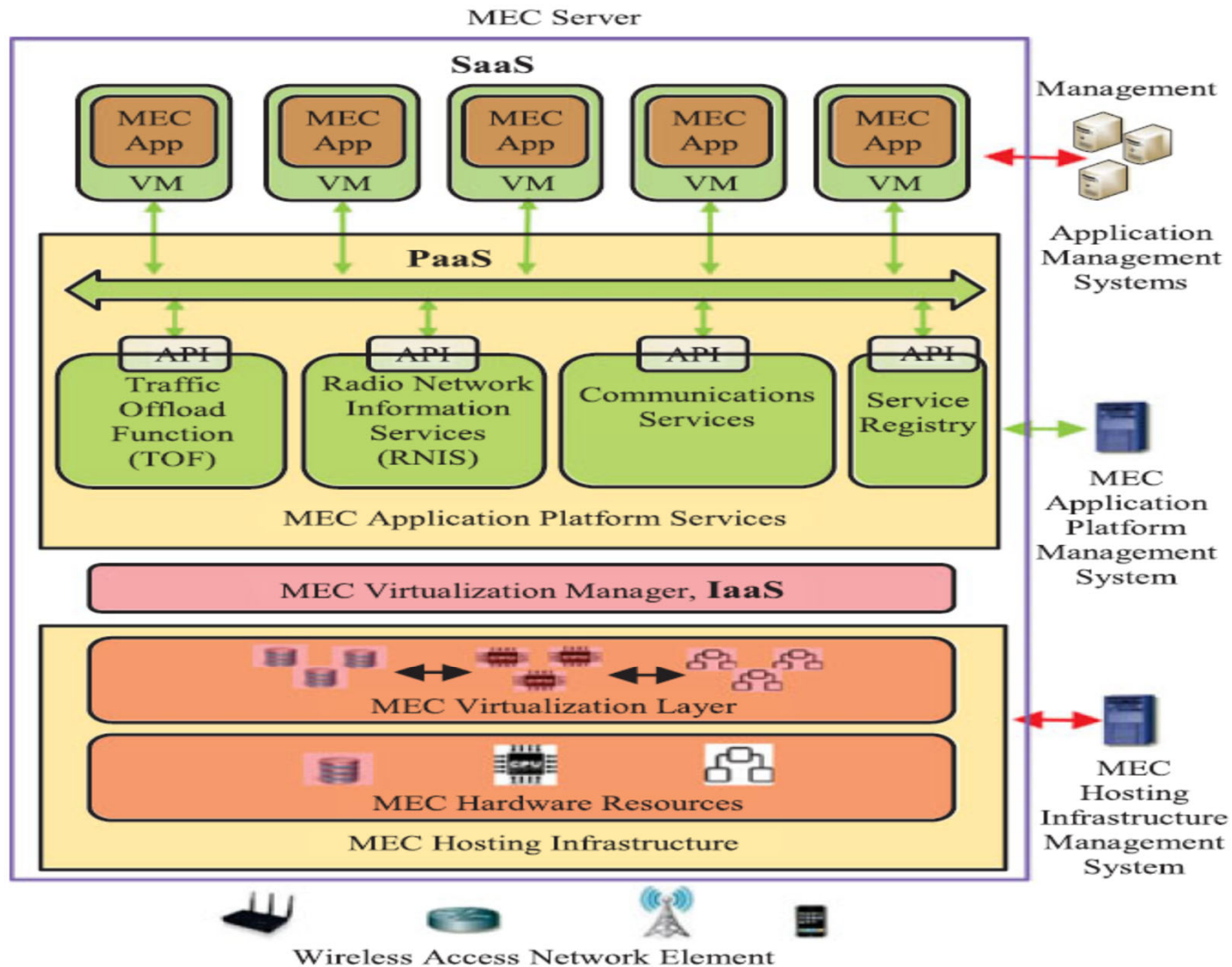
MEC vs. Cloud

TABLE I
CHARACTERISTICS OF MEC AND TRADITIONAL CLOUD COMPUTING

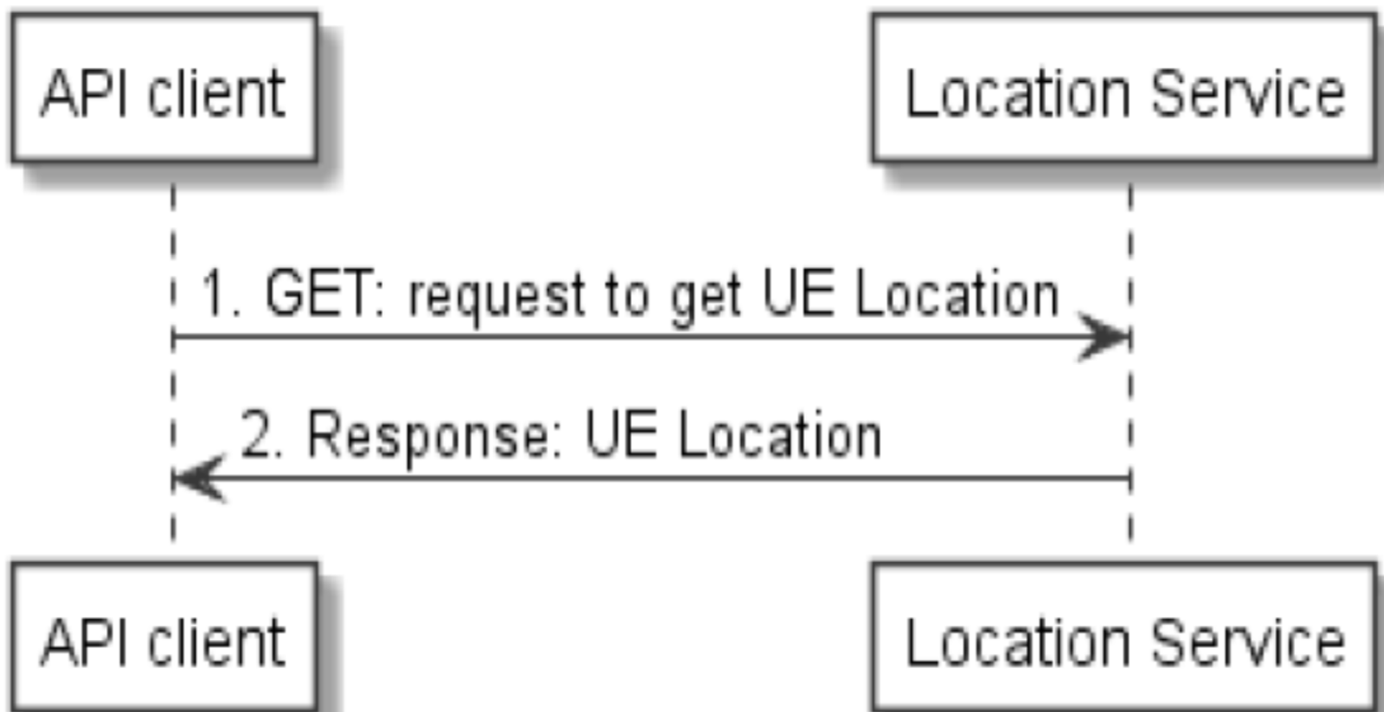
	MEC	Traditional Cloud
Resource & service location	At different levels of the wireless access network, BSs, APs, switches, routers, gateways, and mobile devices (close to mobile users)	Dedicated data centers on Internet (data needs to be sent to the data centers over Internet)
Service context awareness	Aware of local radio network status and user context	Location and user context available via application reporting
Latency	Low latency to support tactile Internet applications (several milliseconds)	Higher latency
Resource capability	Relatively limited (micro-datacenters)	Much more powerful
Resource heterogeneity	More heterogeneous and distributed with varying processing and storage resources and network connectivity.	Well-planned devices and networks in machine rooms.
Mobility	Mobile clients, services hosted on mobile devices	Mobile and fixed clients, services hosted on fixed servers
Services	User requested and network initiated (transparent) services	User requested services



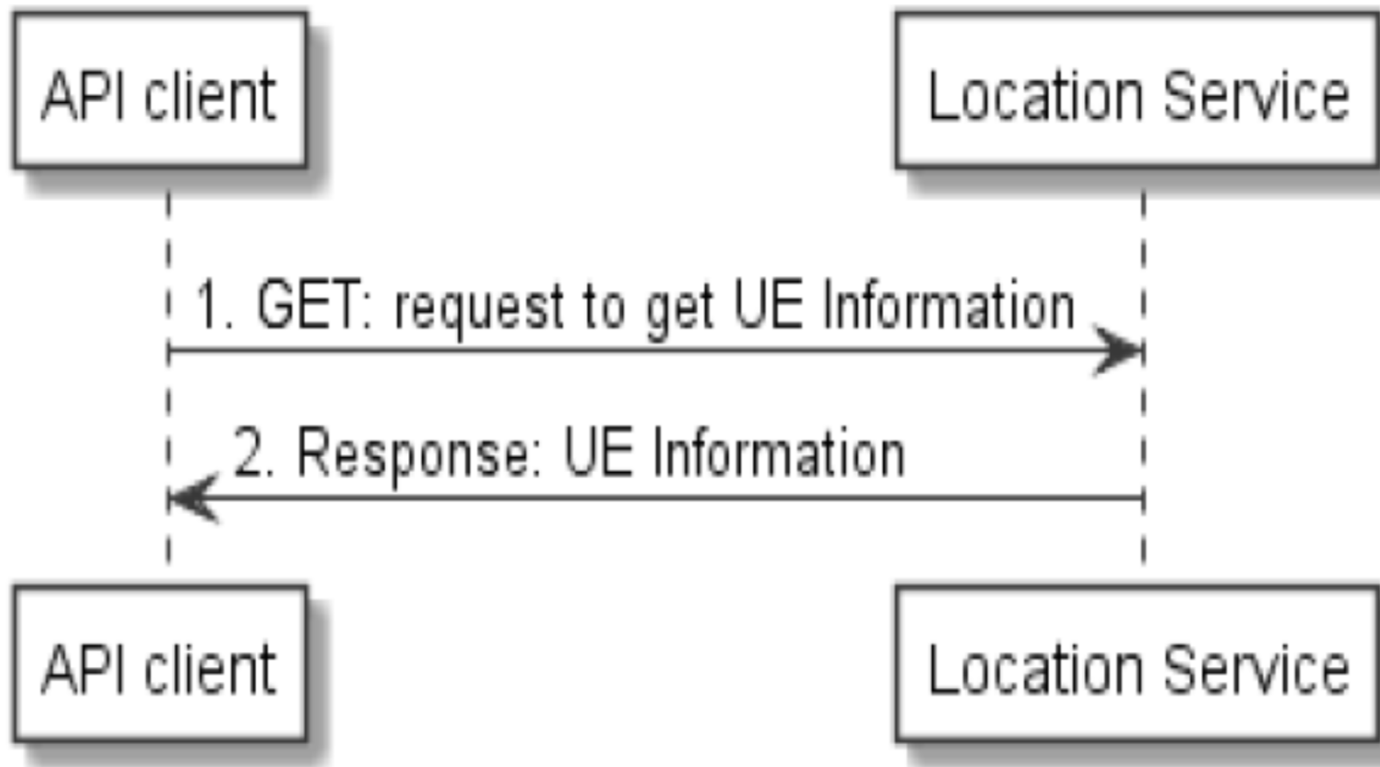
The MEC Server (Ref. 4)



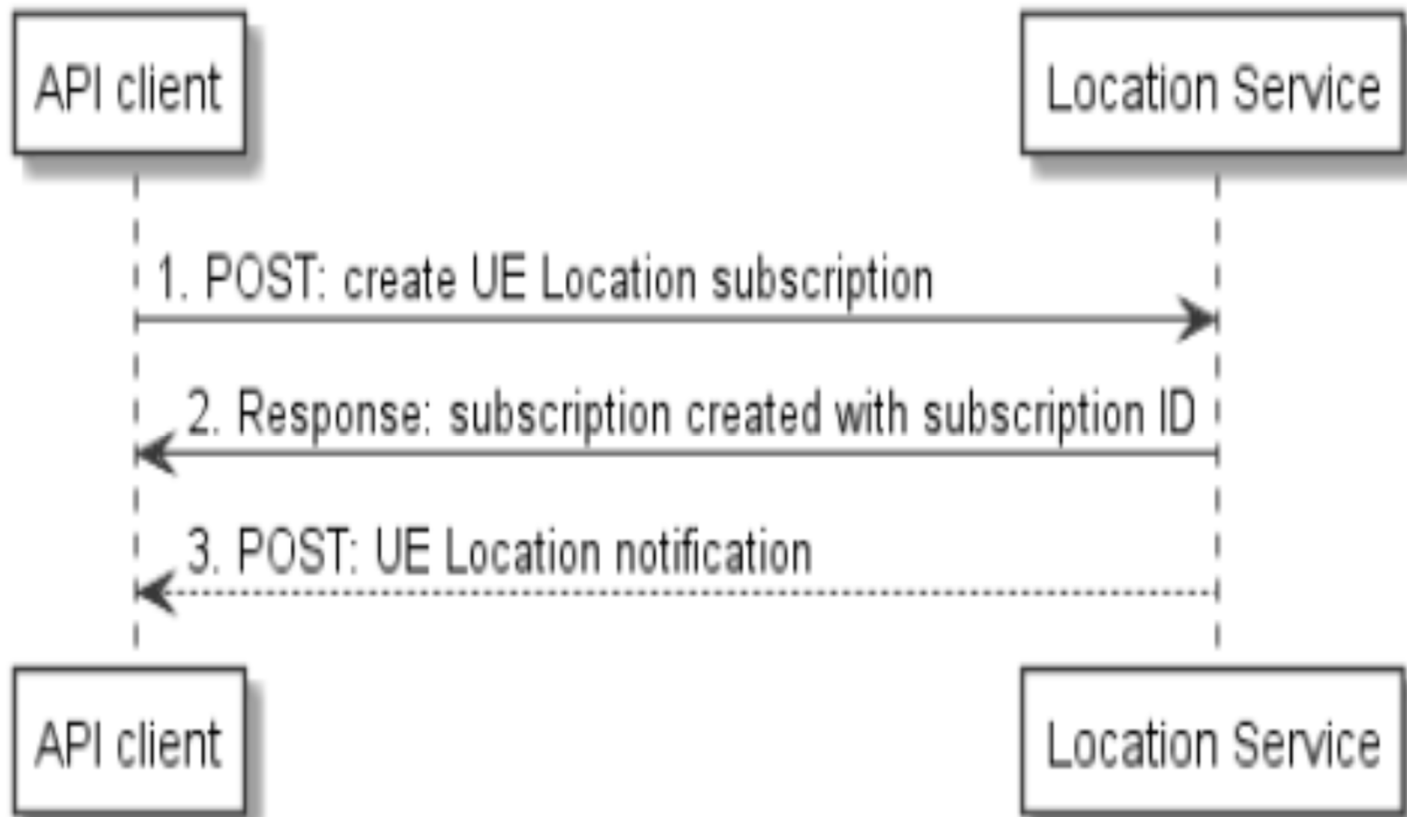
Examples of REST APIs Usage for Location (Ref. 5)



Examples of REST APIs Usage for Location (Ref. 5)



Examples of REST APIs Usage for Location (Ref. 5)





Fog Computing



Introduction

Work started in 2012

- CISCO R&D
- Standardization has now started
 - OpenFog consortium
- Few products on the market
 - Essentially CISCO products
- Wider concept than cloudlets and MEC



Target Applications

Any application that can run on the edge including mobile offloading applications.

+

Applications that can span cloud and fog (i.e. some components running in the cloud while other components are running in the fogs)



Characteristics – Ref 1

Fog complements the cloud

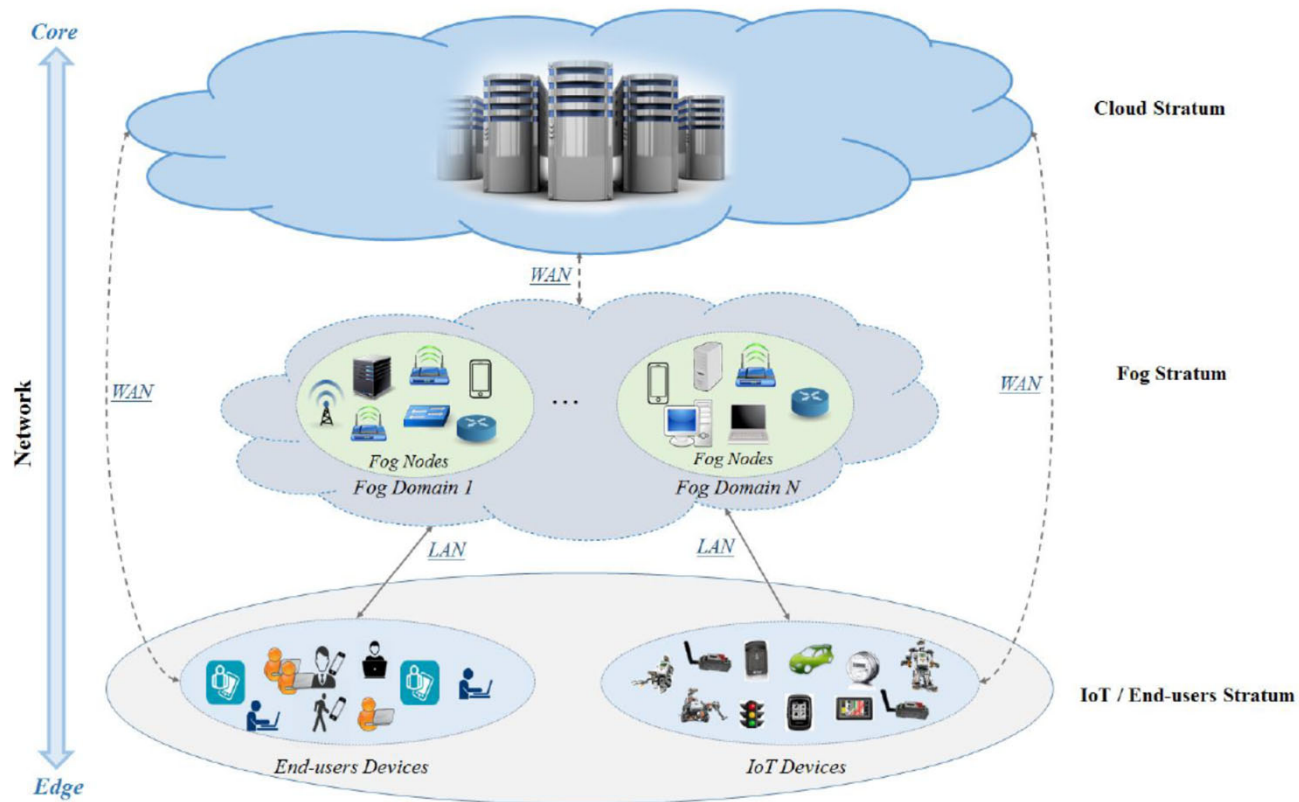


Fig. 4. The Fog System

Characteristics – Ref 1

Fog complements the cloud

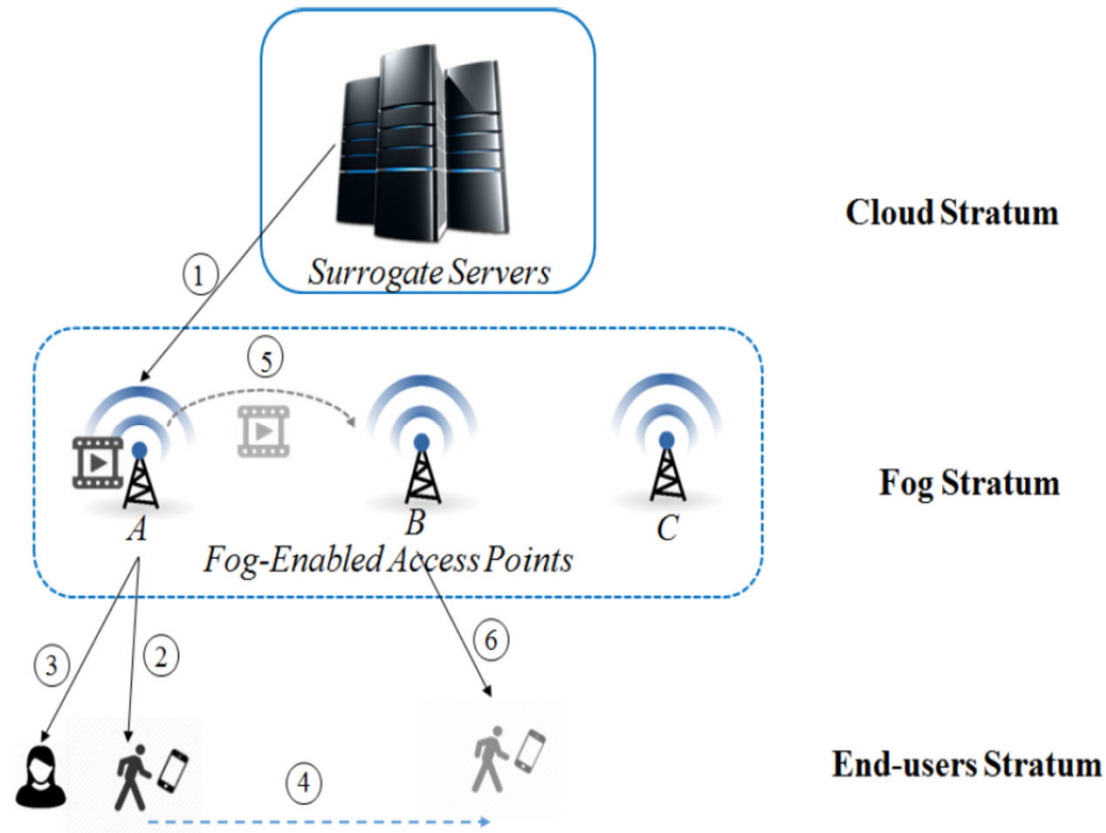


Fig. 6. A Fog System Use Case for CDN

Characteristics – Ref 1

Fog complements the cloud

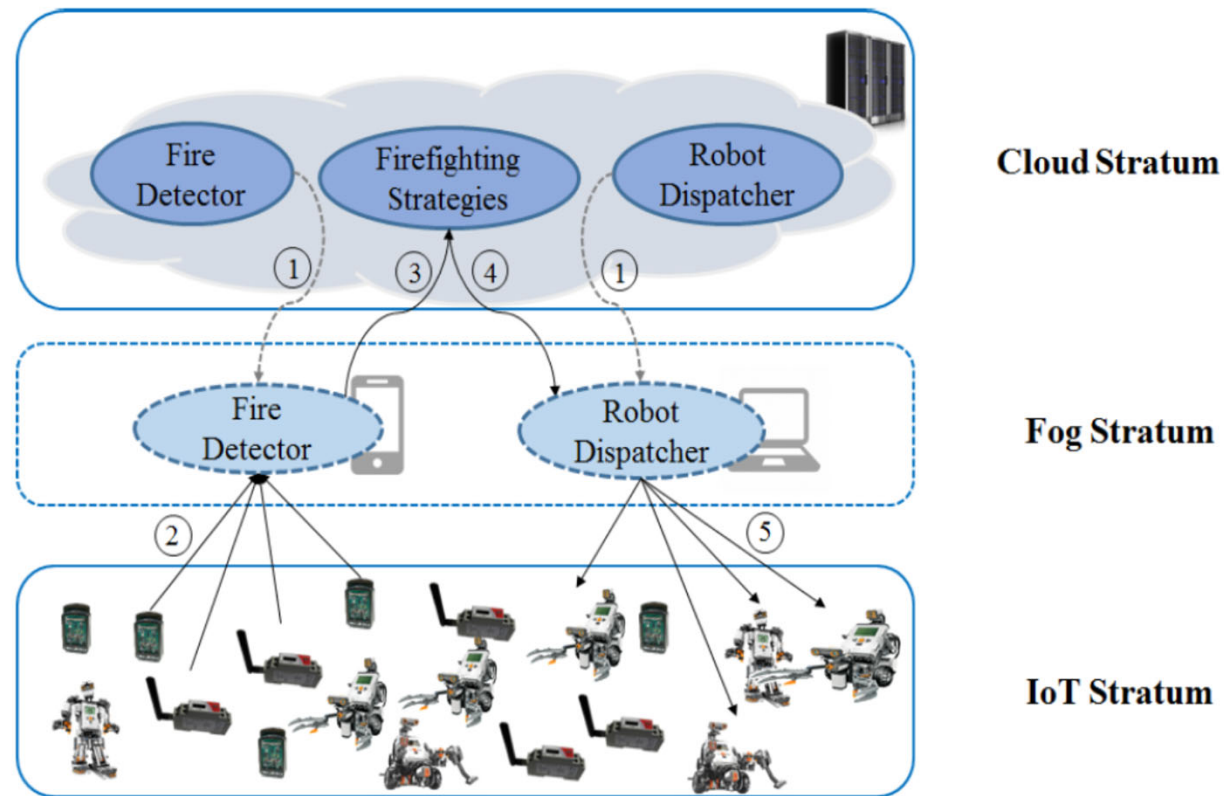


Fig. 7. A Fog System Use Case for Fire Detection and Fighting

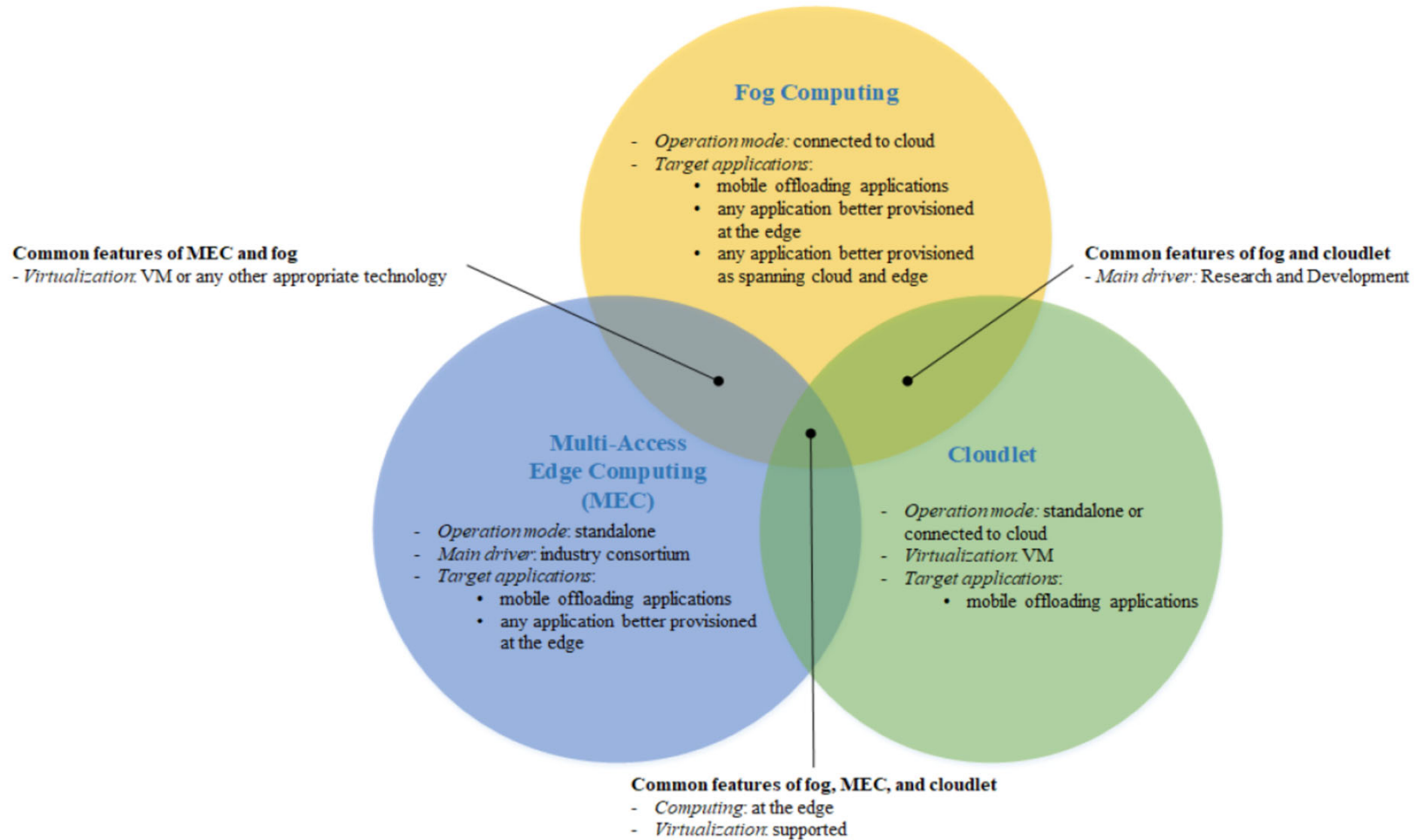




Summary



Summary – Ref 1



5. A Venn diagram for the Relationship between Fog Computing, Cloudlet, and MEC



The End

