Edge Computing

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

(ENCS 691K – Chapter 5)

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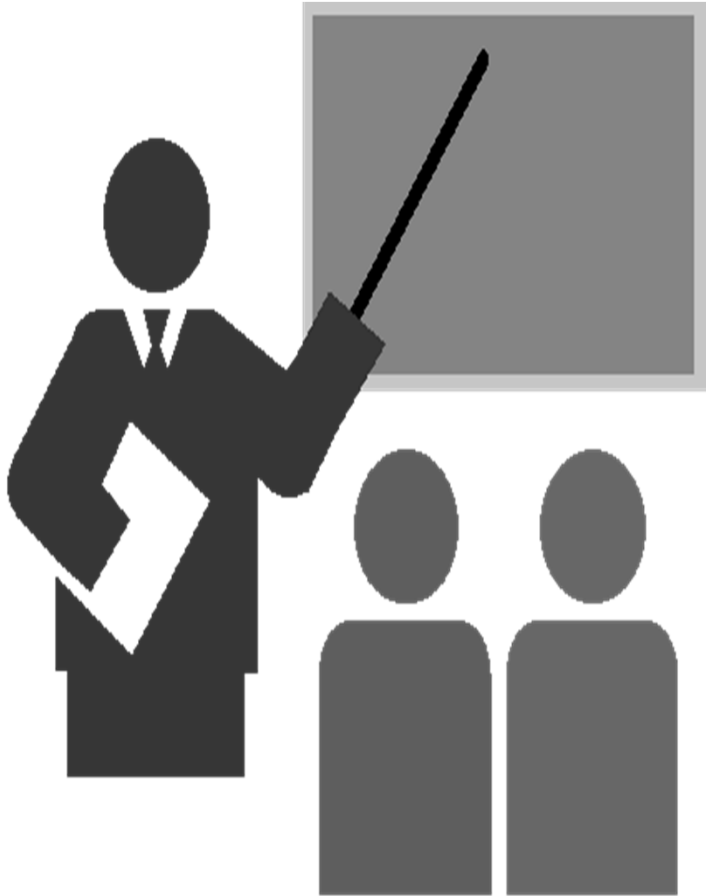**Associate Professor and Canada Research Chair**

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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 Satyanrayanan, 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**

- **Cloudlet**

- **Multi-acess 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
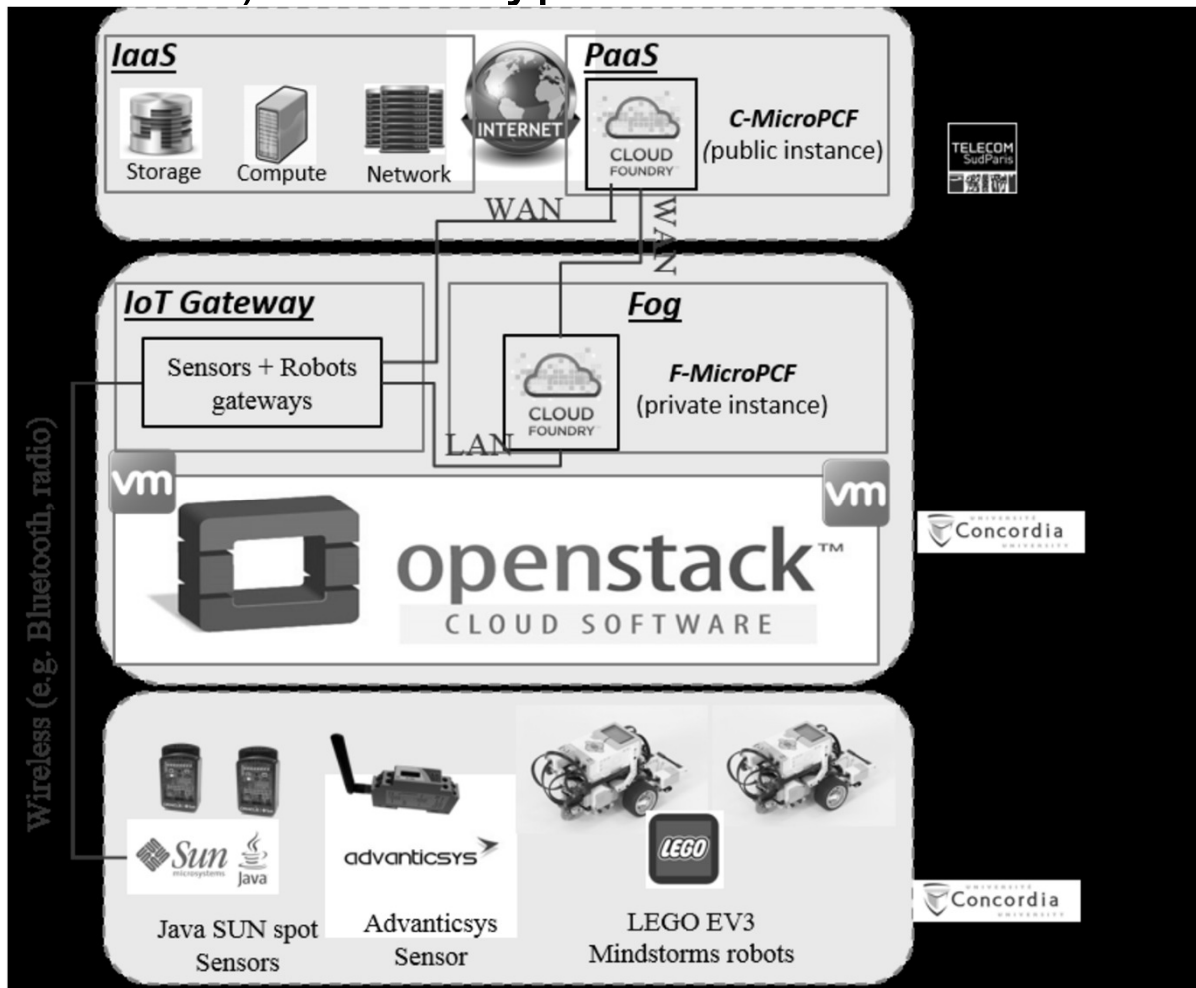   - Cloud owner might not have any data centre at the location

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

END TO END DELAY
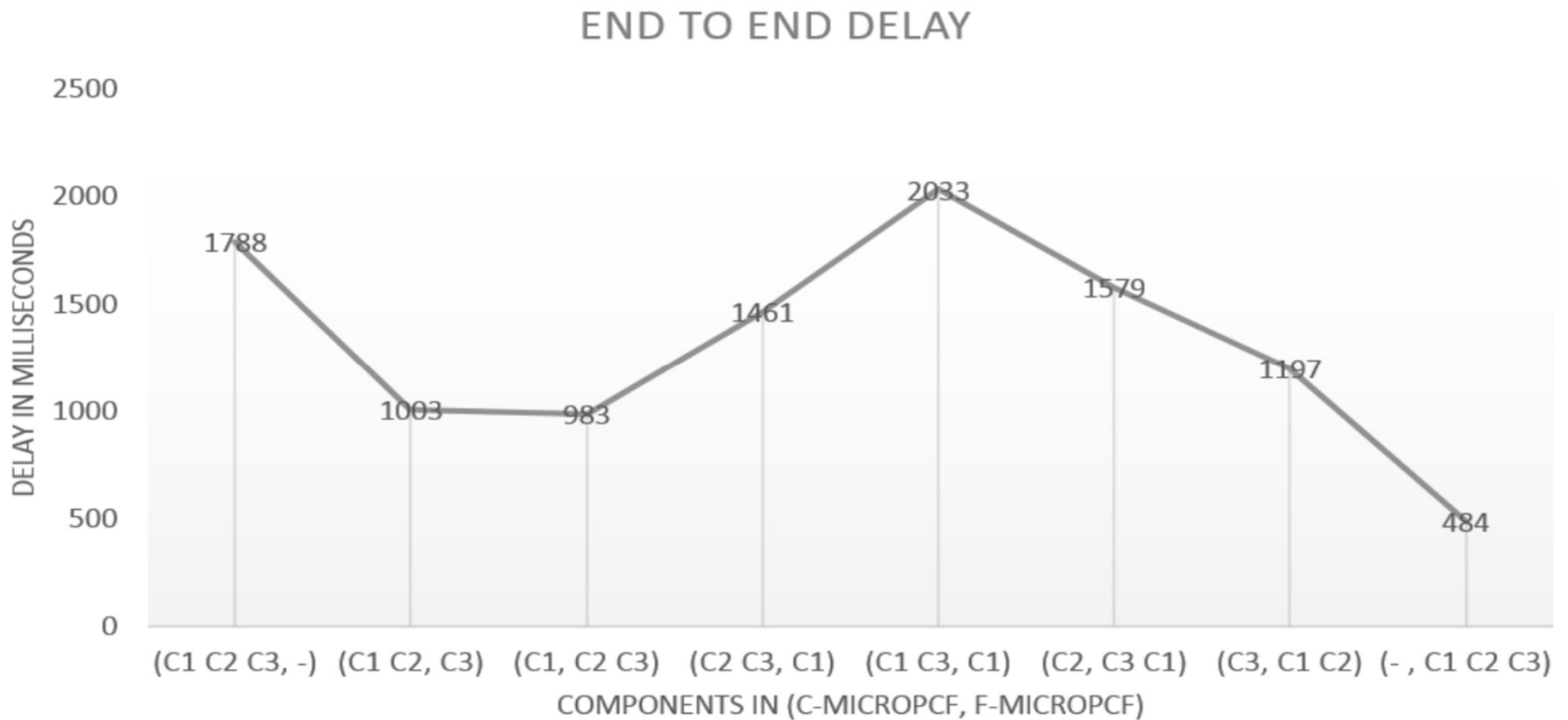
Motivation

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)
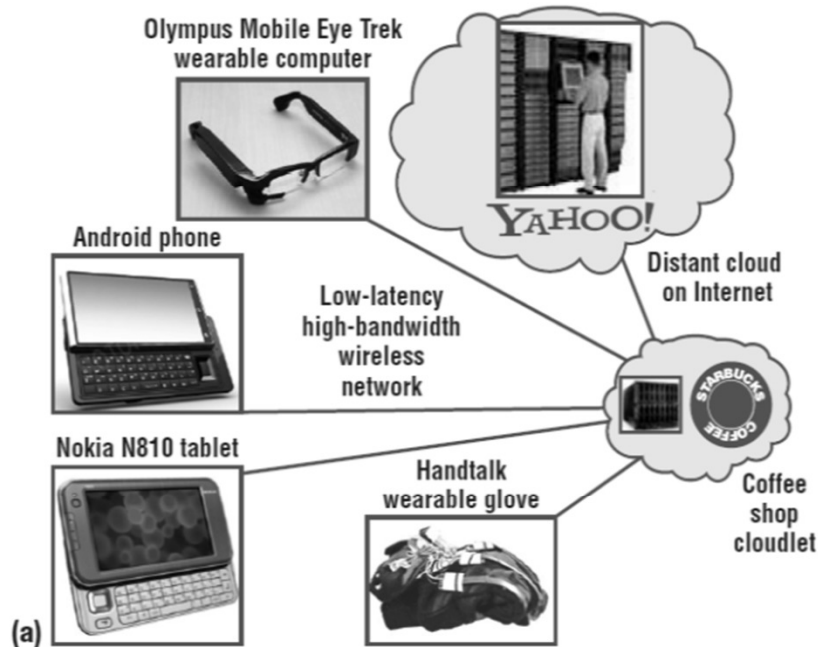
|	Cloudlet	Cloud
State	Only soft state	Hard and soft state
Management	Self-managed; little to no professional attention	Professionally administered, 24/7 operator
Environment	"Datacenter in a box" at business premises	Machine room with power conditioning and cooling
Ownership	Decentralized ownership 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

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
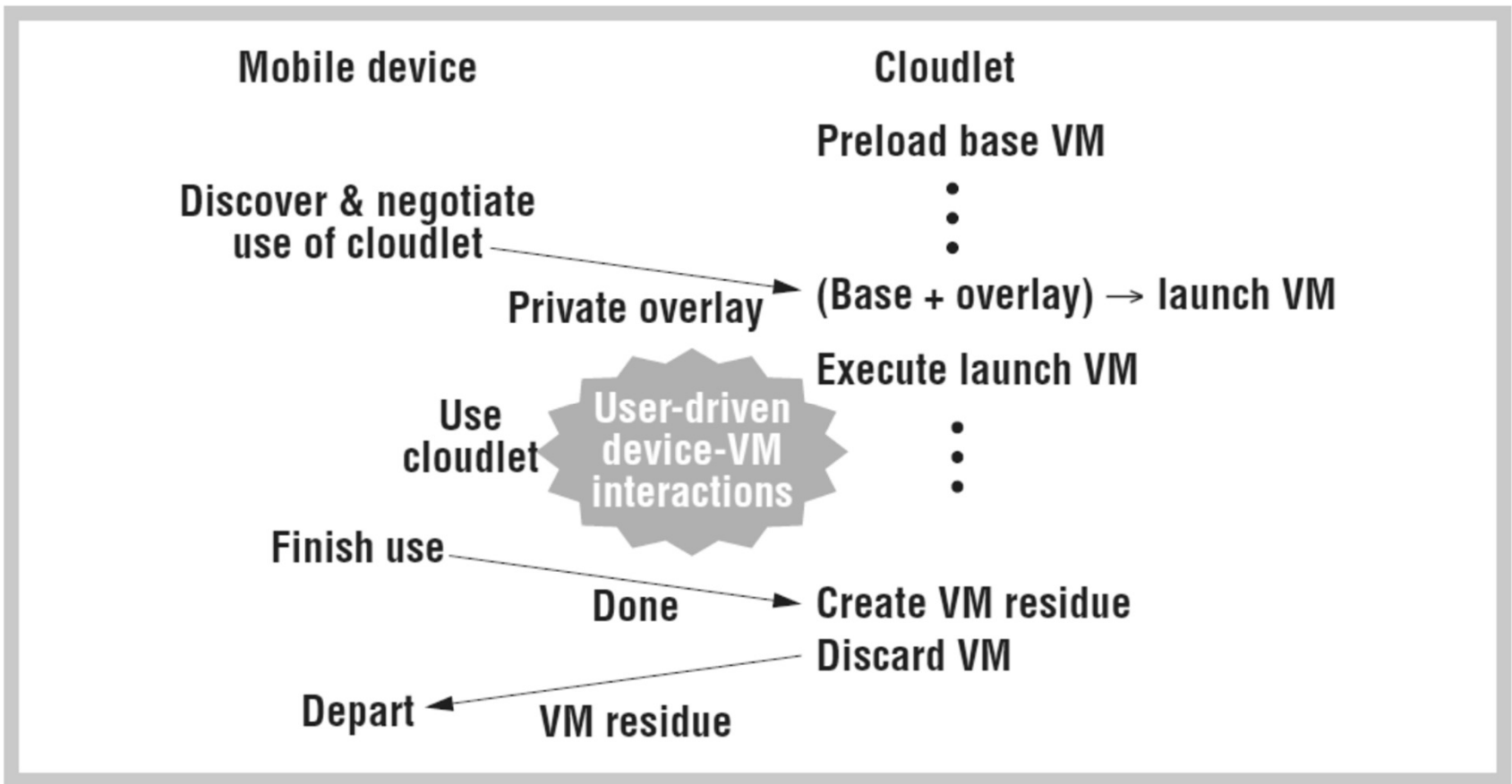
Multi-access Mobile Edge Computing - MEC

(ETSI: An industry consortium

Work started in 2014)

Introduction

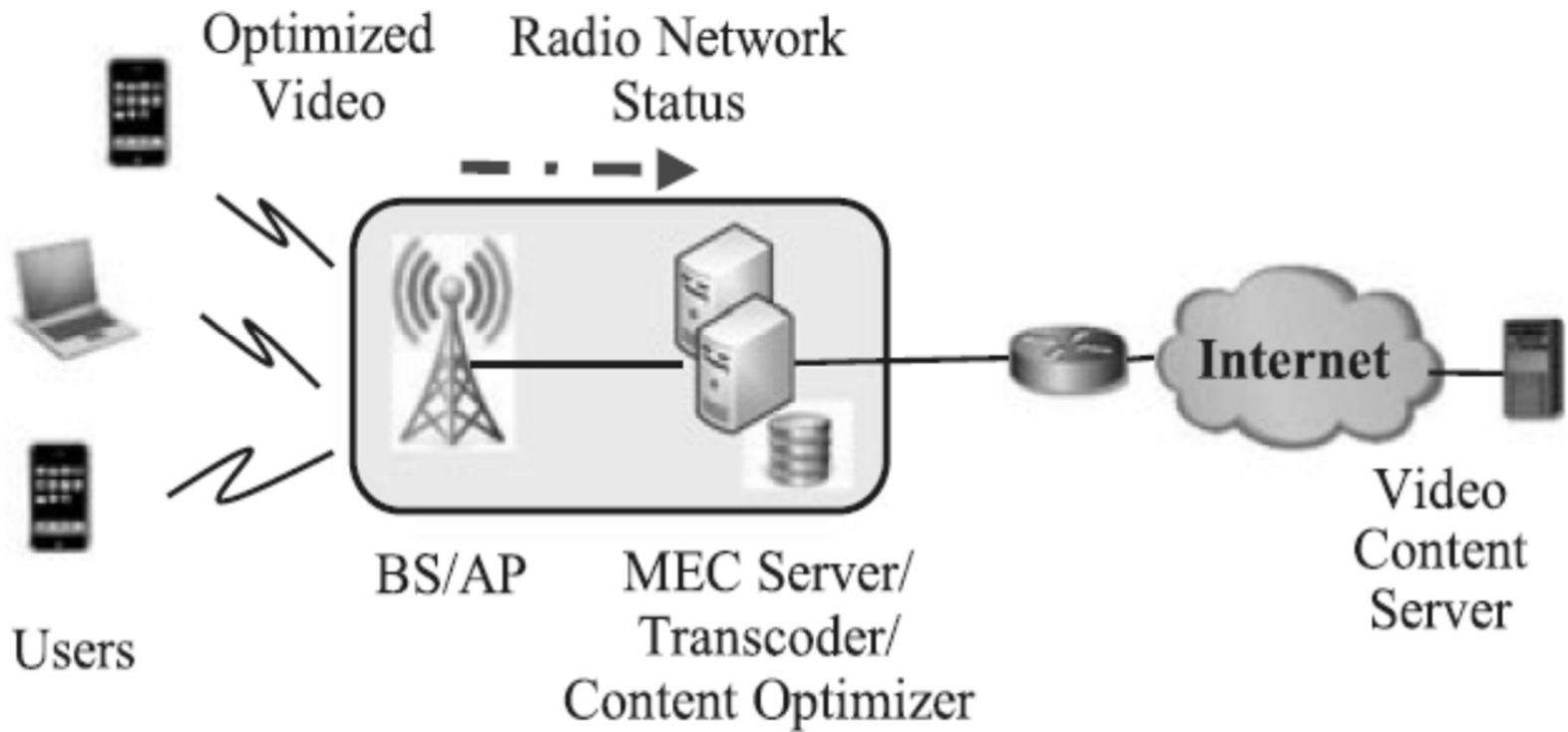## Work started in 2014

- 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
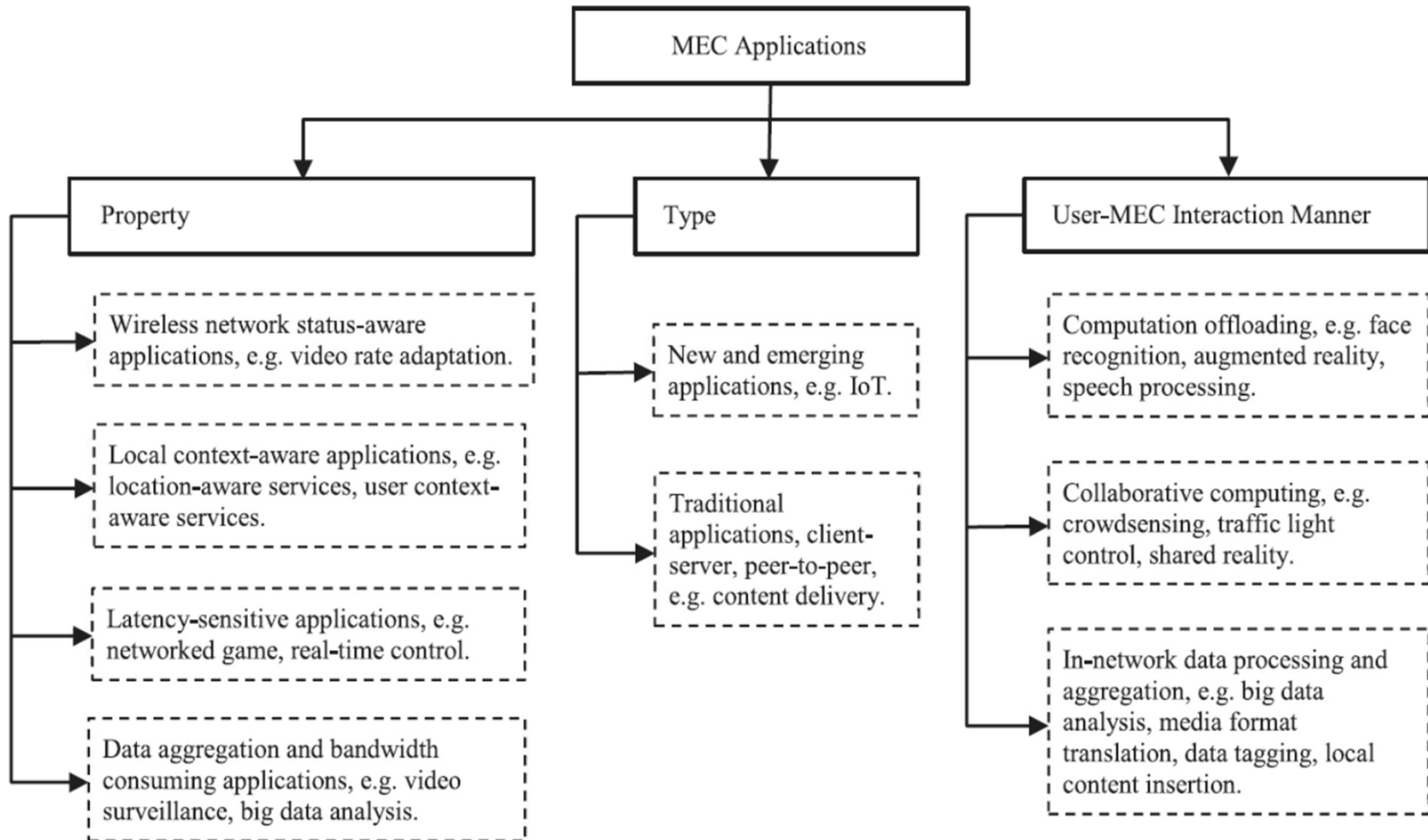
Target Applications

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

- Example and potential categorization (Ref. 4)
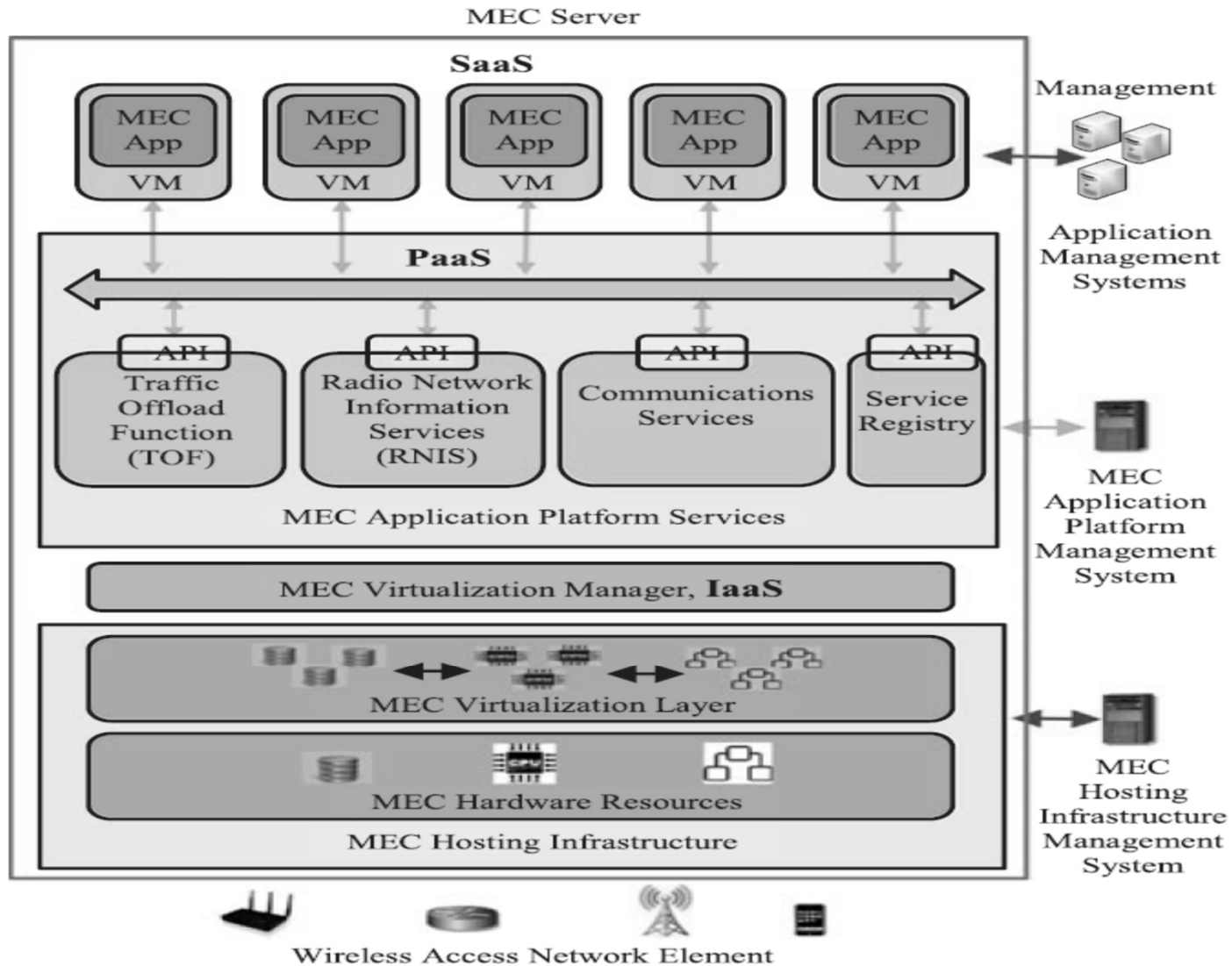
Target Applications (Ref. 4)

Optimized Video

Radio Network Status

BS/AP

MEC Server/ Transcoder/ Content Optimizer

Internet

Video Content Server

Users

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 hosed 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)

MEC Server

SaaS

MEC App VM · MEC App VM · MEC App VM · MEC App VM · MEC App VM

Management

Application Management Systems

PaaS

API — Traffic Offload Function (TOF)

API — Radio Network Information Services (RNIS)

API — Communications Services

API — Service Registry

MEC Application Platform Services

MEC Application Platform Management System

MEC Virtualization Manager, IaaS

MEC Virtualization Layer

MEC Hardware Resources

MEC Hosting Infrastructure

MEC Hosting Infrastructure Management System
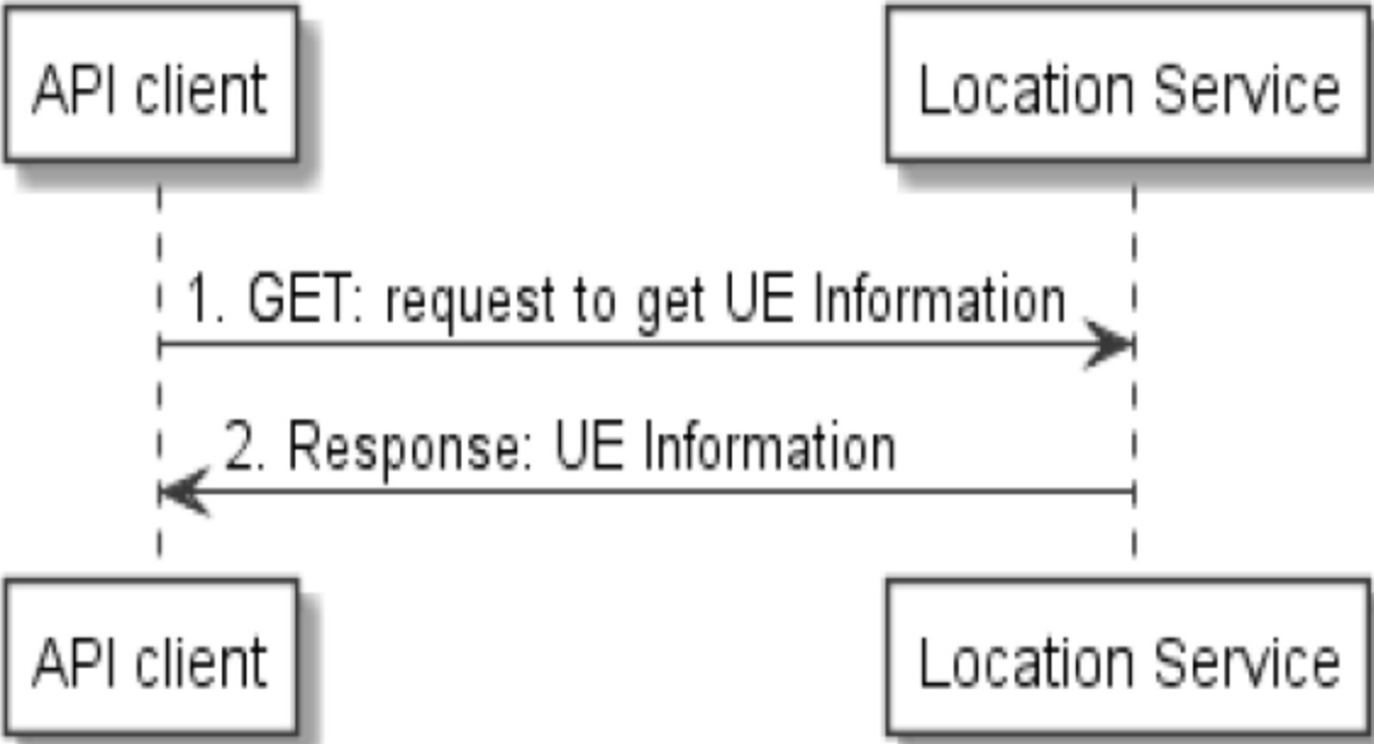
Wireless Access Network Element

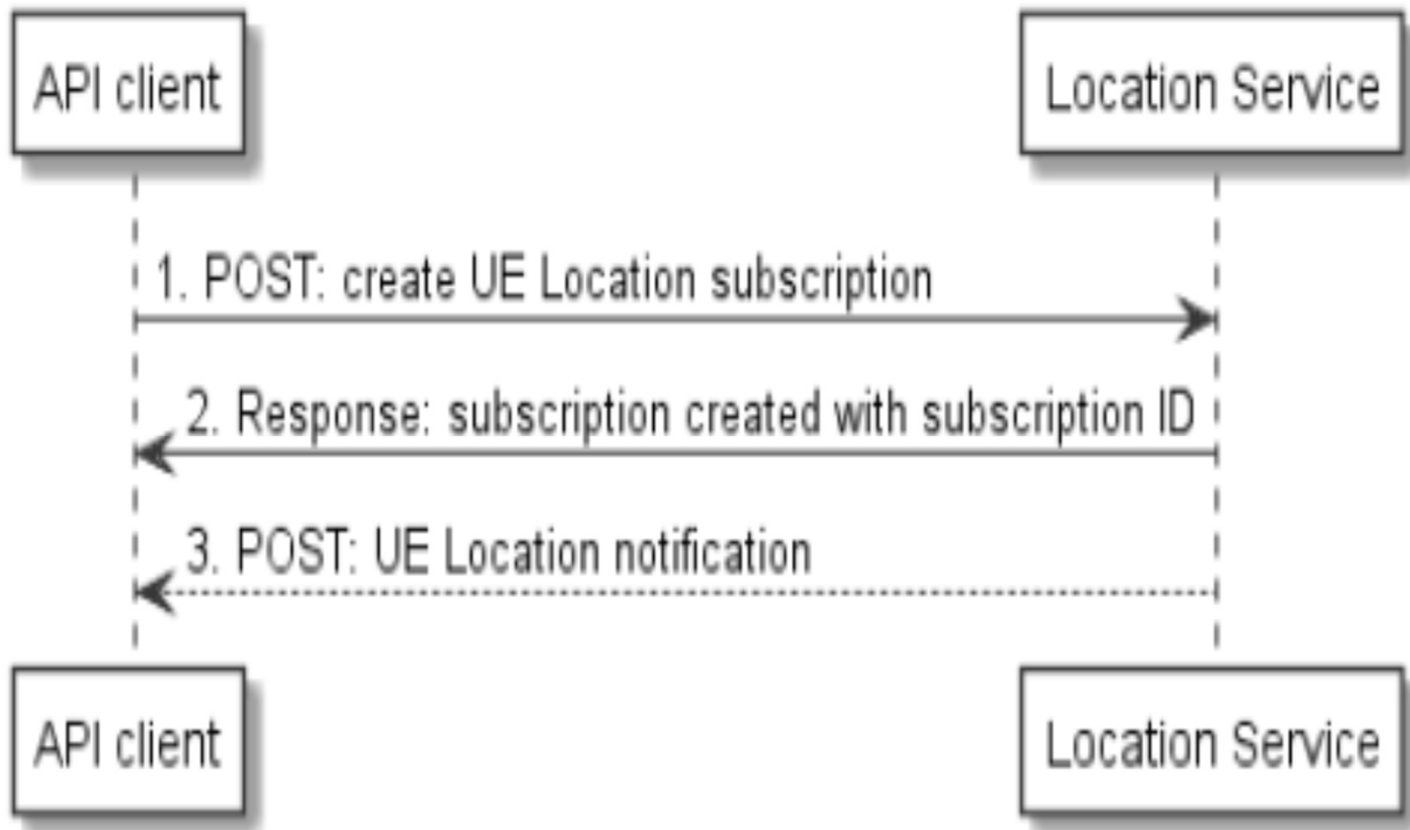# Examples of REST APIs Usage for Location (Ref. 5)

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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
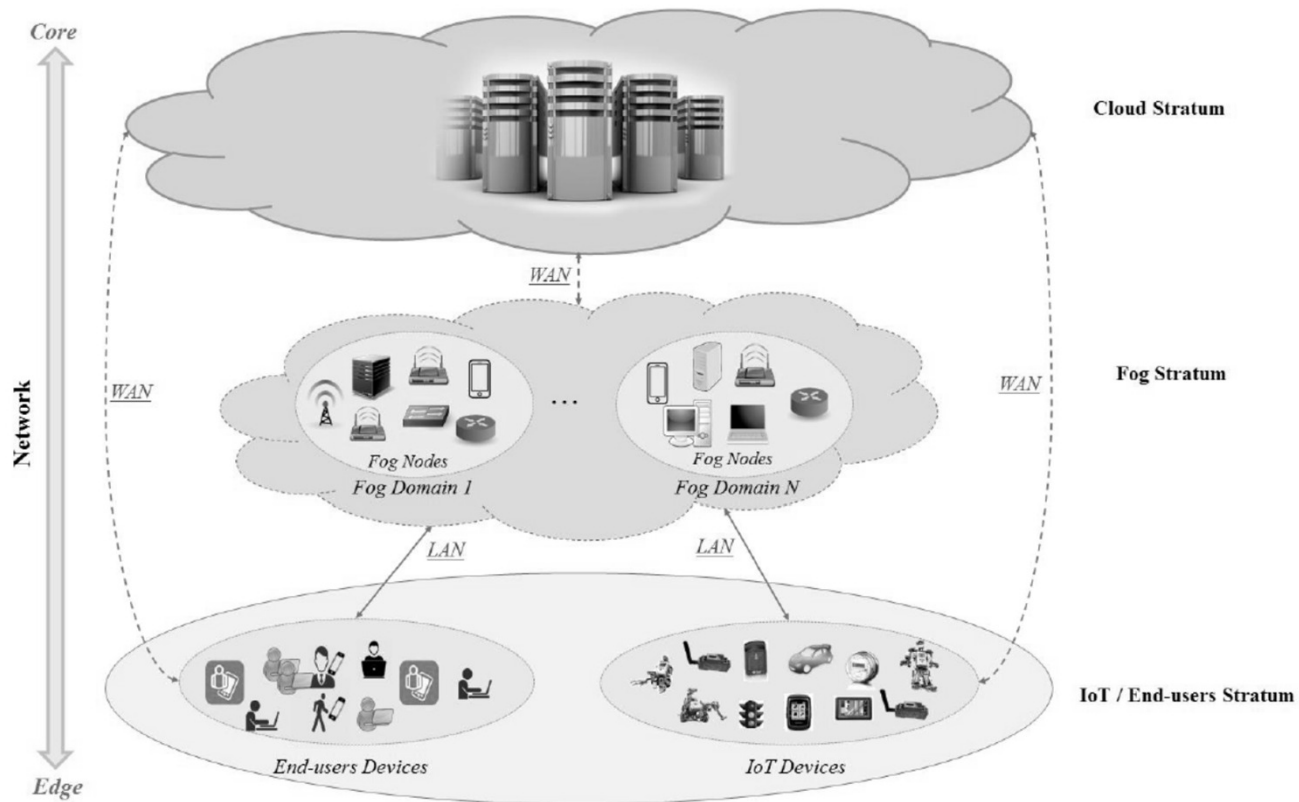
Fog complements the cloud

Fig. 4. The Fog System

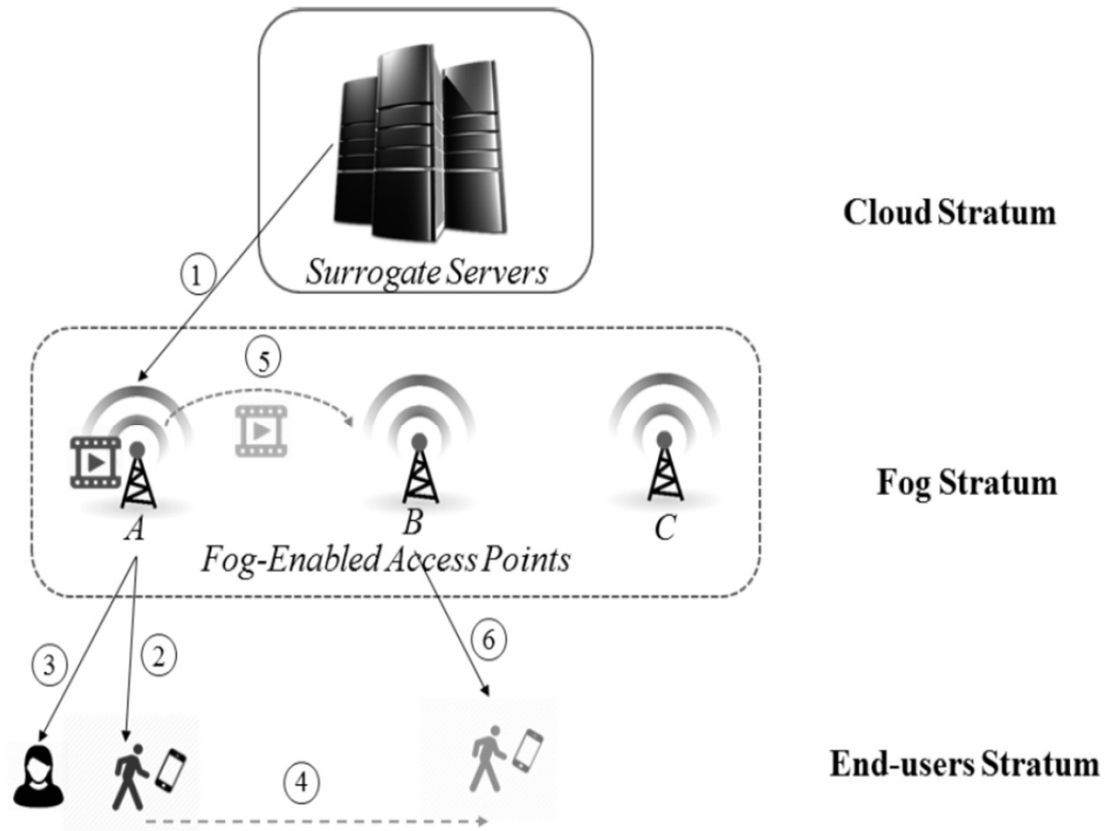# Characteristics – Ref 1

Fog complements the cloud

Fig. 6. A Fog System Use Case for CDN

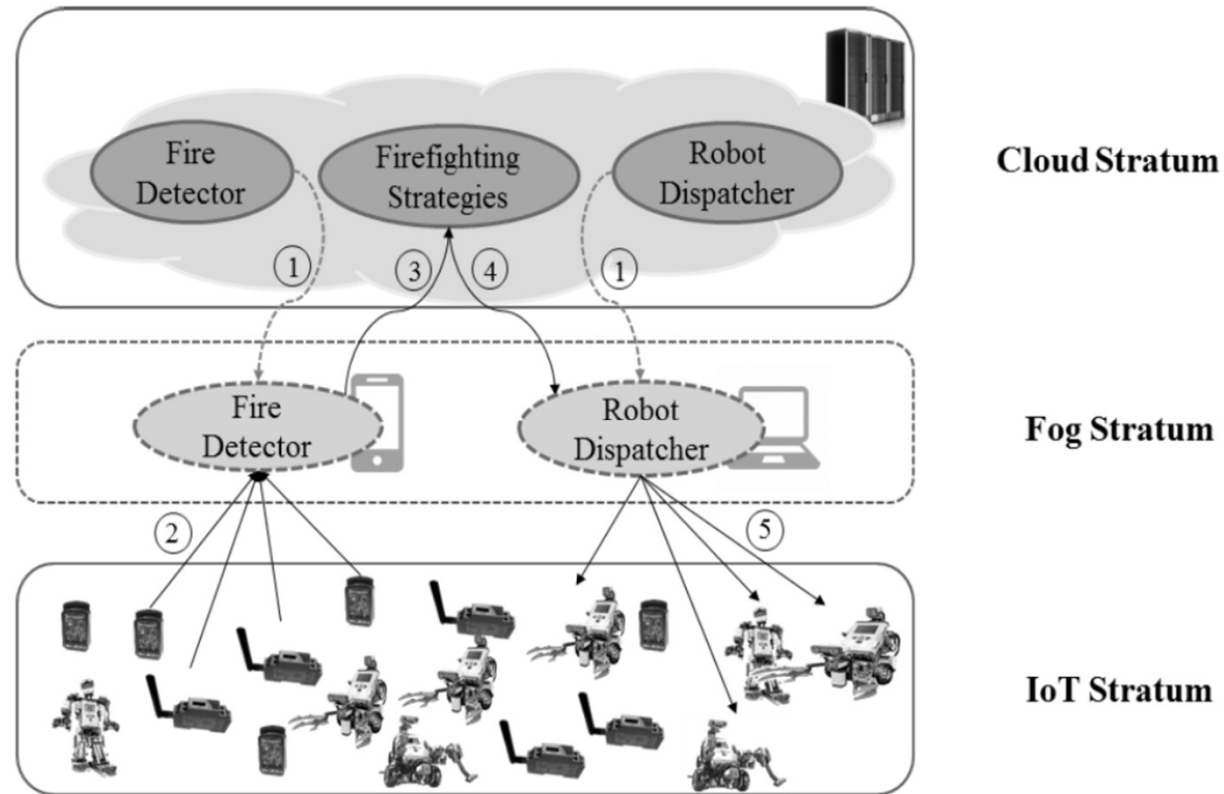# Characteristics – Ref 1

Fog complements the cloud

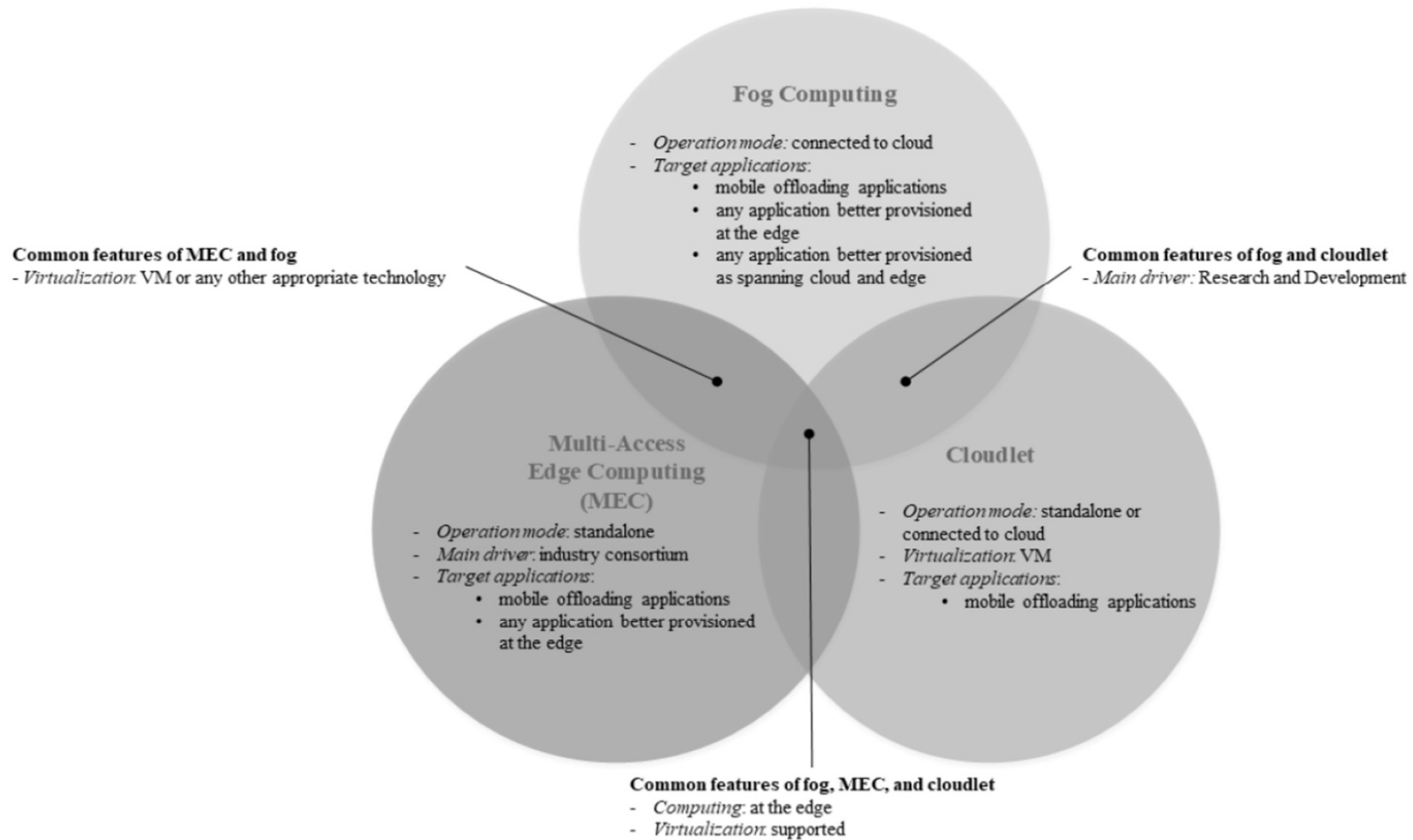Fig. 7. A Fog System Use Case for Fire Detection and Fighting

Summary

Summary – Ref 1

Fog Computing

- *Operation mode:* connected to cloud
- *Target applications:*
  - mobile offloading applications
  - any application better provisioned at the edge
  - any application better provisioned as spanning cloud and edge

Common features of MEC and fog
- *Virtualization.* VM or any other appropriate technology

Common features of fog and cloudlet
- *Main driver:* Research and Development

Multi-Access Edge Computing (MEC)

- *Operation mode:* standalone
- *Main driver:* industry consortium
- *Target applications:*
  - mobile offloading applications
  - any application better provisioned at the edge

Cloudlet

- *Operation mode:* standalone or connected to cloud
- *Virtualization.* VM
- *Target applications:*
  - mobile offloading applications

Common features of fog, MEC, and cloudlet
- *Computing:* at the edge
- *Virtualization.* supported

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

The End