Network Performance Evaluation with EdgeCloudSim

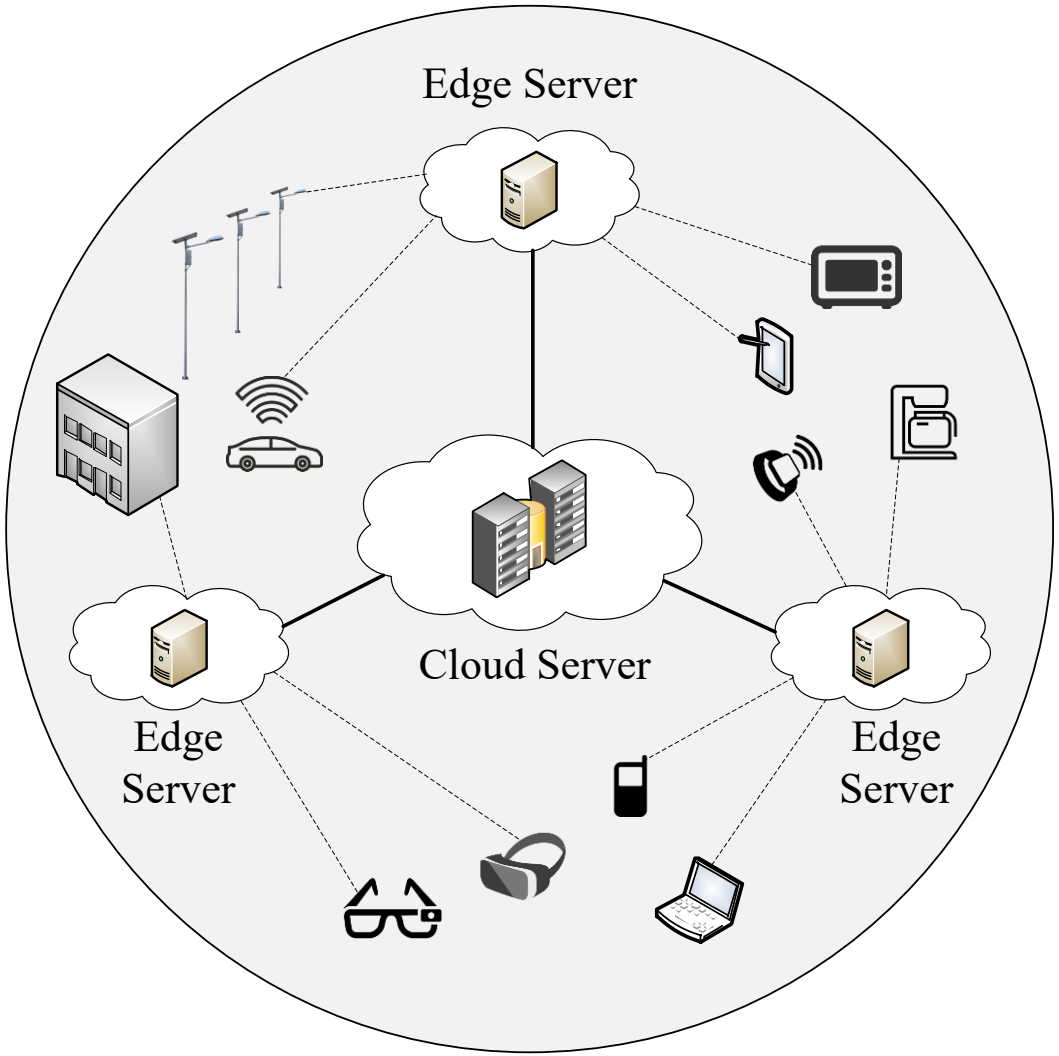
18.05.2021

Çağatay Sönmez

Agenda

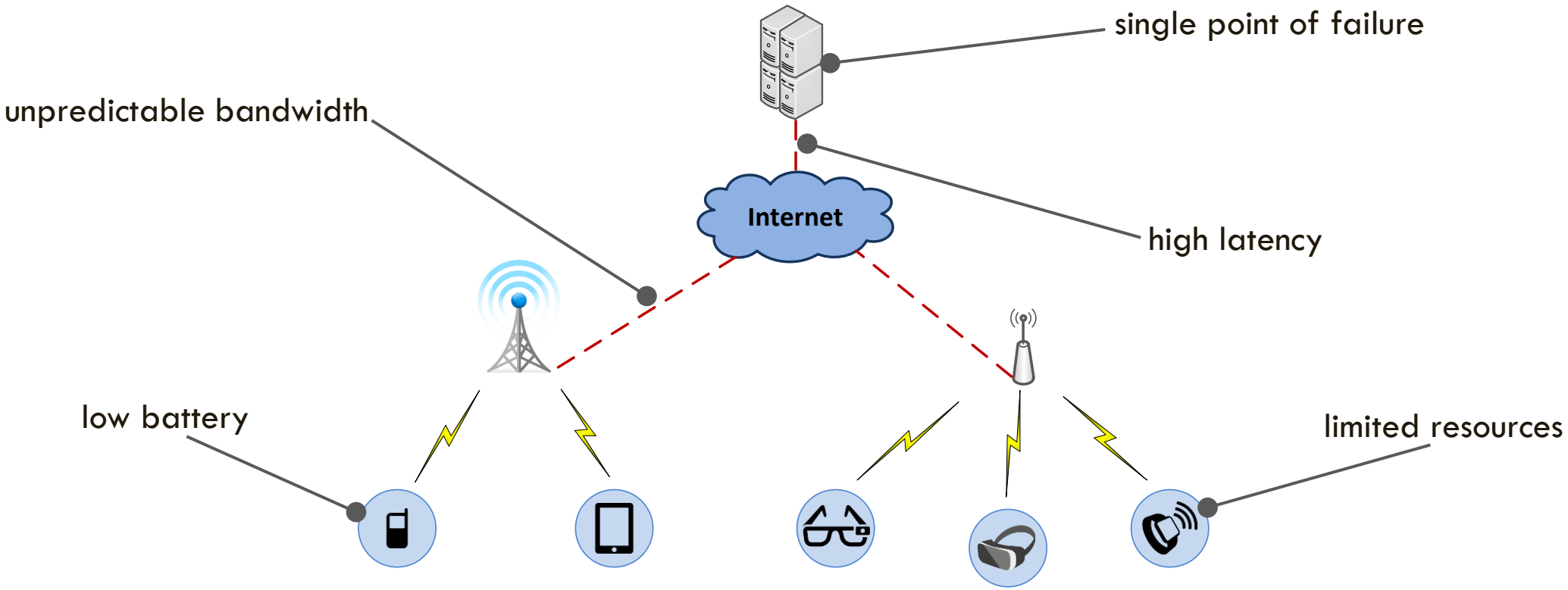
- Introduction to Edge Computing
- Challenges in Edge Computing Systems
- EdgeCloudSim
- Example Performance Evaluation Studies with EdgeCloudSim
  - Fuzzy Logic Based Workload Orchestrator
  - Machine Learning Based Workload Orchestrator
- A Network Performance Evaluation Case Study on EdgeCloudSim

What is Edge Computing

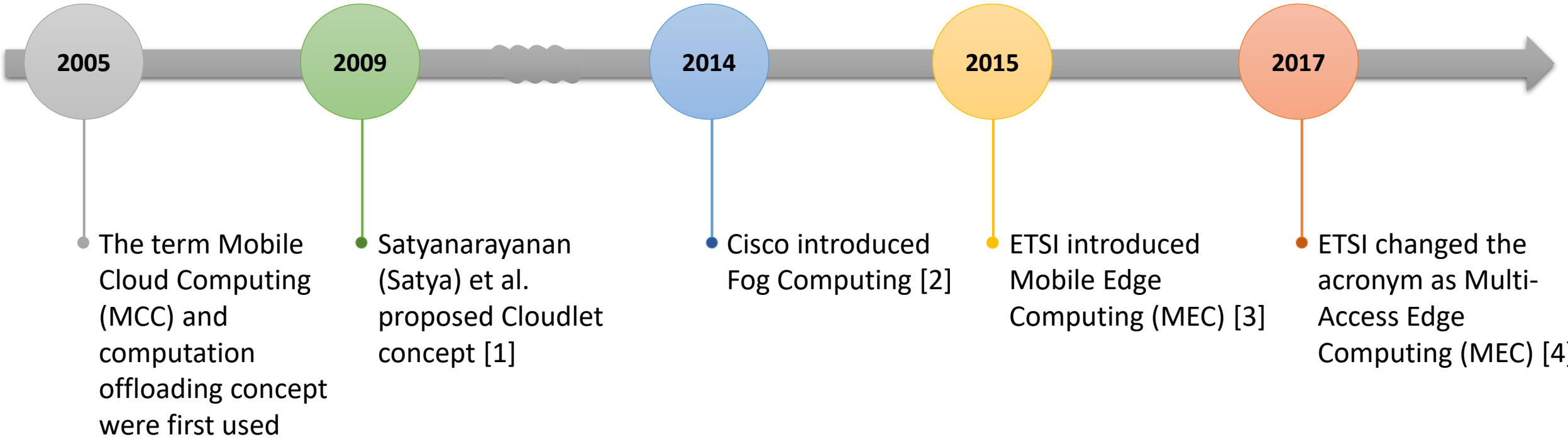


- Makes it possible to get services from nearby (edge) micro cloud server
- Data processing and storage are moved from the mobile device
- Complex operations can be executed on the edge server instead of local execution on the mobile devices

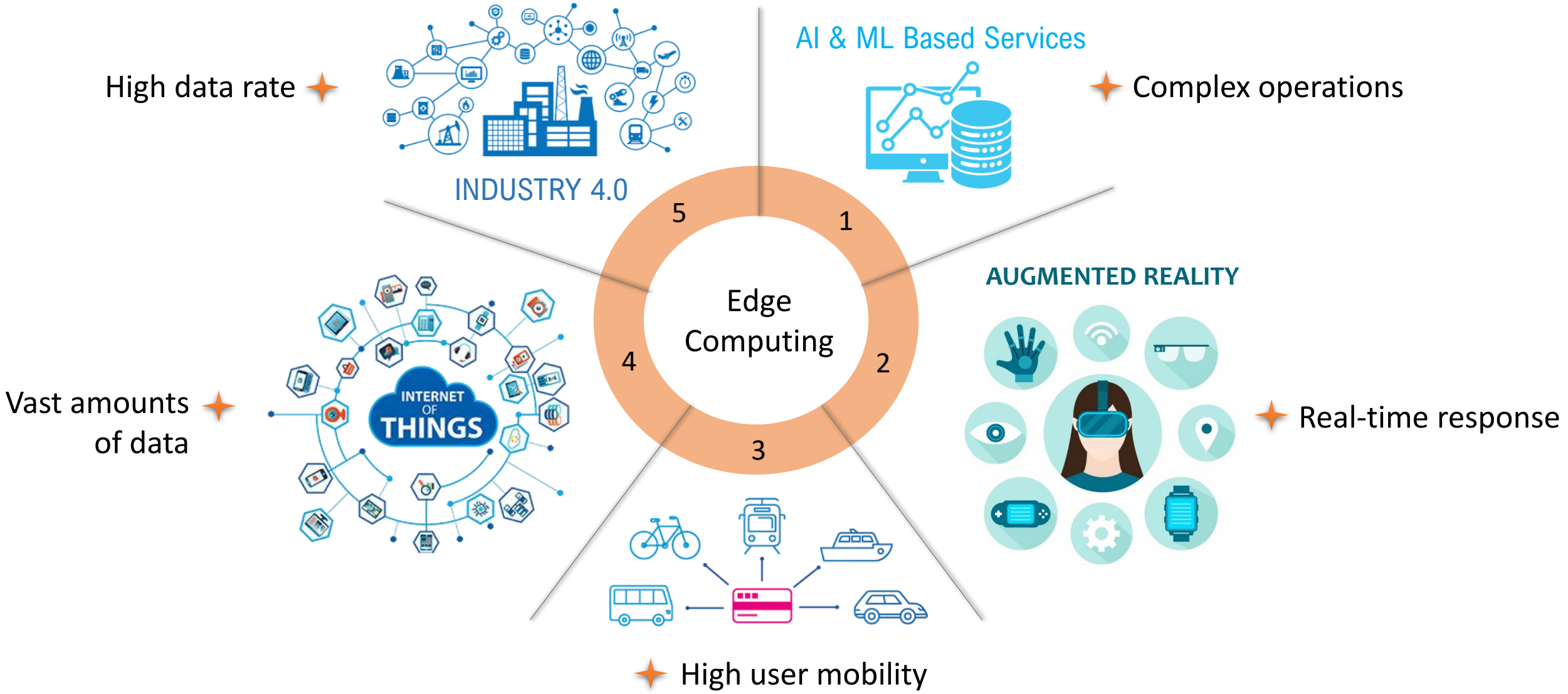
Benefits of Edge Computing



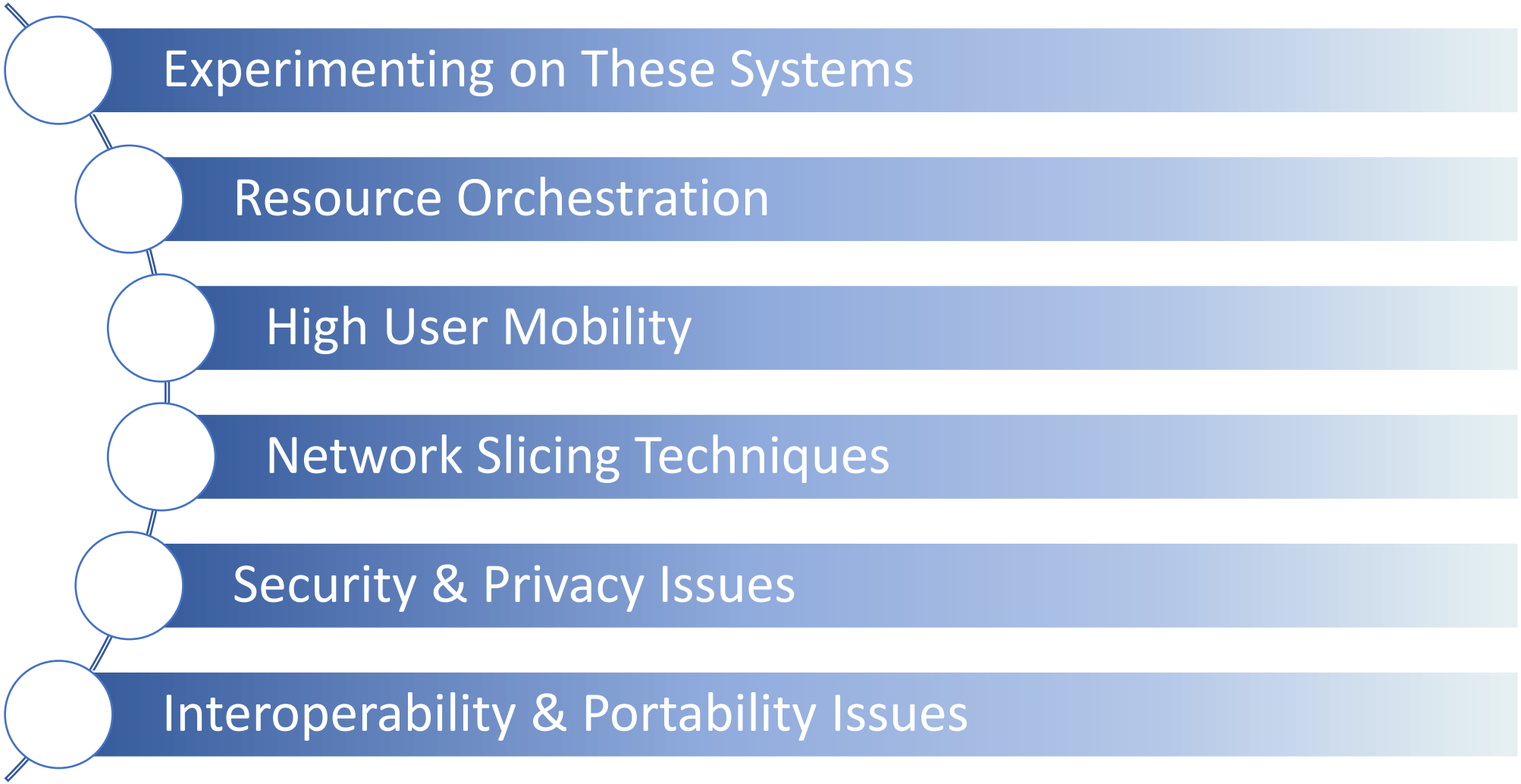
The Evaluation of Edge Computing



Emerging Technologies Driving Edge Computing



Challenges of Edge Computing Systems



Challenges of Edge Computing Systems cont.

Experimenting on These Systems

- Development & deployment difficulty of a real solution
- Setting up & maintaining testbeds are expensive
- Having a small number of edge simulators
- The difficulty of developing an edge simulator

Challenges of Edge Computing Systems cont.

Resource Orchestration

- How to offload problem: a mechanism for task offloading
- When to offload problem: the granularity of task offloading
- Where to offload problem: workload orchestration
- The difficulty of scaling cloud resources horizontally or vertically

EdgeCloudSim

C. Sonmez, A. Ozgovde and C. Ersoy, "EdgeCloudSim: An environment for performance evaluation of edge computing systems," *Transactions on Emerging Telecommunications Technologies*, Vol. 29, No. 11, p. e3493, 2018

What is EdgeCloudSim

- EdgeCloudSim is a new simulator
- Provides a simulation environment specific to edge computing scenarios
- EdgeCloudSim is based on CloudSim but adds some additional functionalities
- Extensible and easy-to-use
- Publicly available on GitHub [5]
- Has high reputation
  - 221 citations based on Google Scholar [6] data as of May 2021
  - A discussion forum [7] with 120 active members as of May 2021
  - More than 6500 views on YouTube channel [8]

What is EdgeCloudSim

- EdgeCloudSim
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- EdgeCloudSim ...alities
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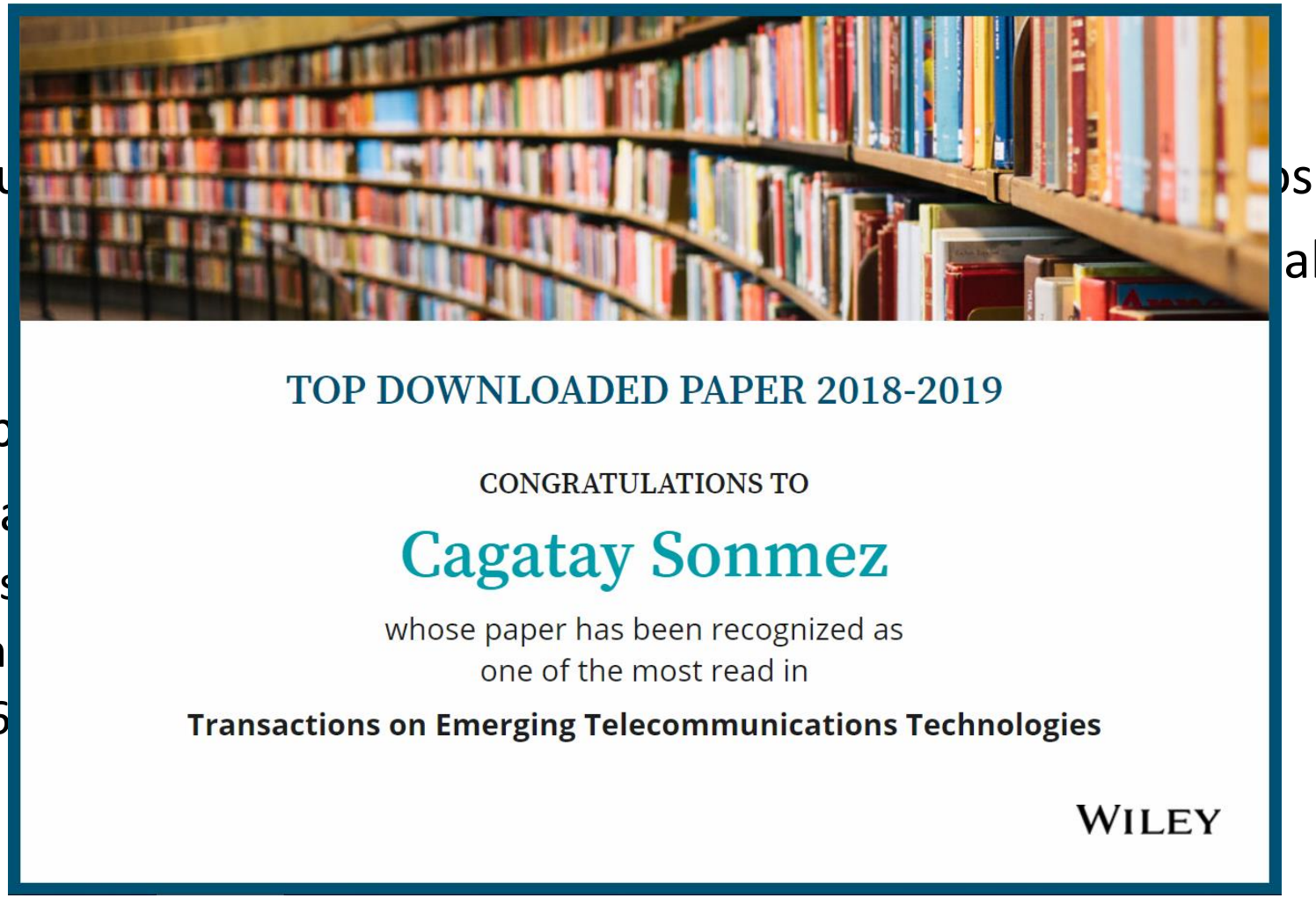
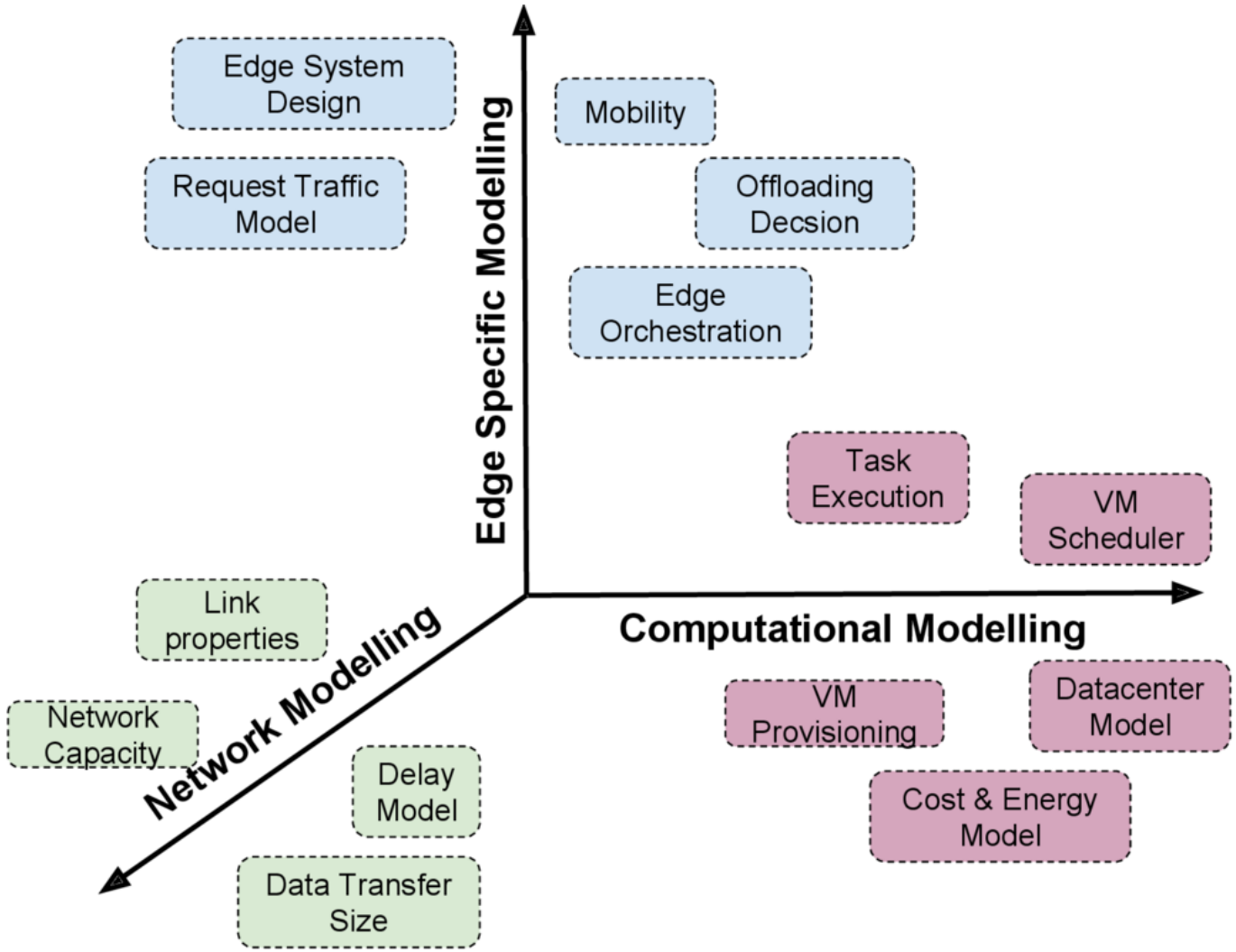
  - A discussion
  - More than 6



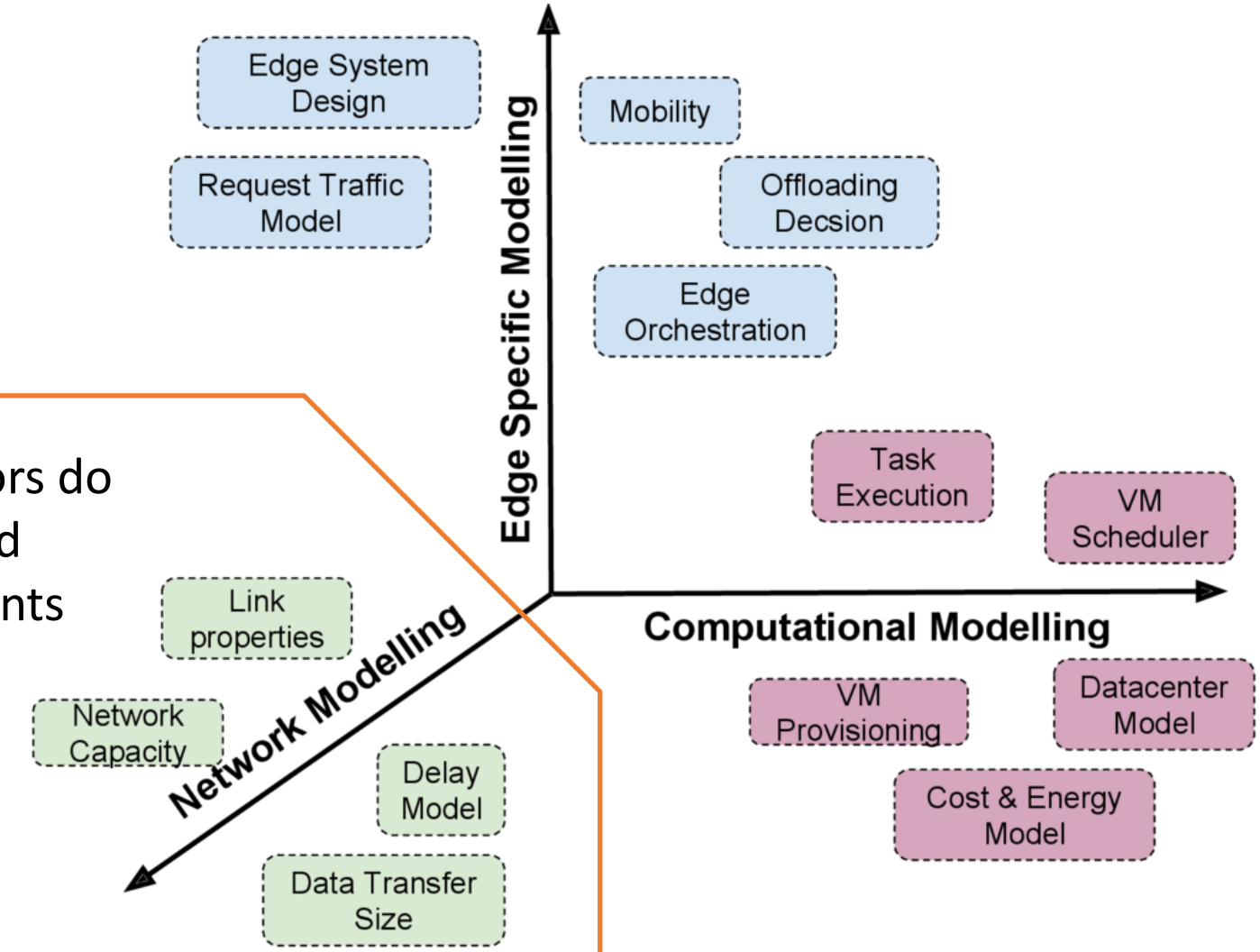
Motivation of Developing a Simulator

- **Real-word Deployments**
  - Design and development
  - Deployment of the datacenters
  - Managing mobile clients
- **Testbeds**
  - Repeatable and scalable experiments
  - Setting up and maintaining testbeds
  - Cost
- **Simulators**
  - Realistic modeling of the components
  - Scenario development
  - Configuration

Motivation of Developing an Edge Comp. Sim.



Motivation of Developing an Edge Comp. Sim.



- Network simulators do not consider cloud computing elements
  - Datacenters
  - Hosts
  - VMs
  - Brokers

Motivation of Developing an Edge Comp. Sim.

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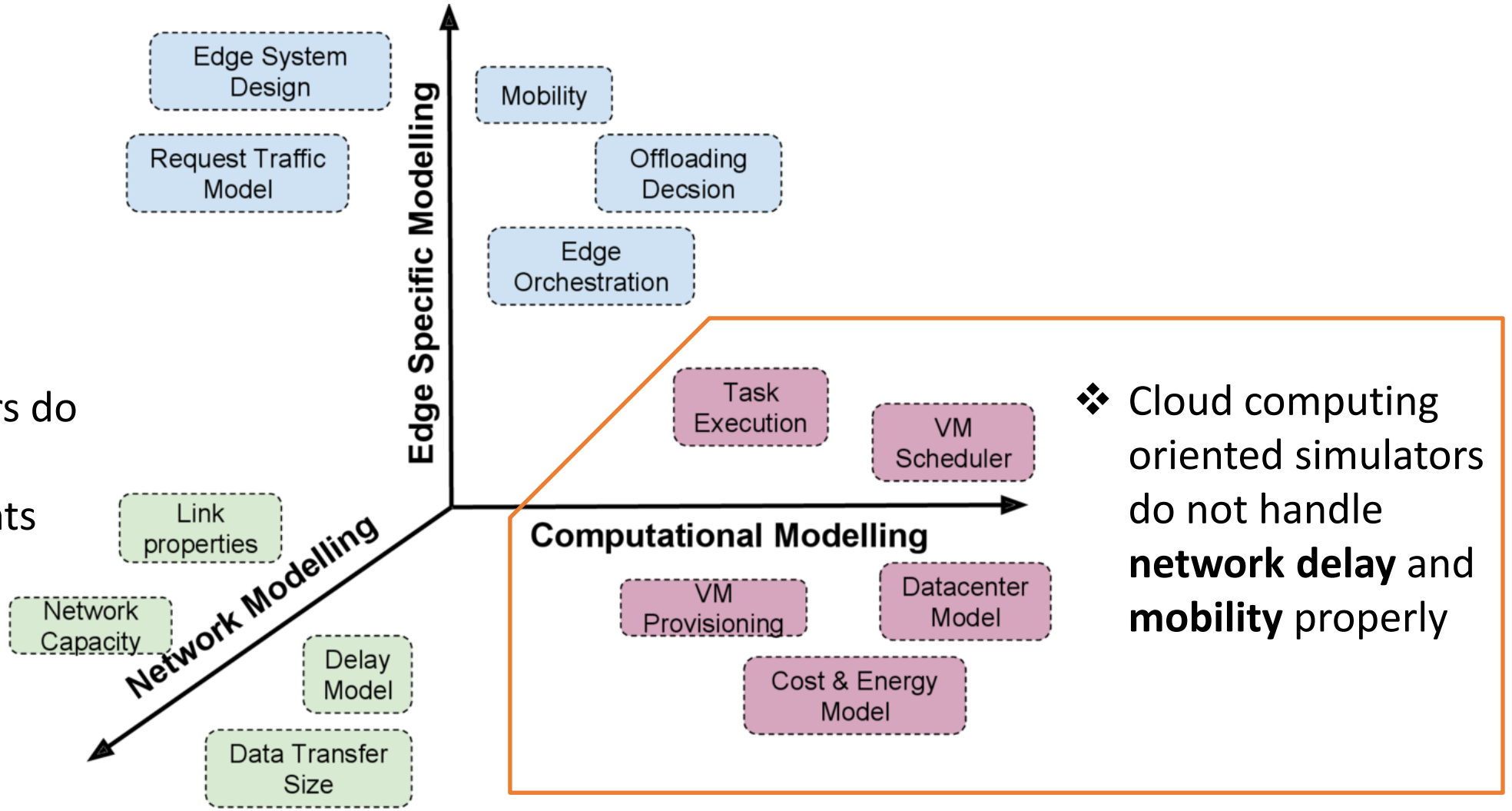
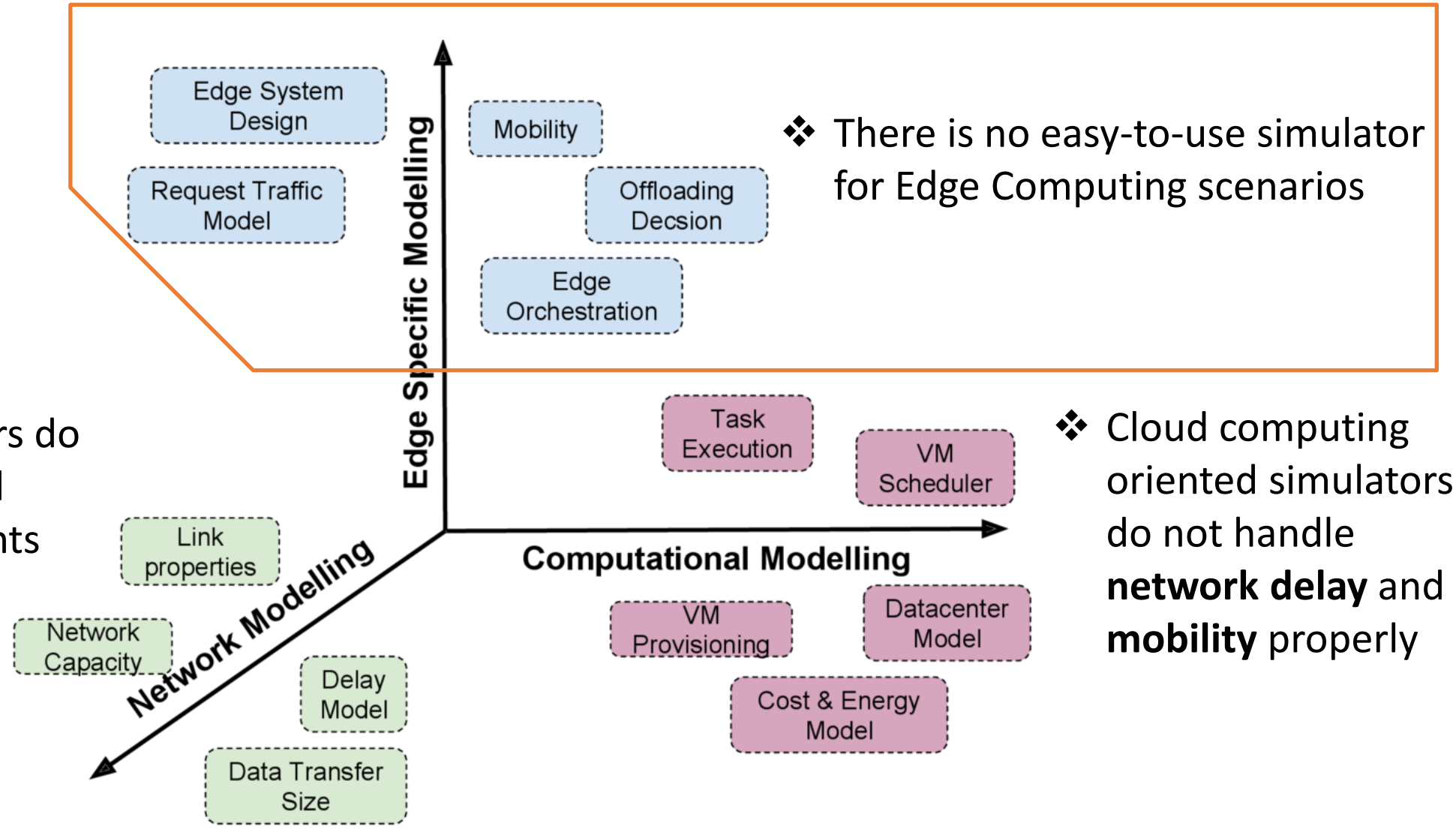


- Cloud computing oriented simulators do not handle **network delay** and **mobility** properly

Motivation of Developing an Edge Comp. Sim.

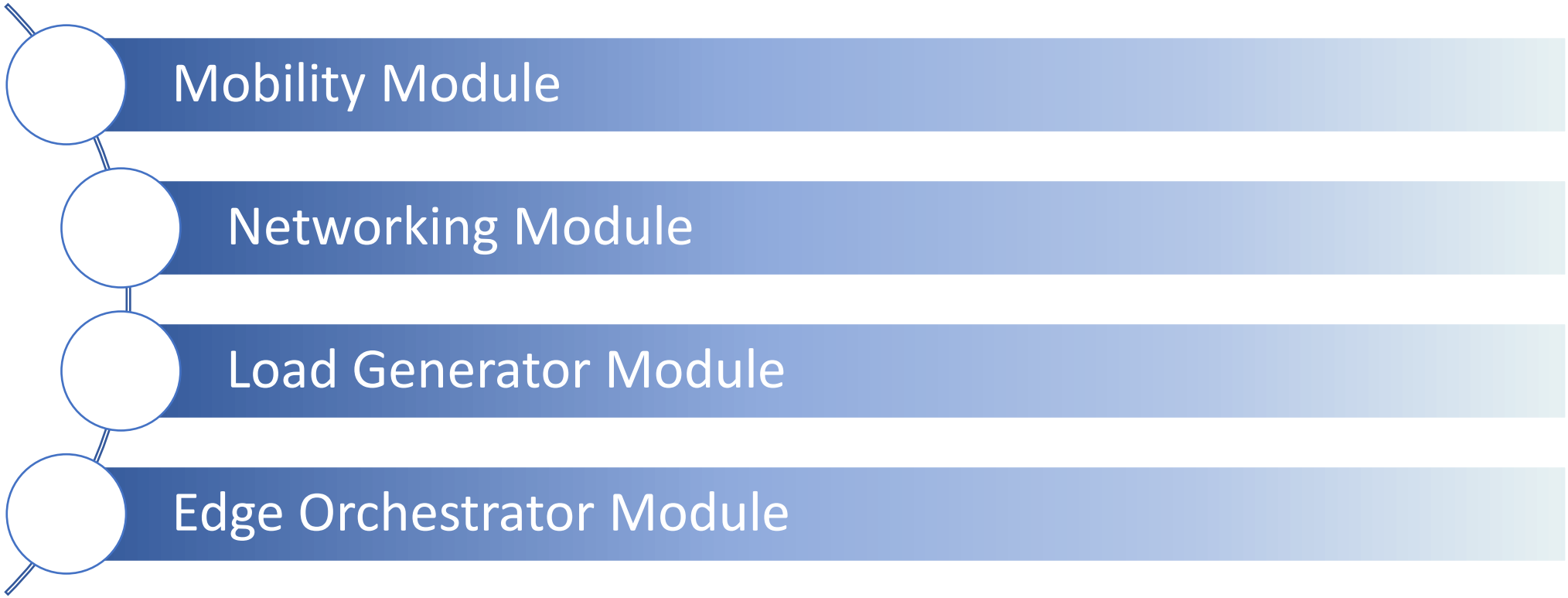


- There is no easy-to-use simulator for Edge Computing scenarios

- Network simulators do not consider cloud computing elements
  - Datacenters
  - Hosts
  - VMs
  - Brokers

- Cloud computing oriented simulators do not handle **network delay** and **mobility** properly

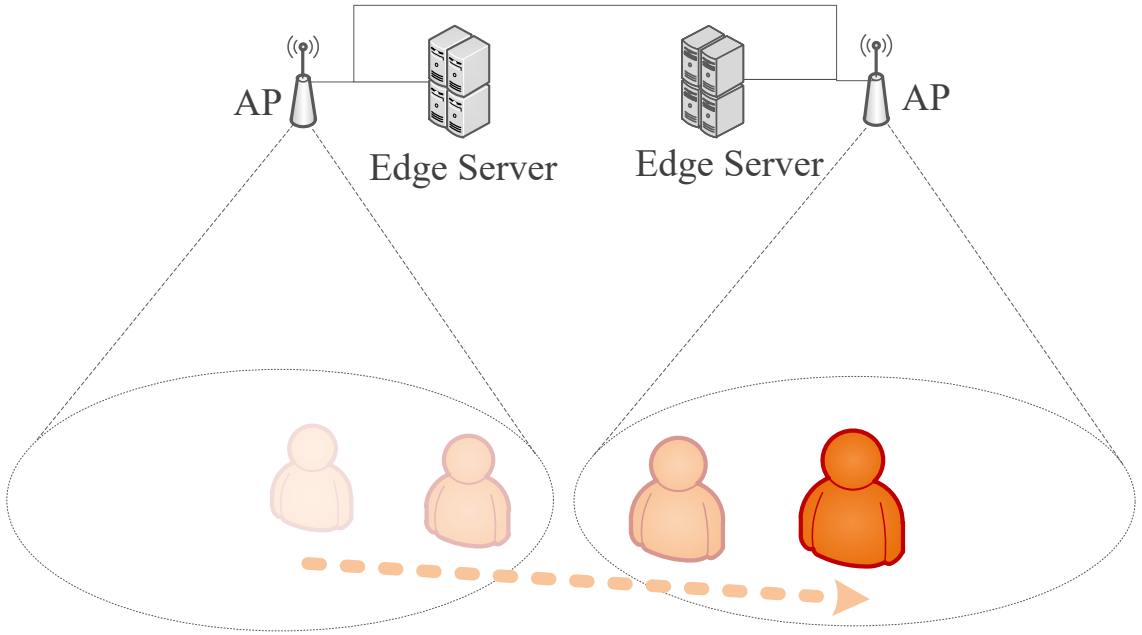
EdgeCloudSim Core Modules



EdgeCloudSim Core Modules cont.

Mobility Module

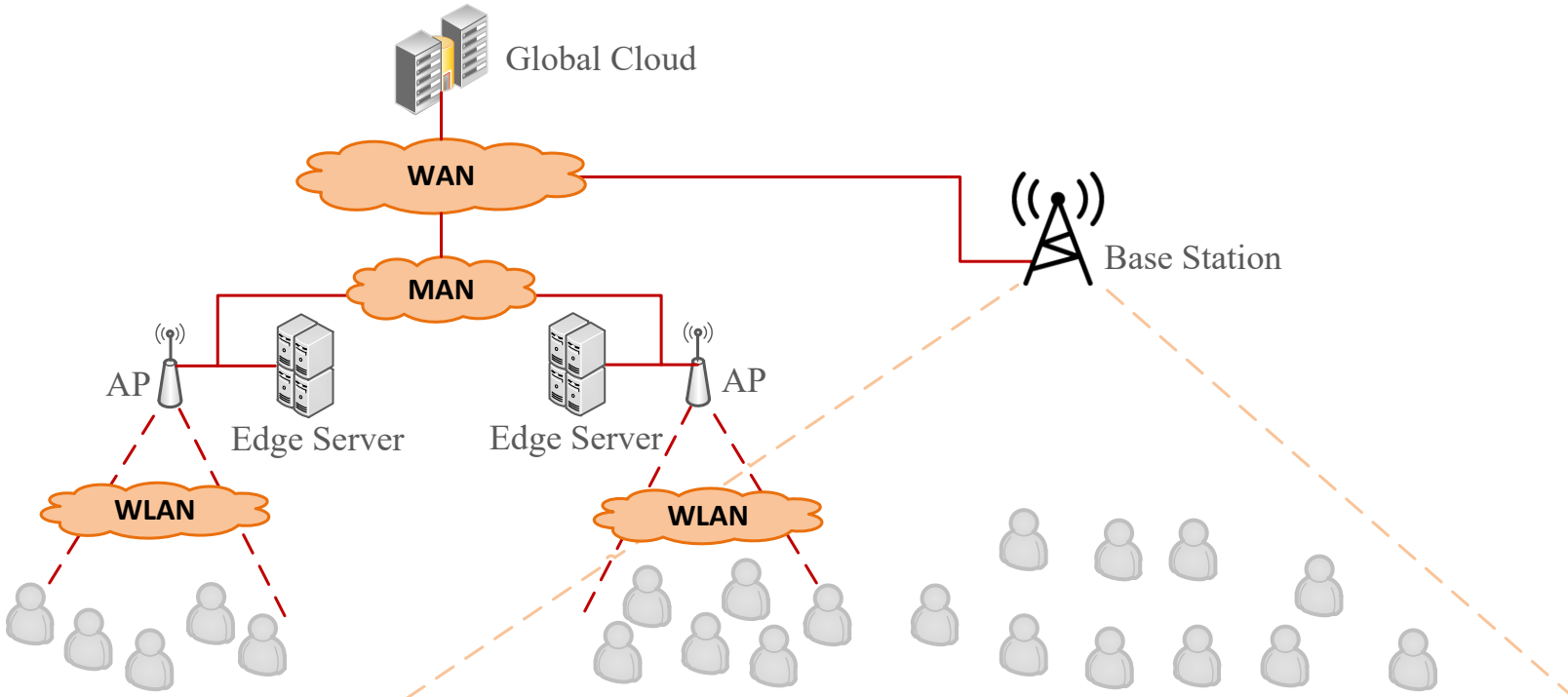
- Manages the location of edge devices and clients



EdgeCloudSim Core Modules cont.

Networking Module

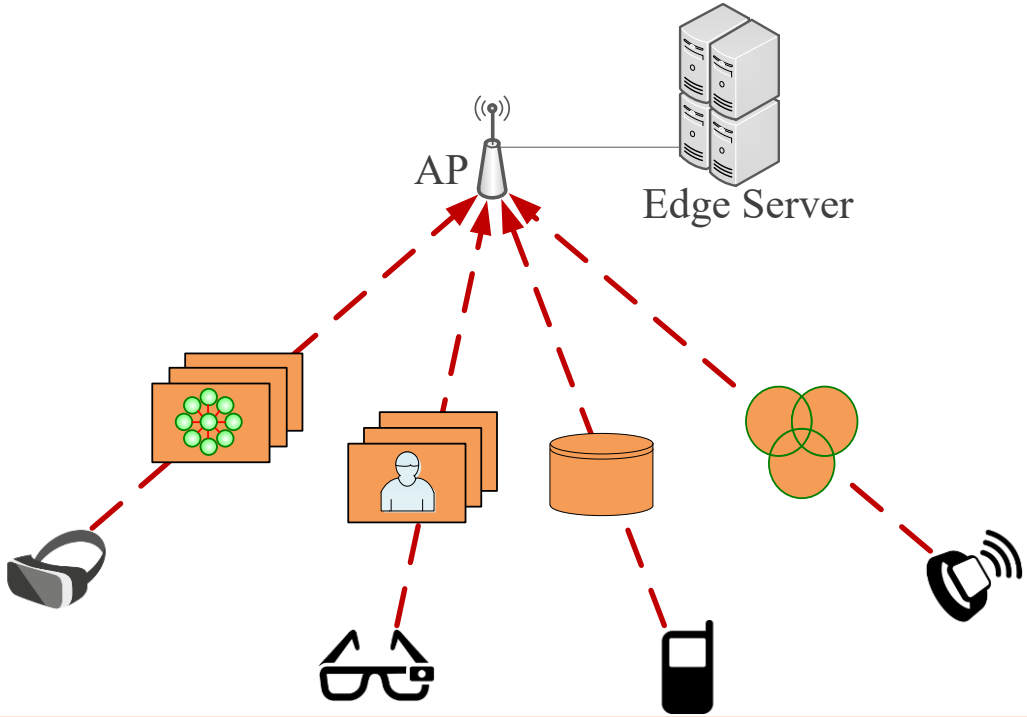
- Adds link delays between the network components



EdgeCloudSim Core Modules cont.

Load Generator Module

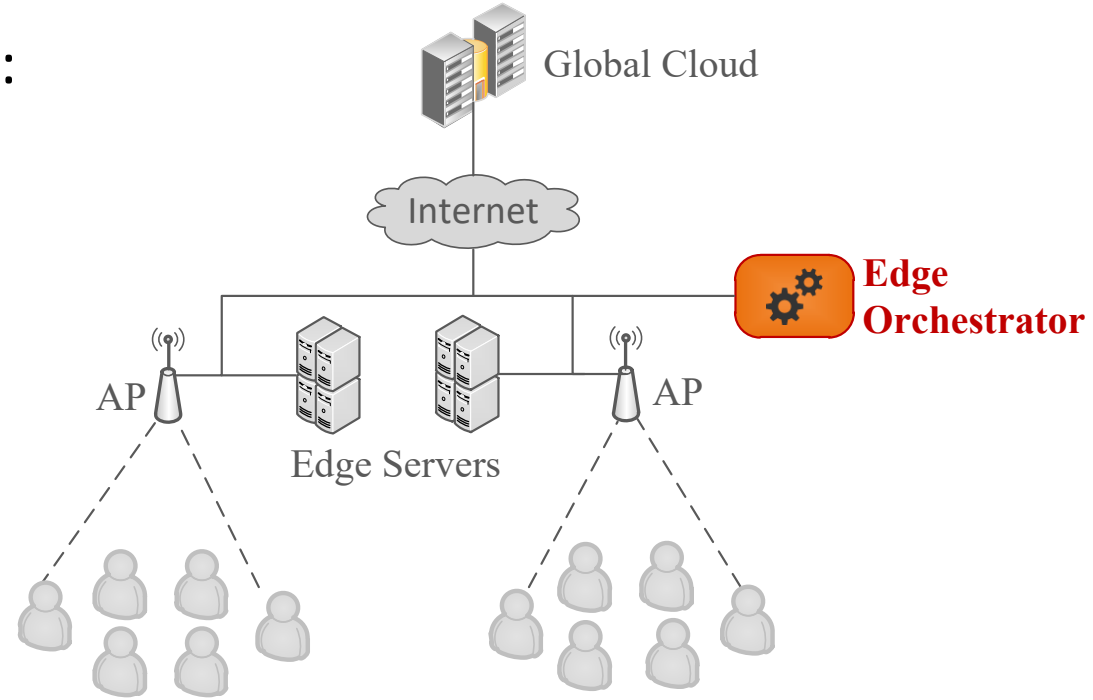
- Generates tasks based on the simulated scenario



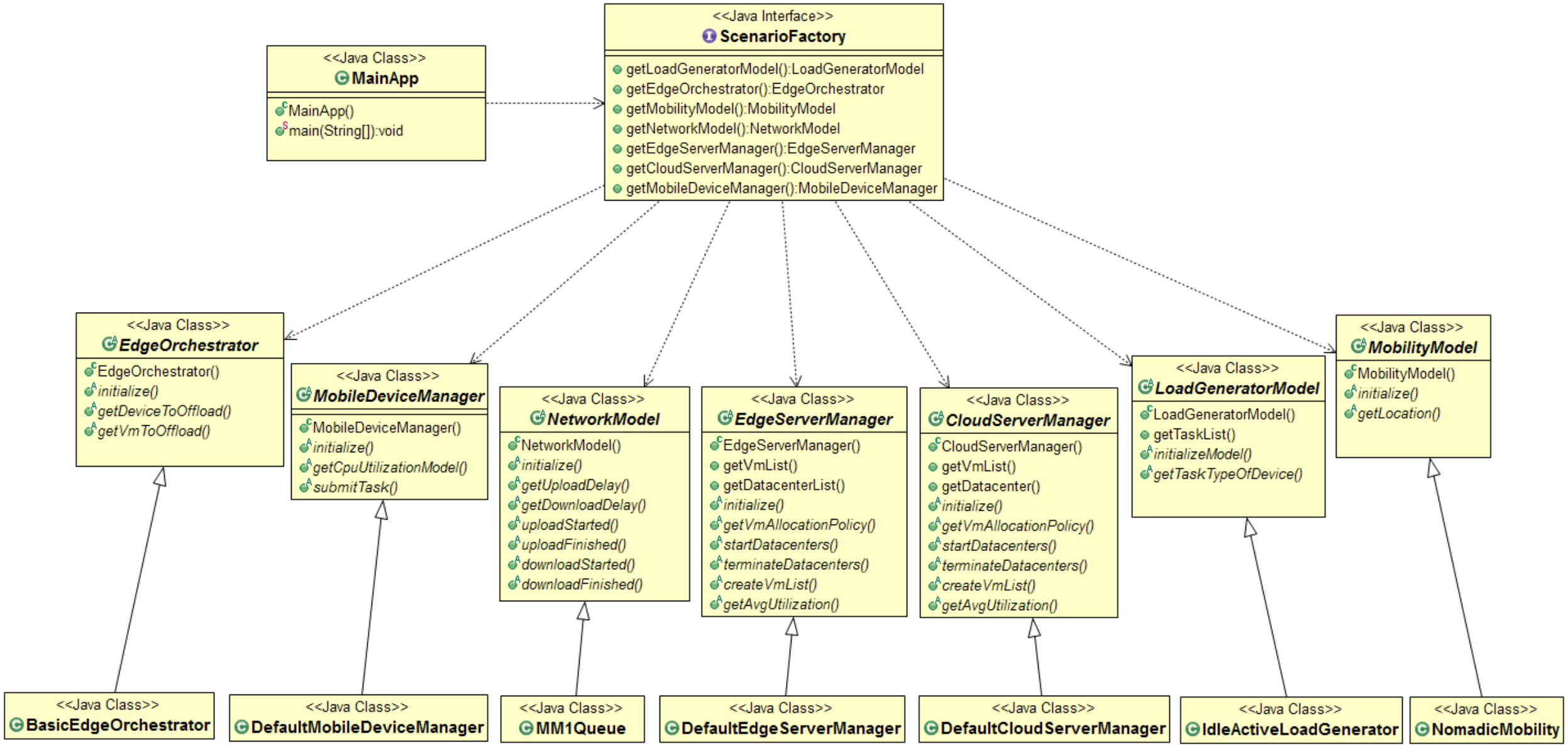
EdgeCloudSim Core Modules cont.

Edge Orchestrator Module

- The edge orchestrator can be considered as the central nervous system
- It makes critical decisions, such as:
  - Resource provisioning
  - Scales up/down the servers
  - Generates/terminates VMs
  - Migrates tasks
  - Coordinates services



Extensibility



Ease of Use

Problems

- Too many parameters are used in the simulations
- Managing parameters programmatically is difficult

Solution

- EdgeCloudSim reads parameters dynamically
  - ✓Simulation settings are managed in configuration file
  - ✓Application properties are stored in xml file
  - ✓Edge devices (datacenters, hosts, VMs etc.) are defined in xml file

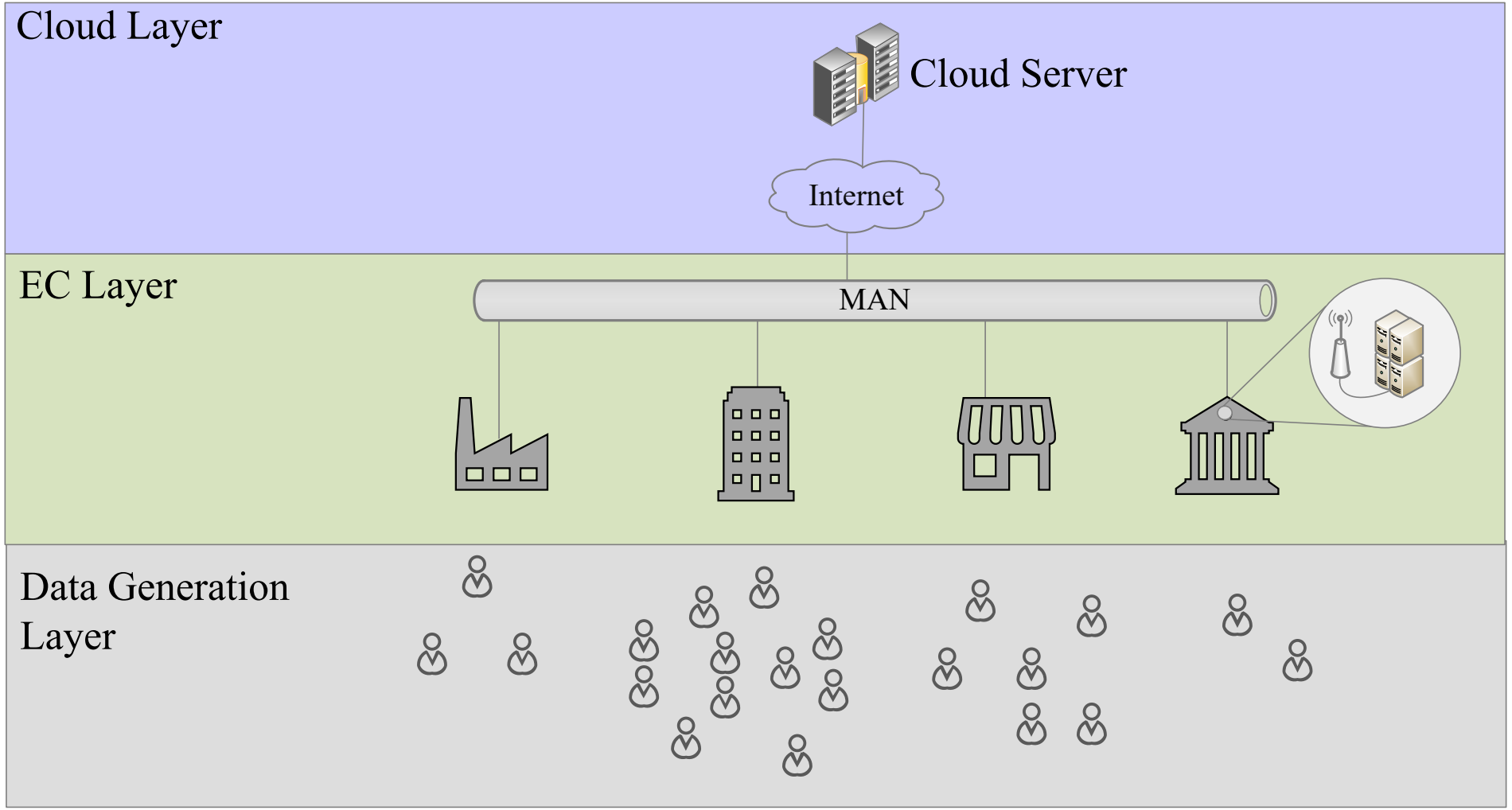
Publications using EdgeCloudSim

- ✓ C. Sonmez, A. Ozgovde and C. Ersoy, “EdgeCloudSim: An environment for performance evaluation of Edge Computing systems”, *Second International Conference on Fog and Mobile Edge Computing (FMEC)*, pp. 39-44, May 2017
- ✓ C. Sonmez., A. Ozgovde and C. Ersoy, “Performance evaluation of single-tier and two-tier cloudlet assisted applications”, *IEEE International Conference on Communications Workshops (ICC Workshops)*, pp. 302-307, May 2017.
- ✓ C. Sonmez, A. Ozgovde and C. Ersoy, “EdgeCloudSim: An environment for performance evaluation of edge computing systems”, *Transactions on Emerging Telecommunications Technologies*, Vol. 29, No. 11, p. e3493, 2018.
- ✓ C. Sonmez, A. Ozgovde and C. Ersoy, “Fuzzy Workload Orchestration for Edge Computing”, *IEEE Transactions on Network and Service Management*, Vol. 16, No. 2, pp. 769-782, 2019.
- ✓ C. Sonmez, C. Tunca, A. Ozgovde and C. Ersoy, “Machine Learning Based Workload Orchestrator for Vehicular Edge Computing”, *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 4, pp. 2239-2251, April 2021, doi: 10.1109/TITS.2020.3024233.

Fuzzy Logic Based Workload Orchestrator

C. Sonmez, A. Ozgovde and C. Ersoy, "Fuzzy Workload Orchestration for Edge Computing," in *IEEE Transactions on Network and Service Management*, vol. 16, no. 2, pp. 769-782, June 2019.

Multi-tier Edge Computing Architecture



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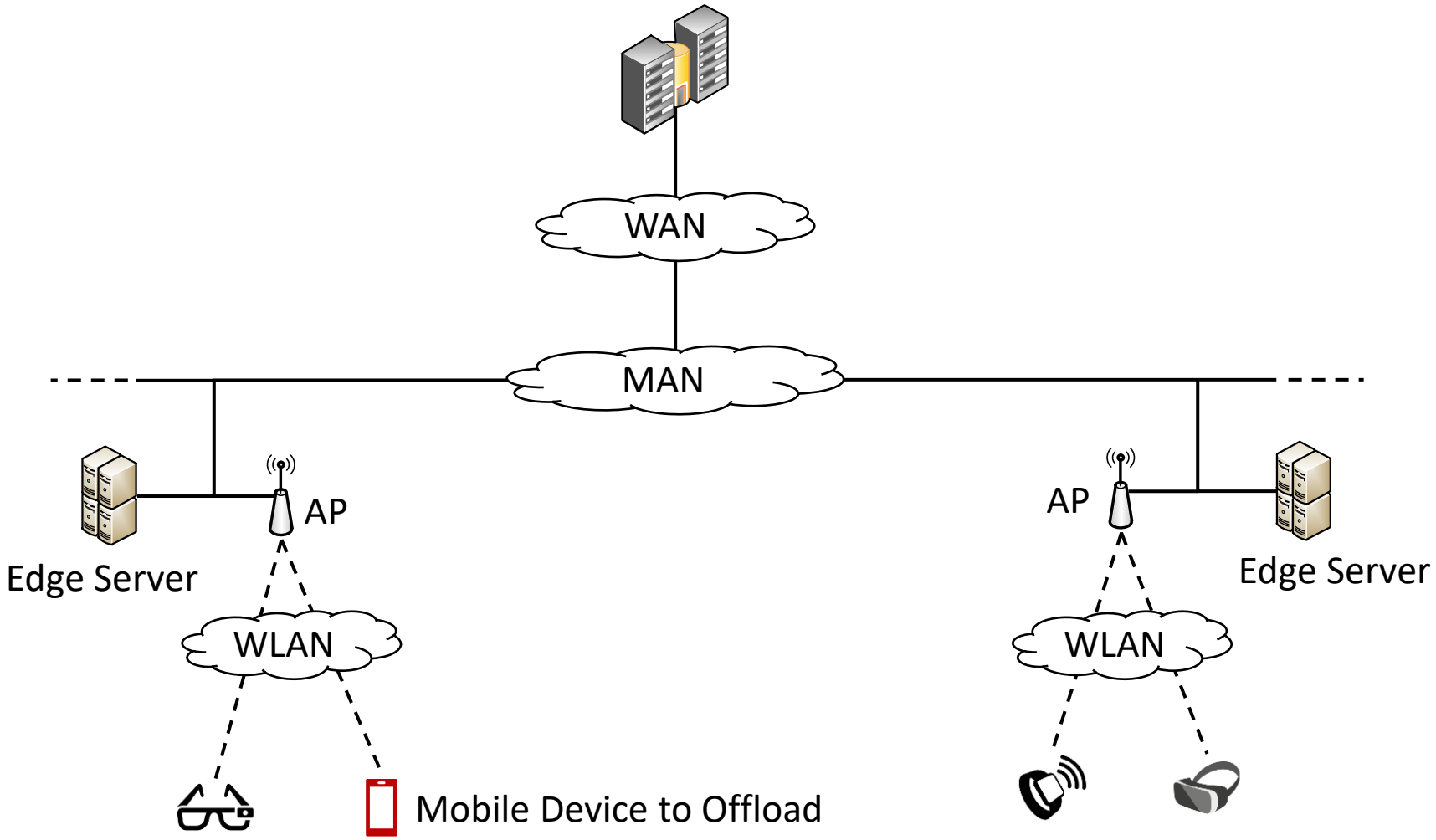

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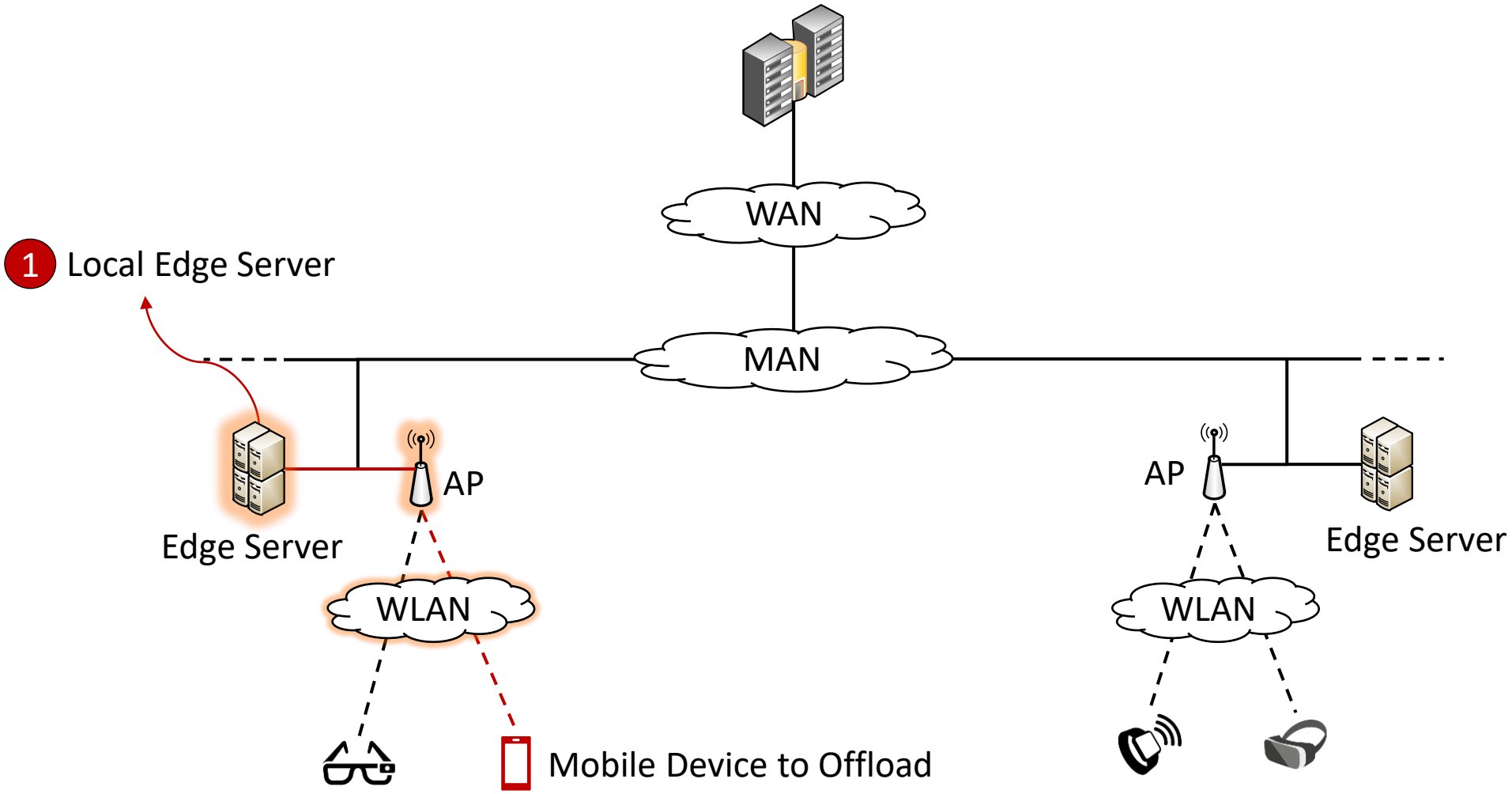

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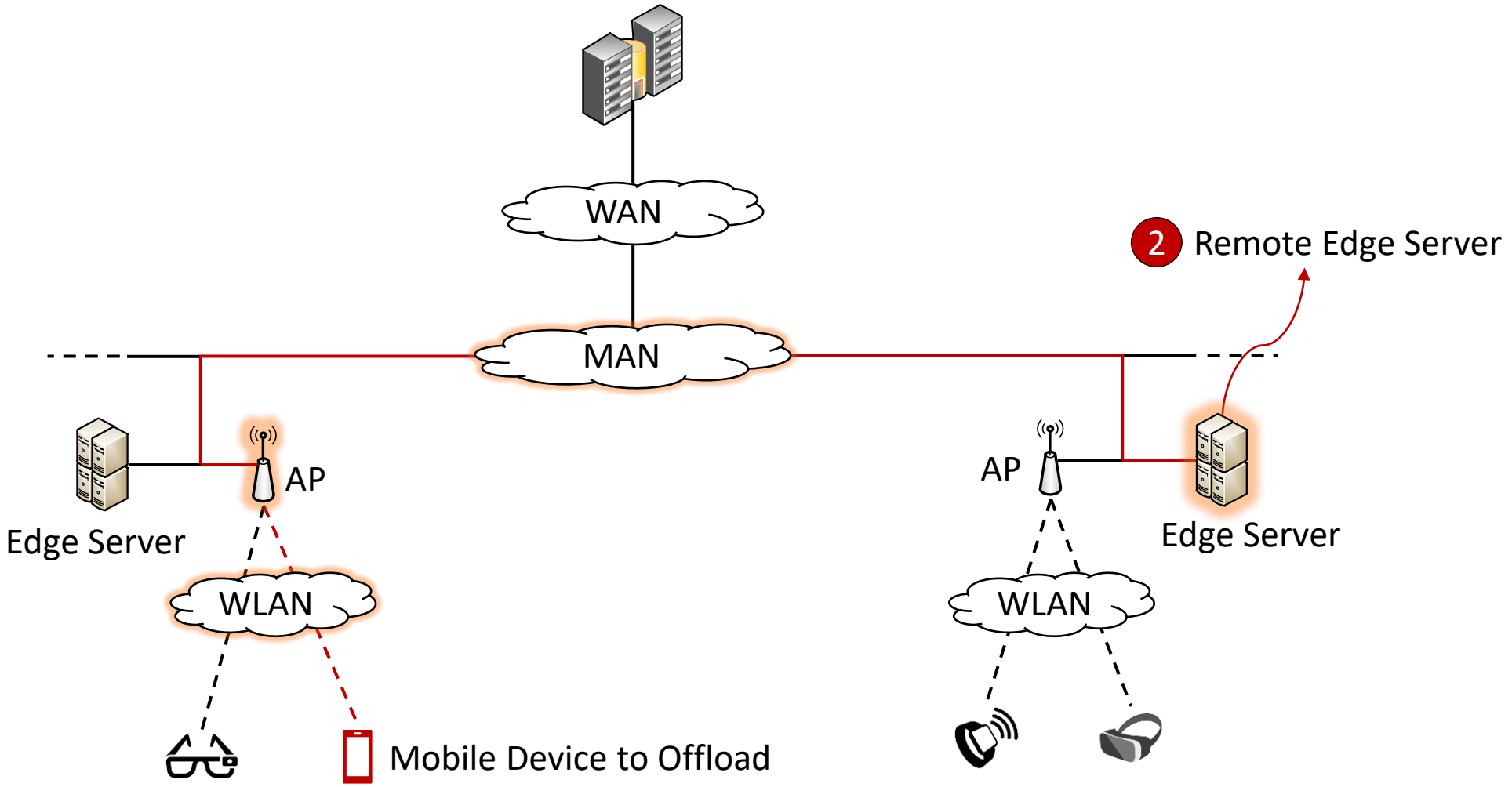

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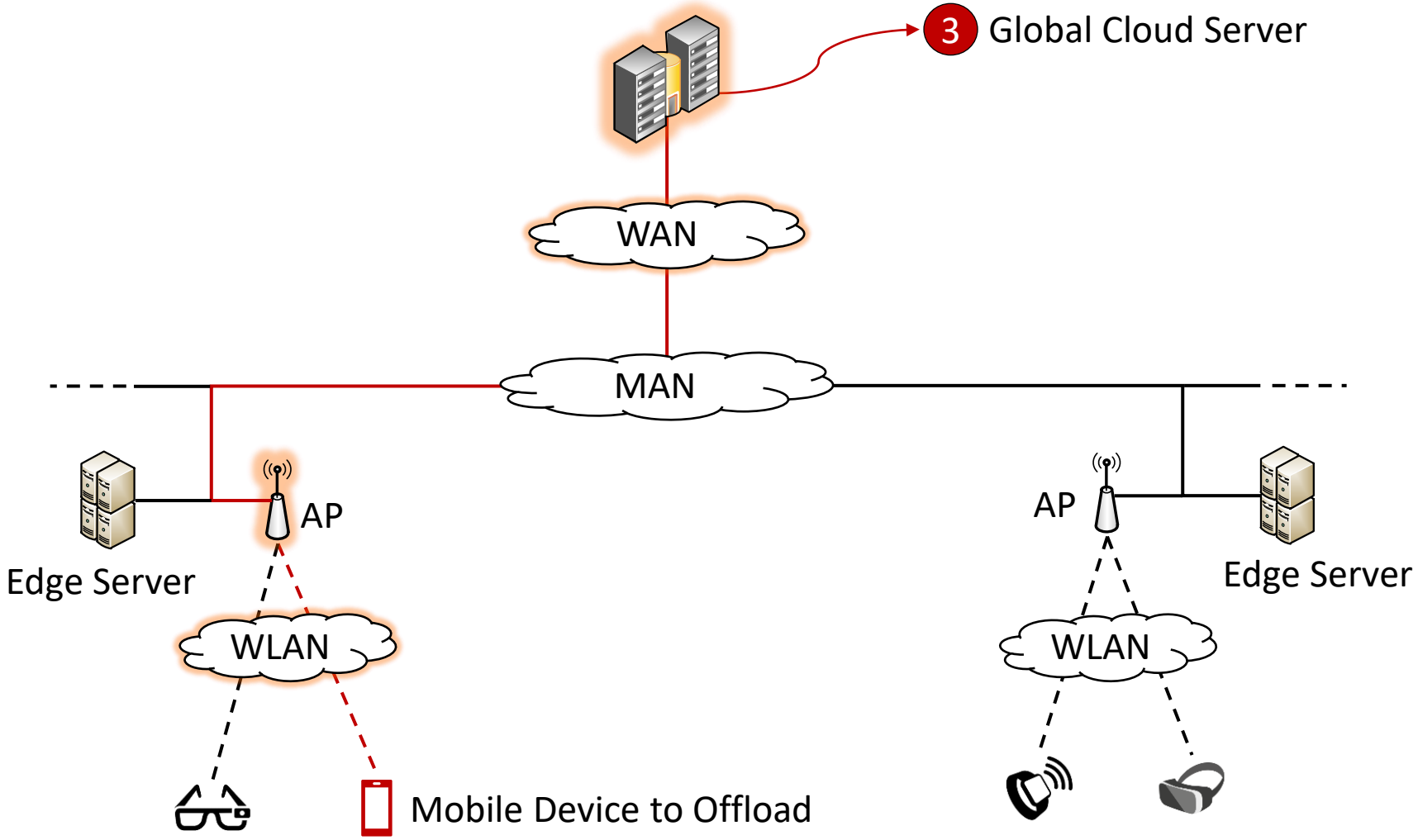

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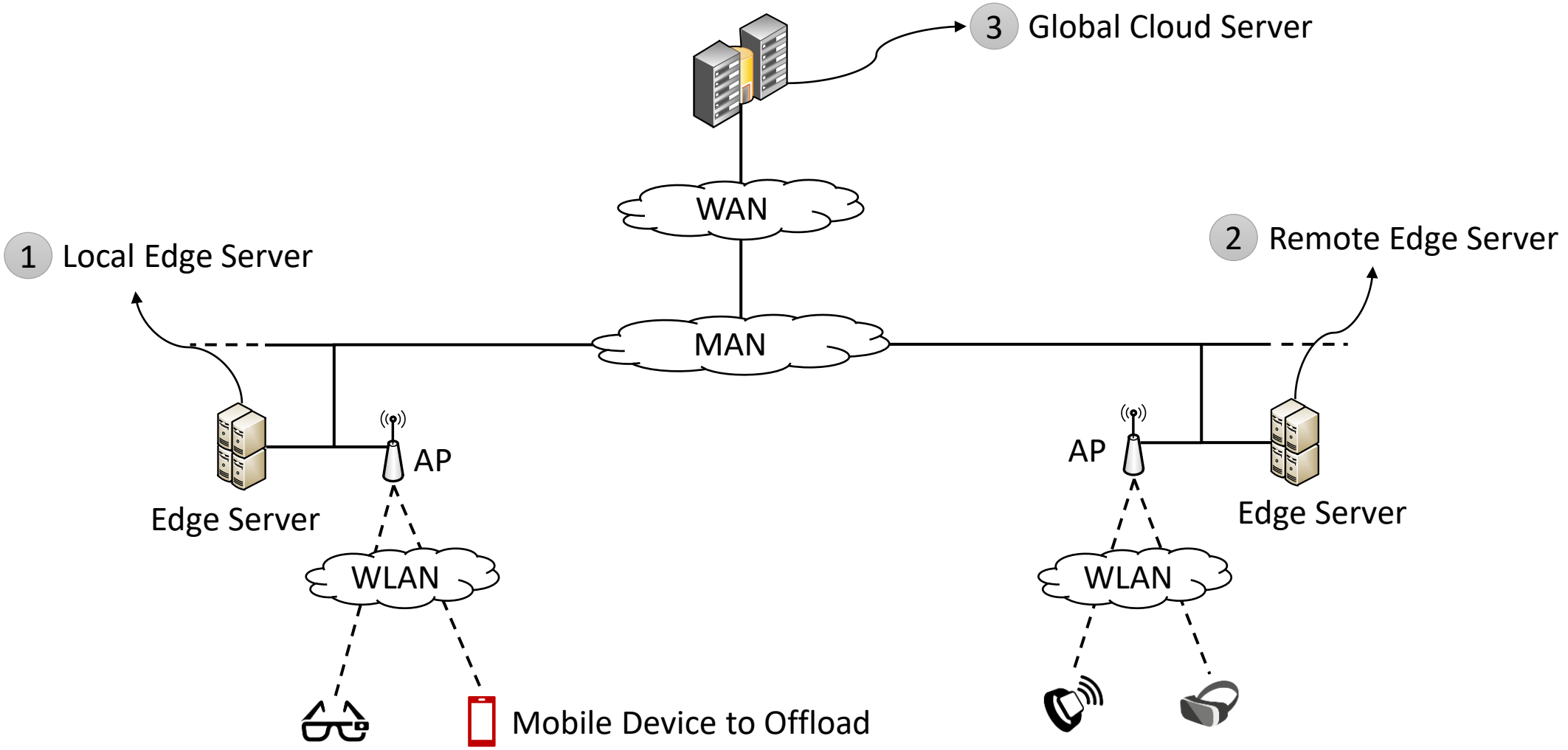
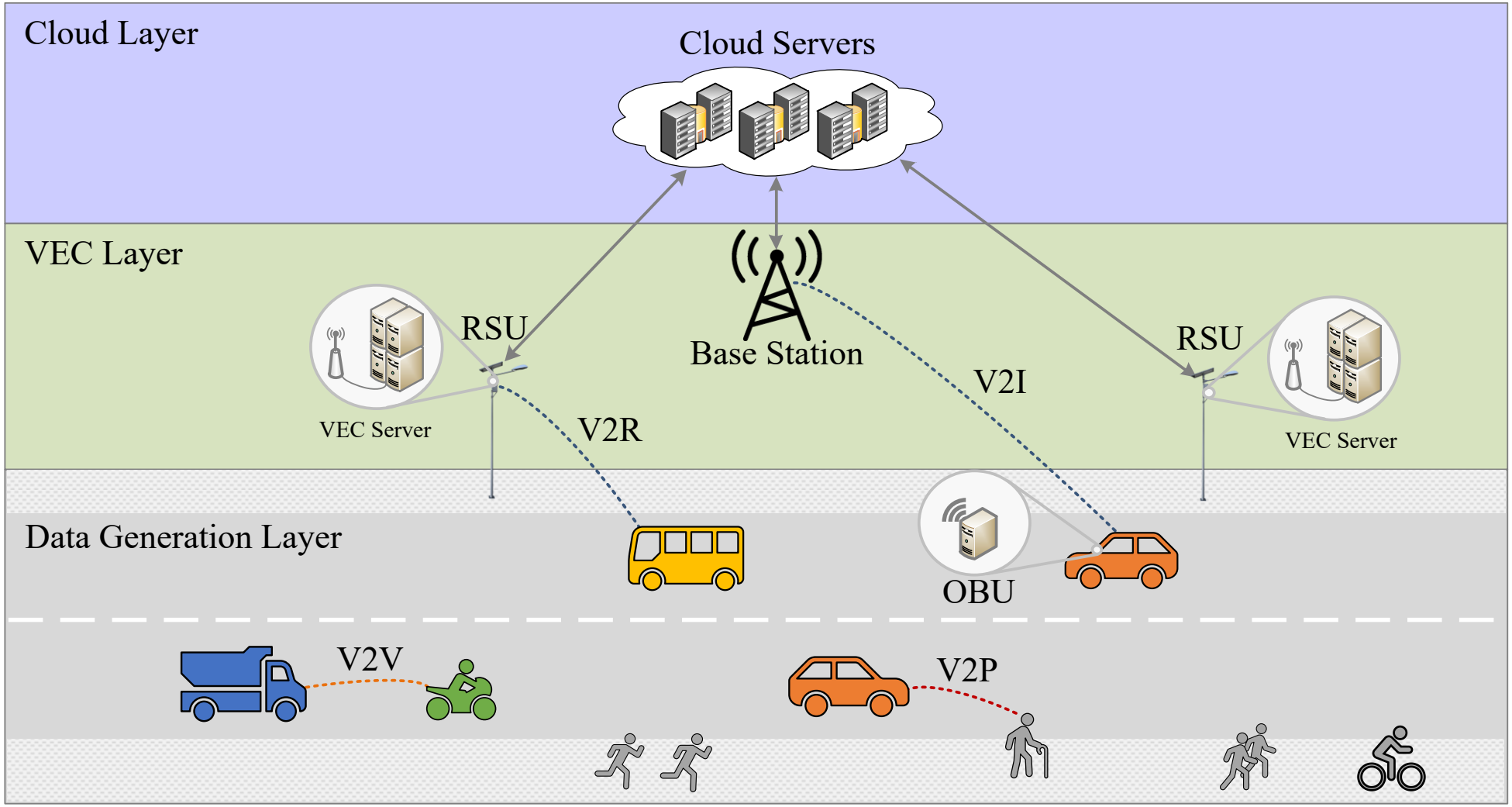


Machine Learning Based Workload Orchestrator

C. Sonmez, A. Ozgovde and C. Ersoy, "Machine Learning Based Workload Orchestrator for Vehicular Edge Computing," *IEEE Transactions on Intelligent Transportation Systems*, 2020 (revised & resubmitted)

Vehicular Edge Computing Architecture



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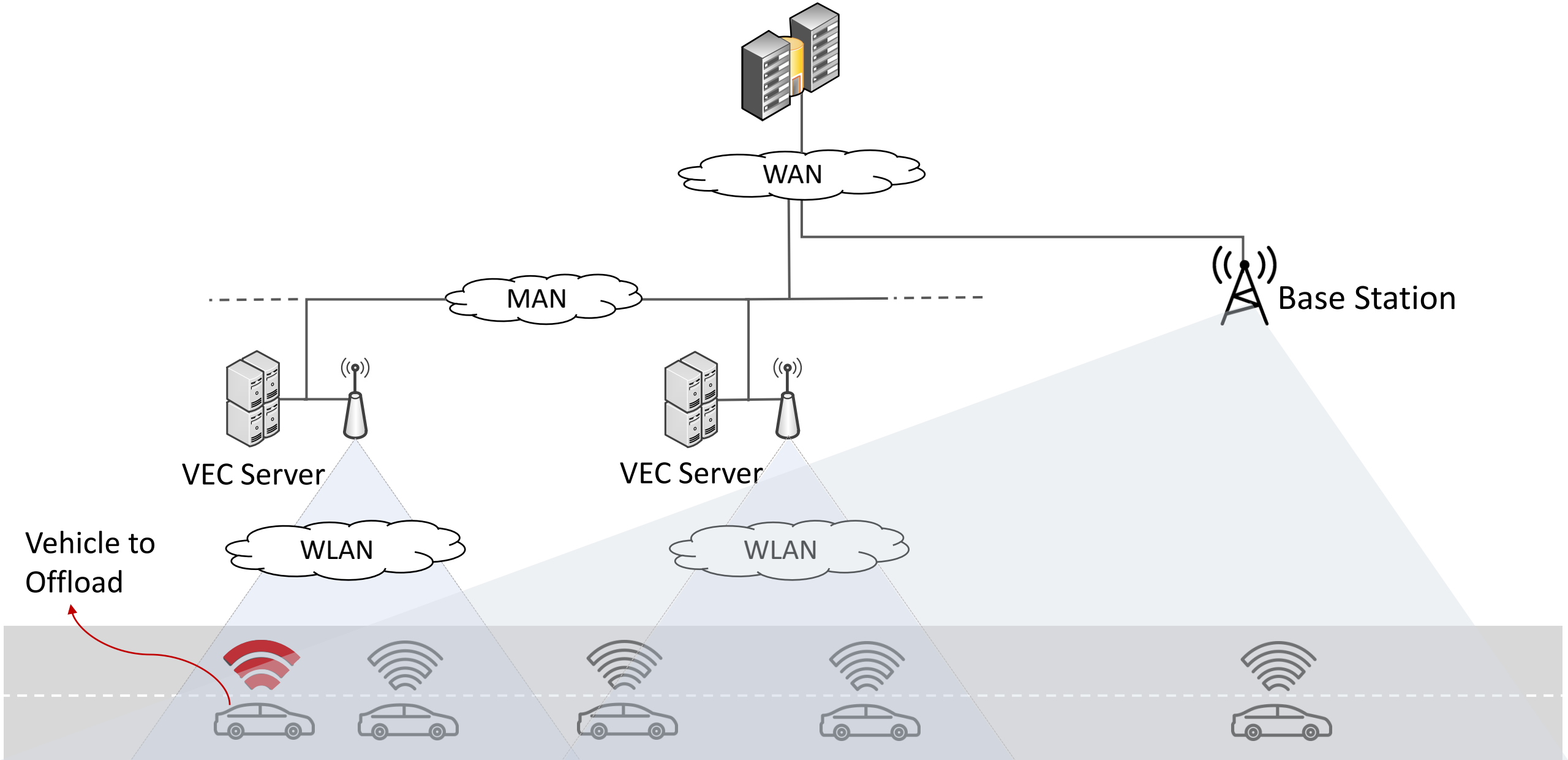

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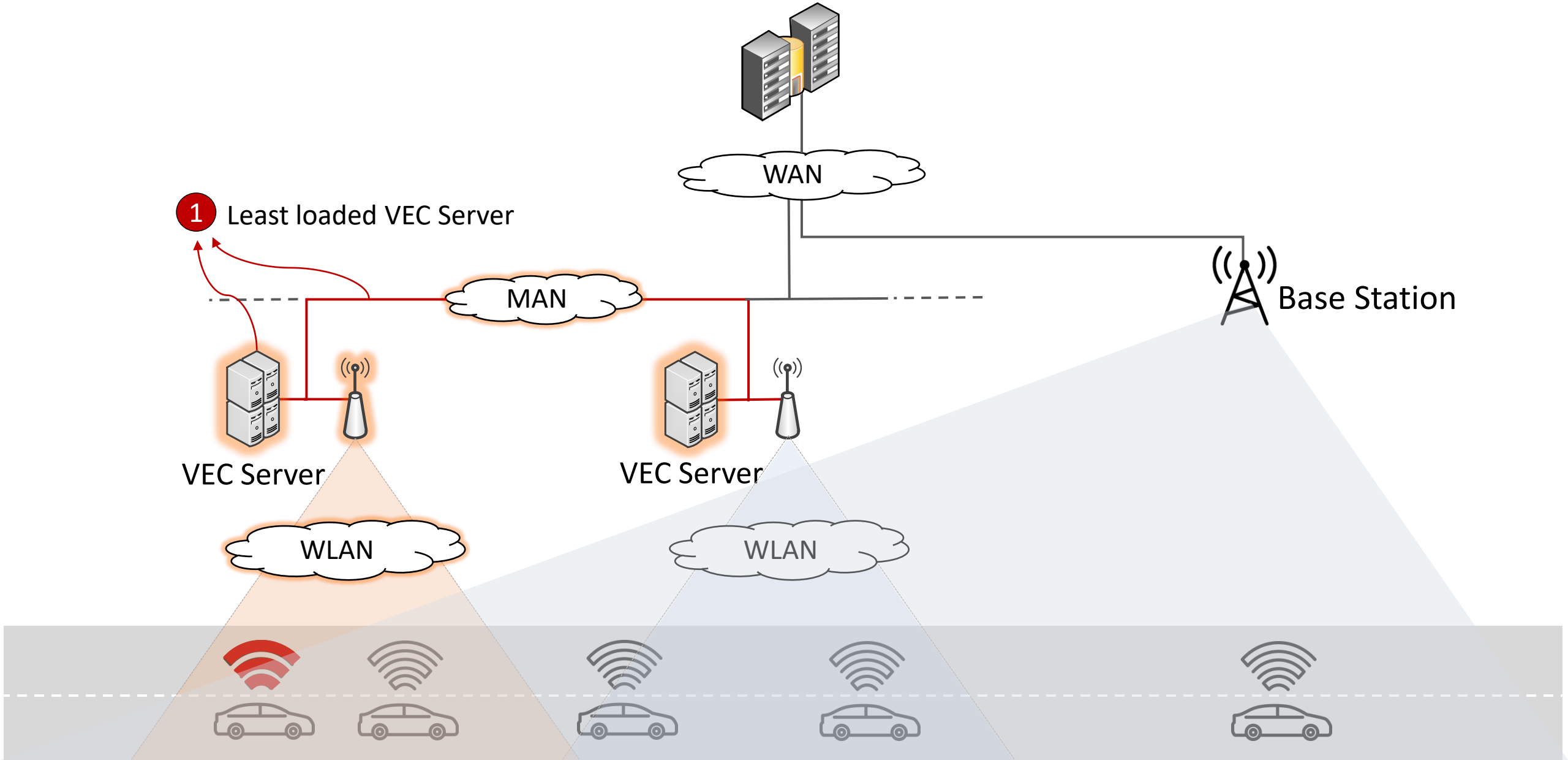

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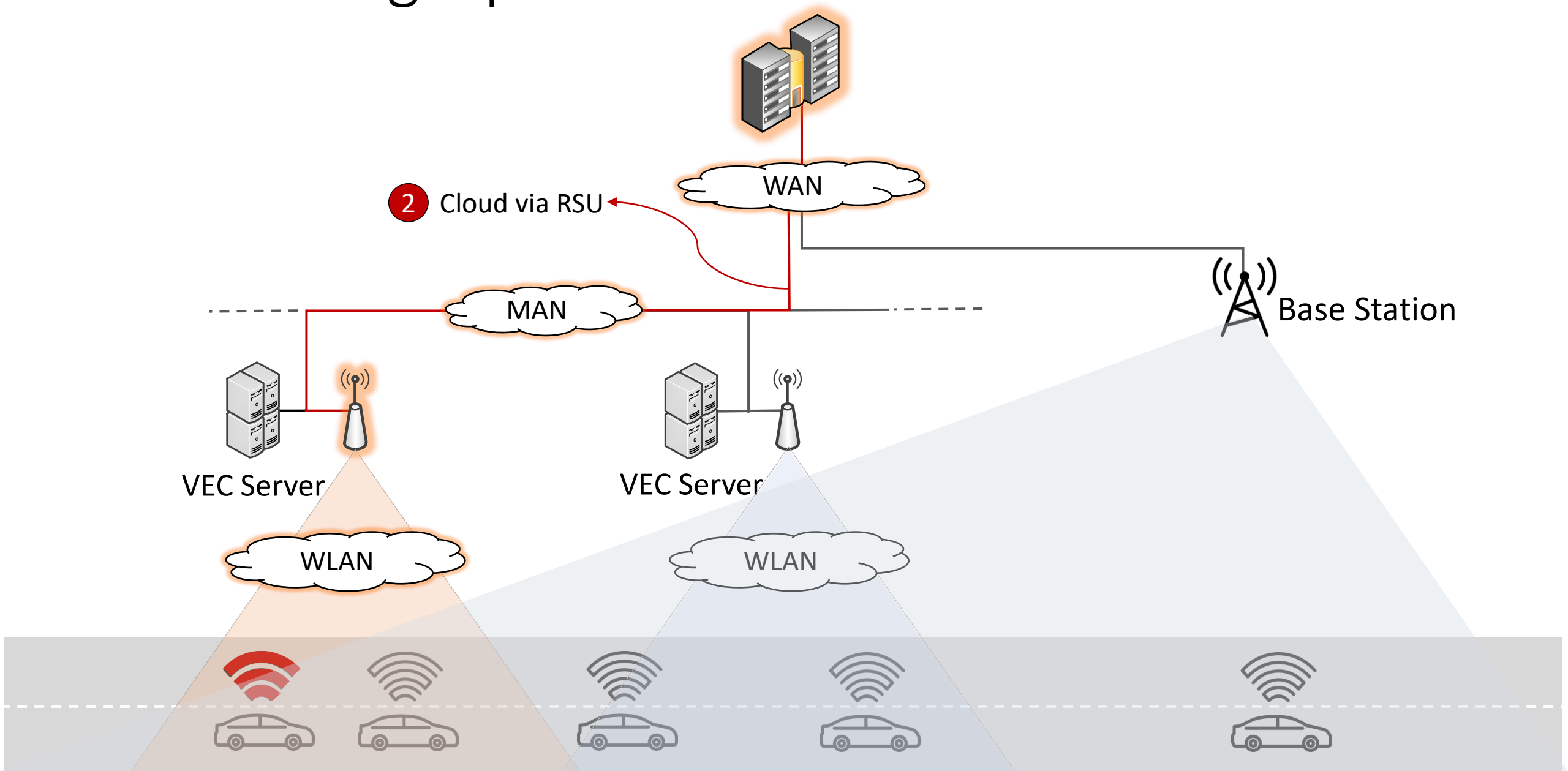

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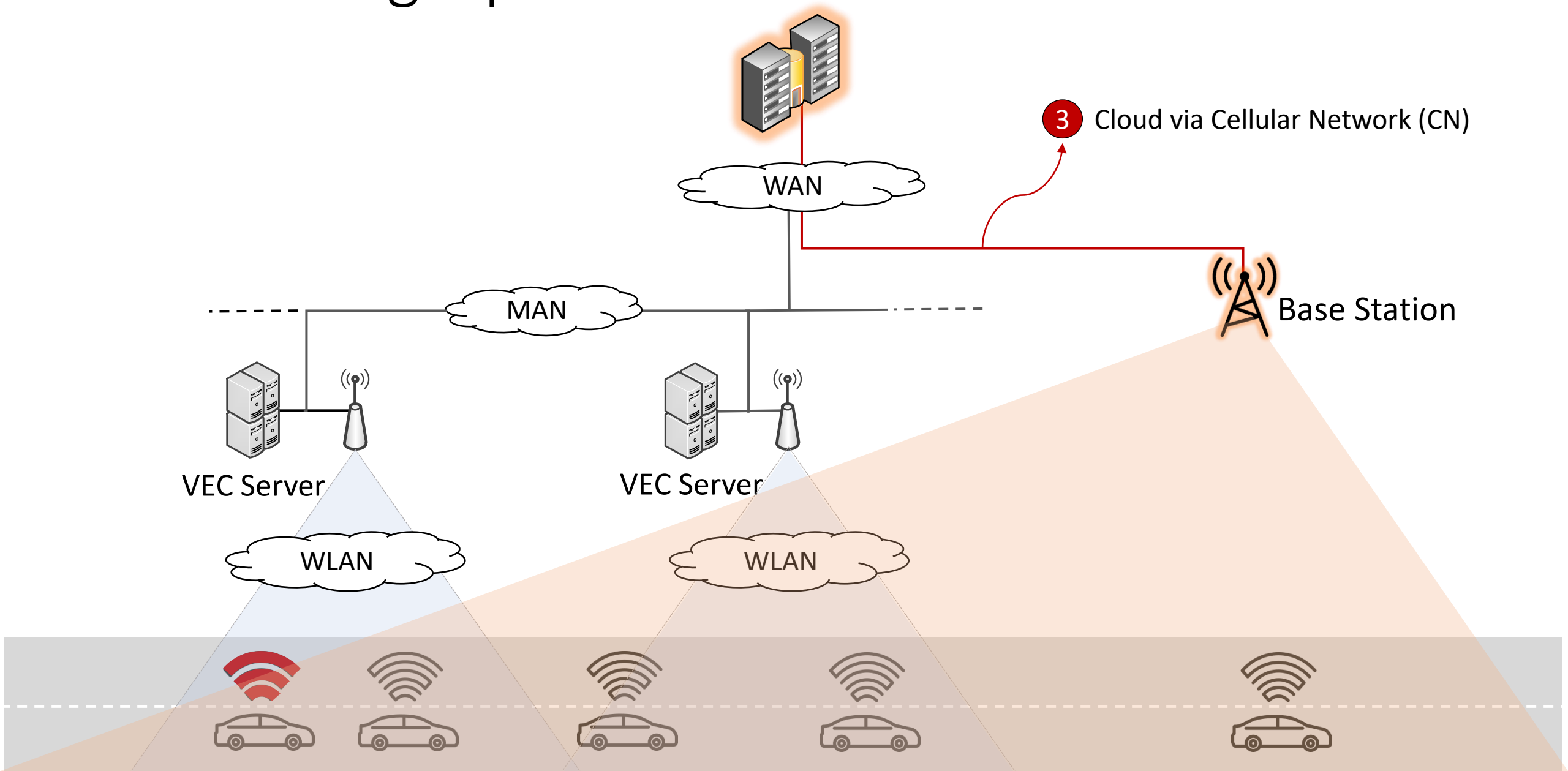

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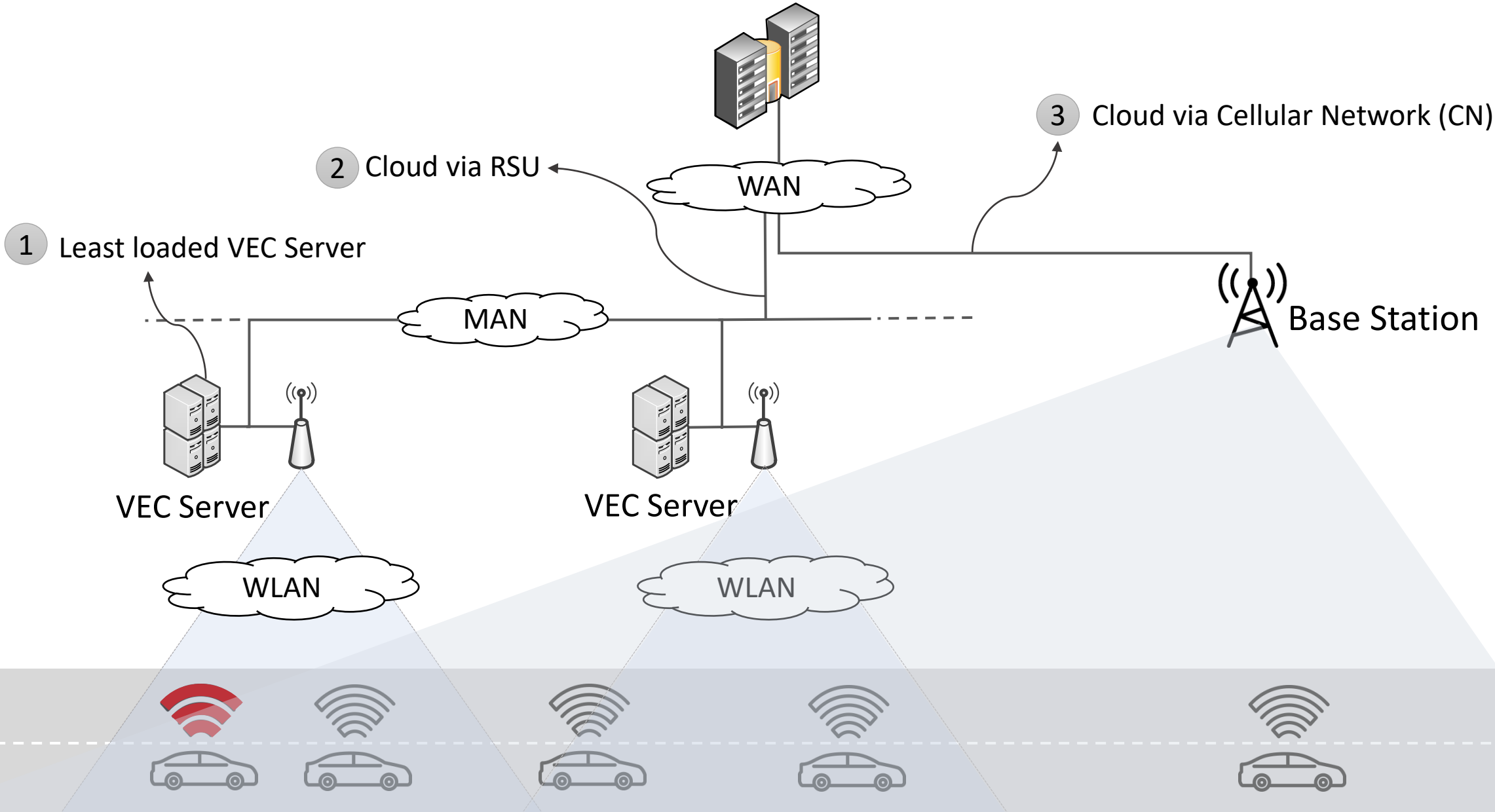
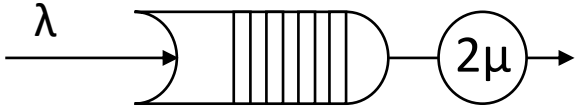


Case Study with EdgeCloudSim

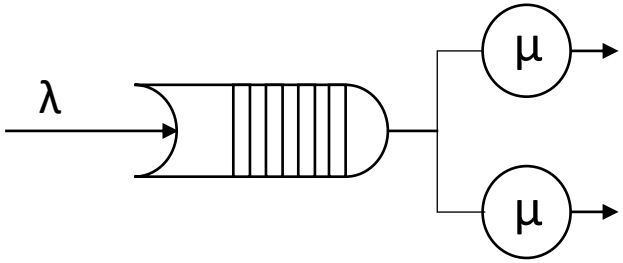
Network Performance Evaluation of Different Scenarios

Which One Provides the Best Network Delay?

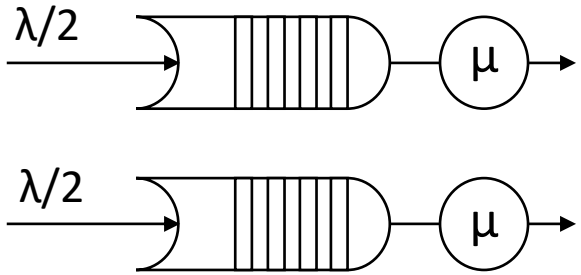
Case 1



Case 2

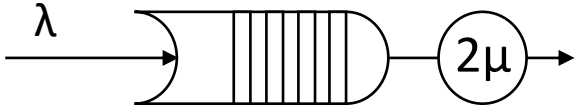


Case 3



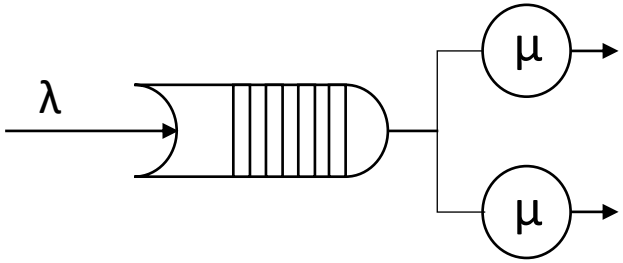
Which One Provides the Best Network Delay?

Case 1



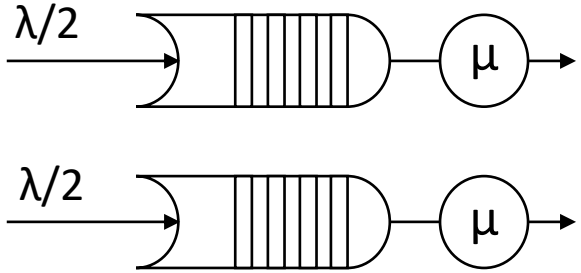
M/M/1 Queue

Case 2



M/M/2 Queue

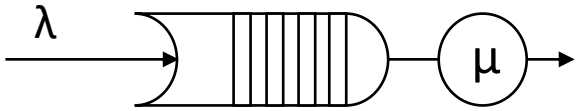
Case 3



M/M/1 Queue

Case 1: M/M/1 Queue

- Arrivals occur at rate λ according to a Poisson process
- Service times have an exponential distribution with rate parameter μ
- A **single** server serving with first-come first-served discipline



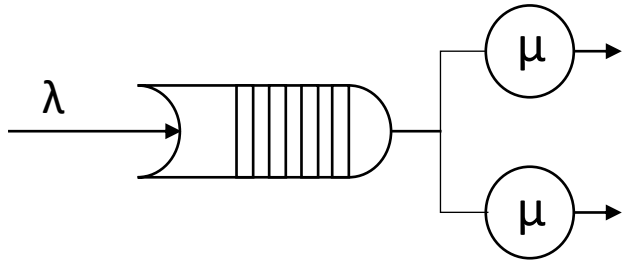
- Response time $E(T) = \frac{1}{\mu - \lambda}$, $\mu > \lambda$

capacity/packet length (p/s)

rate of the traffic (p/s)

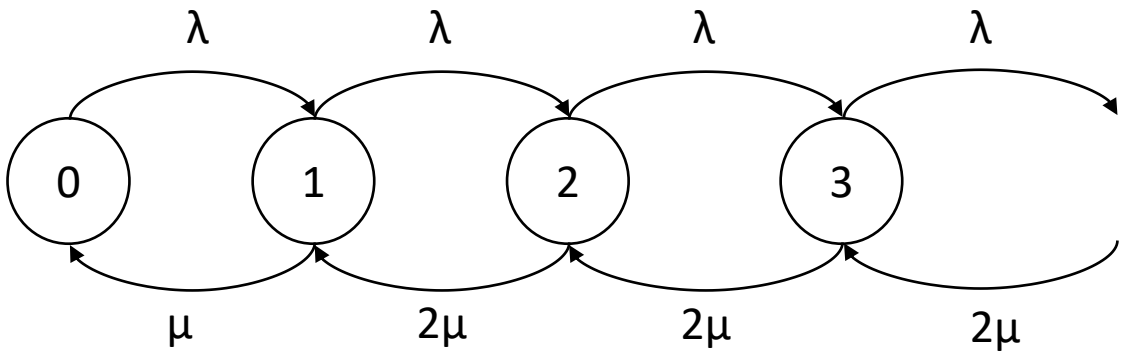
Case 2: M/M/2 Queue

- Arrivals occur at rate λ according to a Poisson process
- Service times have an exponential distribution with rate parameter μ
- A single queue with **multiple** servers



- Response time can be calculated with birth-death process model

Case 2: M/M/2 Queue cont.



$$P_0 \lambda = P_1 \mu$$

$$P_1 (\lambda + \mu) = P_0 \lambda + P_2 2\mu$$

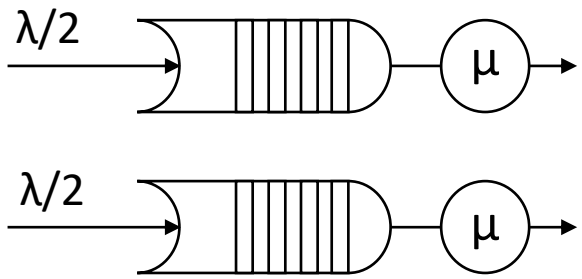
$$P_n (\lambda + 2\mu) = P_{n-1} \lambda + P_{n+1} 2\mu$$

$$\Sigma P_n = 1$$

After some math…

$$E(T) = \frac{4\mu}{(2\mu - \lambda)(2\mu + \lambda)}$$

Case 3: Two Parallel M/M/1 Queue

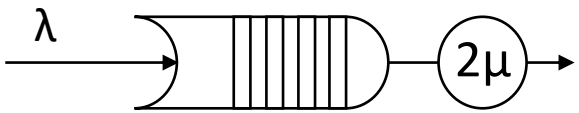


$$E(T) = \frac{1}{\mu - \lambda/2} \times 2$$

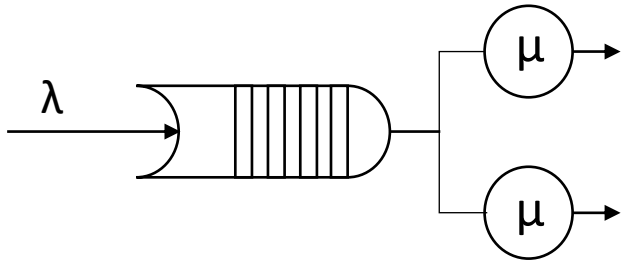
$$E(T) = \frac{4}{2\mu - \lambda}$$

Expected Network Delay for All Cases

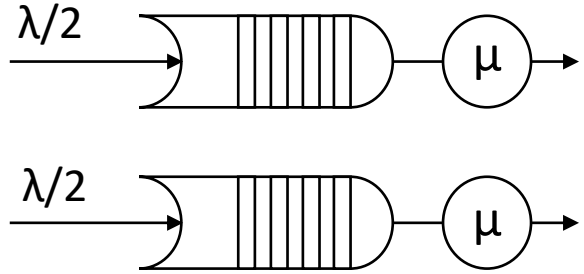
Case 1



Case 2



Case 3

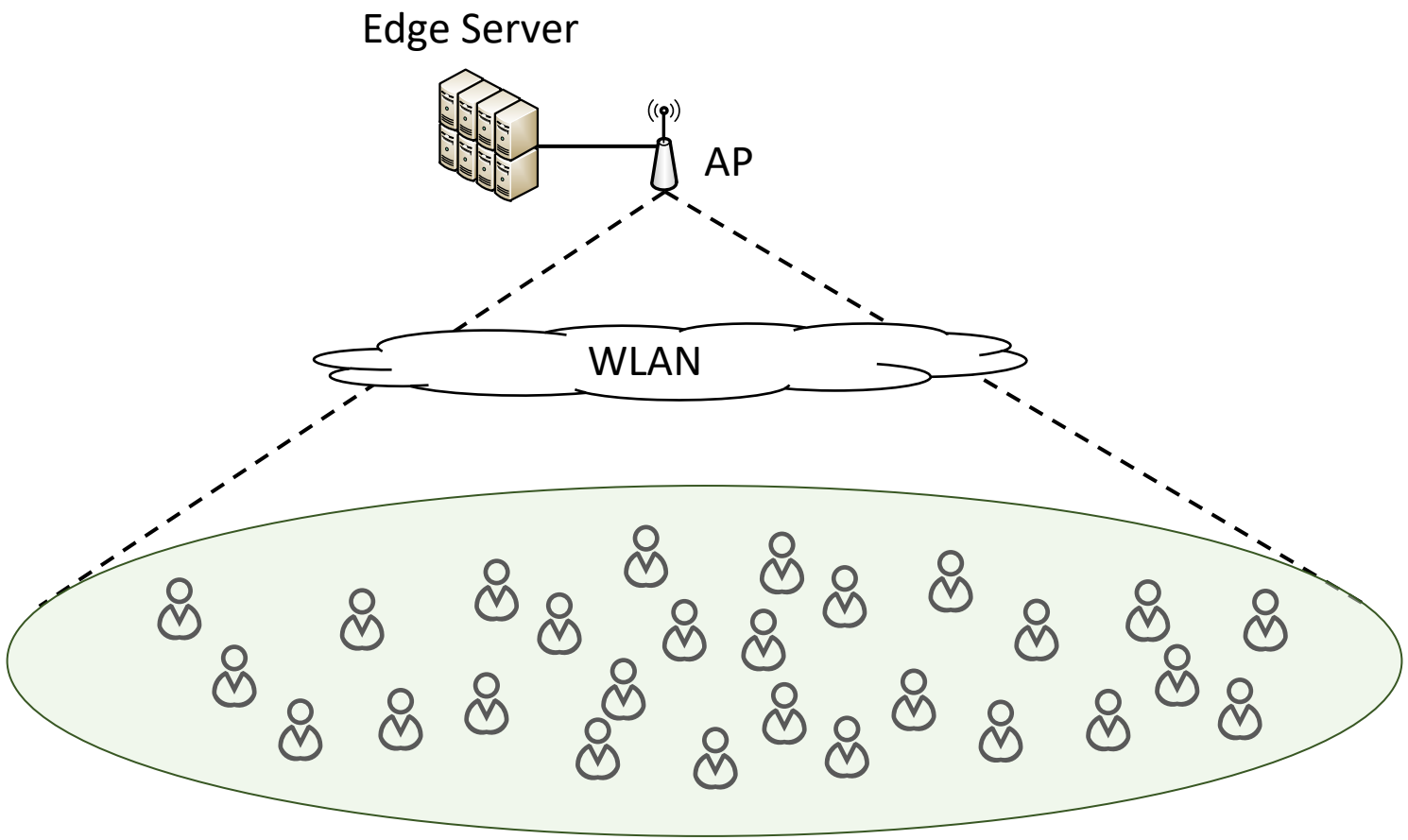


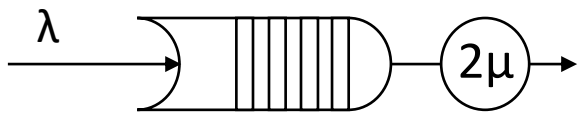
$$E(T) = \frac{1}{2\mu - \lambda} < E(T) = \frac{4\mu}{(2\mu - \lambda)(2\mu + \lambda)} < E(T) = \frac{4}{2\mu - \lambda}$$

Simulation Study on EdgeCloudSim

- Three cases are implemented on EdgeCloduSim
- An environment with 1000 to 2000 mobile clients is simulated
- Clients are utilizing an application that generates task according to a Poisson process
- Important simulation parameters are provided in the following slides
- You can find the source code of this simulation on GitHub
  - https://github.com/CagataySonmez/NetworkPerformanceEvaluation-EdgeCloudSim

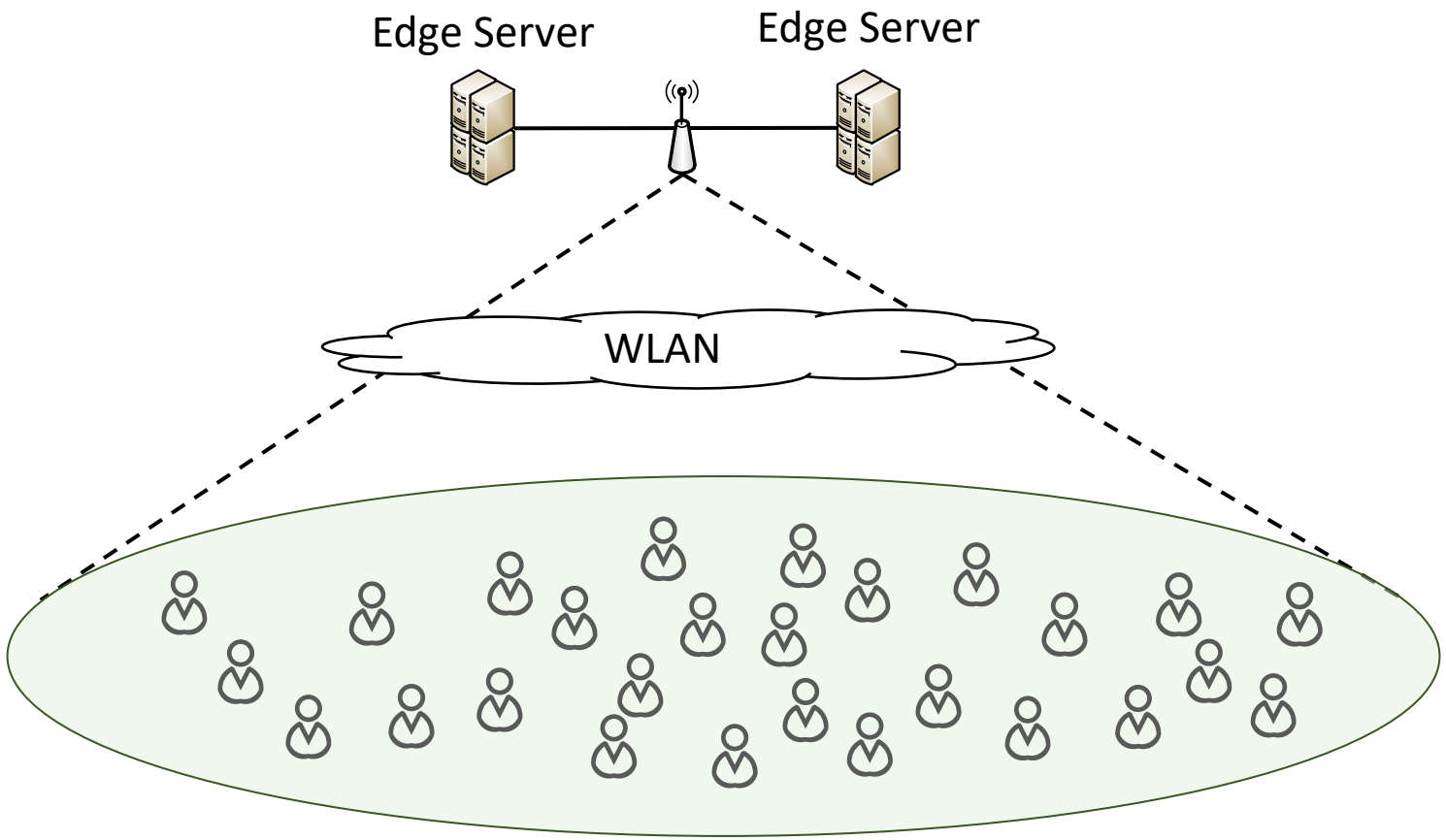
Implementation of Case1

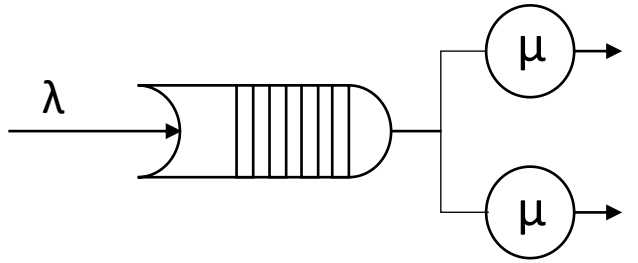




Parameter	Value
WLAN Bandwidth	100 Mbps
Number of Core Edge Server	4
Capacity of Edge Server	20 GIPS

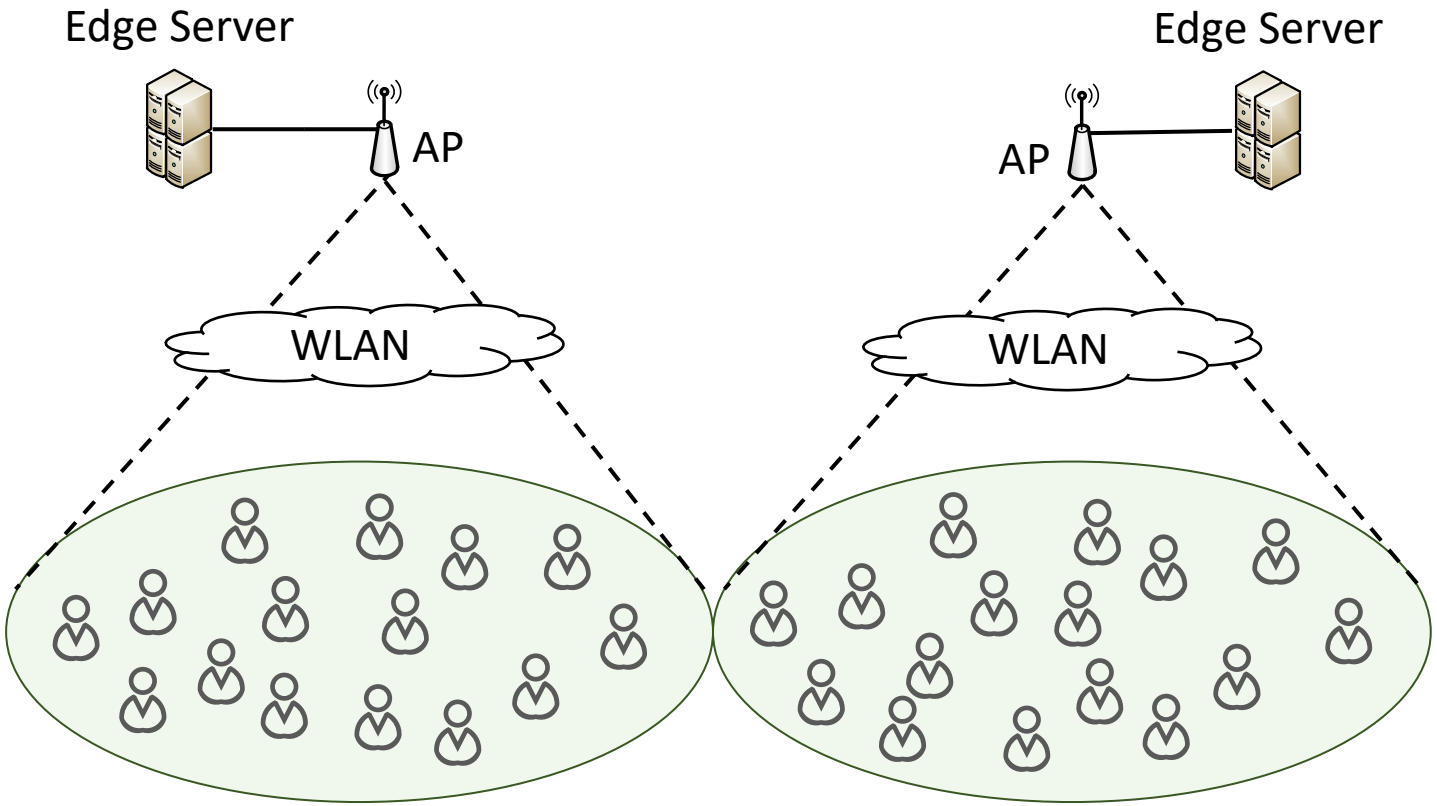
Implementation of Case2

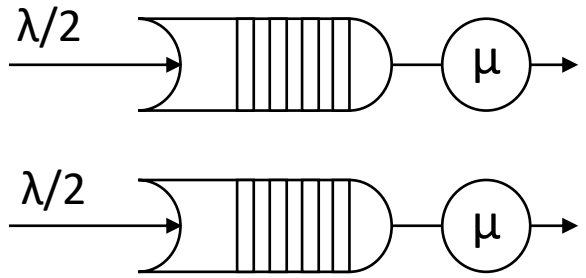




Parameter	Value
WLAN Bandwidth	50 Mbps
Number of Core Edge Server	2
Capacity of Edge Server	10 GIPS

Implementation of Case3





Parameter	Value
WLAN Bandwidth	50 Mbps
Number of Core Edge Server	2
Capacity of Edge Server	10 GIPS

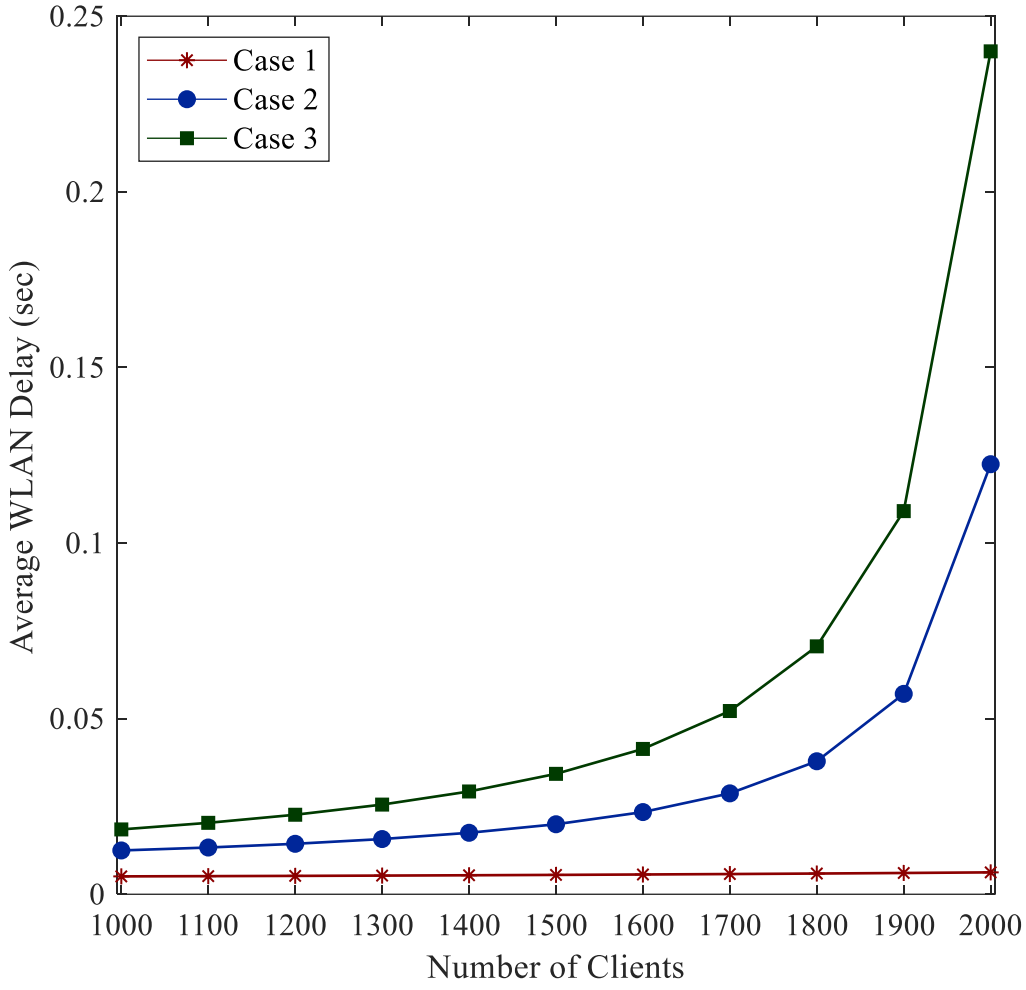
Application Used in Simulations

Parameter	Sample App
Task Interarrival (sec)	5
Active/Idle Period (sec)	30/1
VM Utilization on Edge/Cloud (%)	3
Task Length (GI)	500
Upload Data Size (KB)	30
Download Data Size (KB)	30

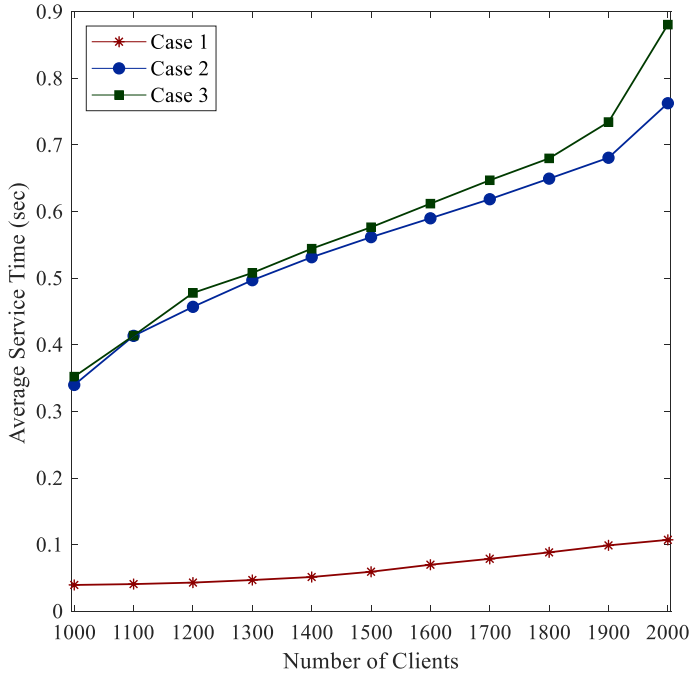
Simulation Parameters

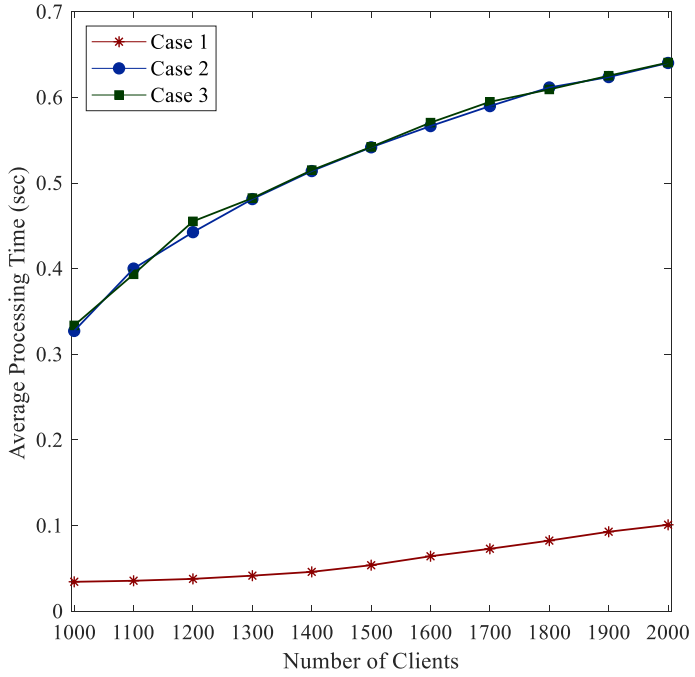
Parameter	Value
Simulation Time	30 minutes
Warm-up Period	5 minutes
Number of repetition	25
Mobility Model	Nomadic Mobility
Number of Mobile Clients	1000 to 2000
Length of the Simulated Area	6 KM

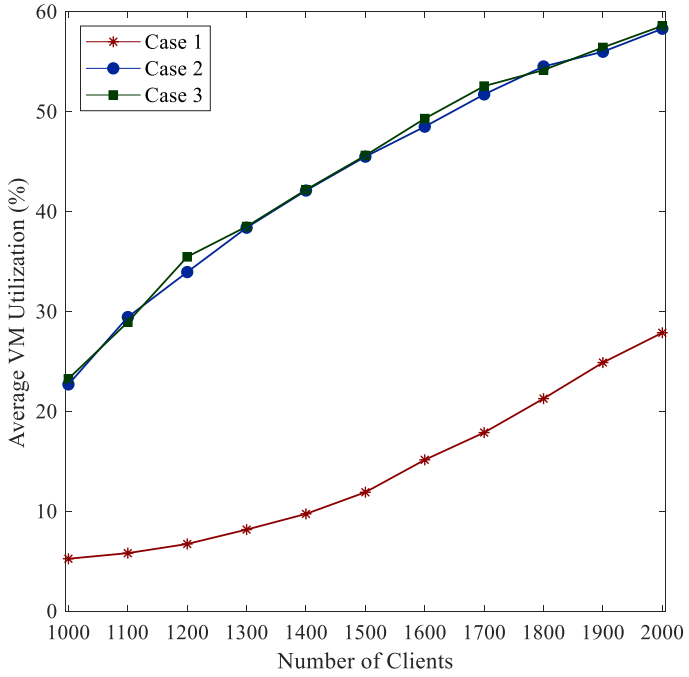
Average WLAN Delay



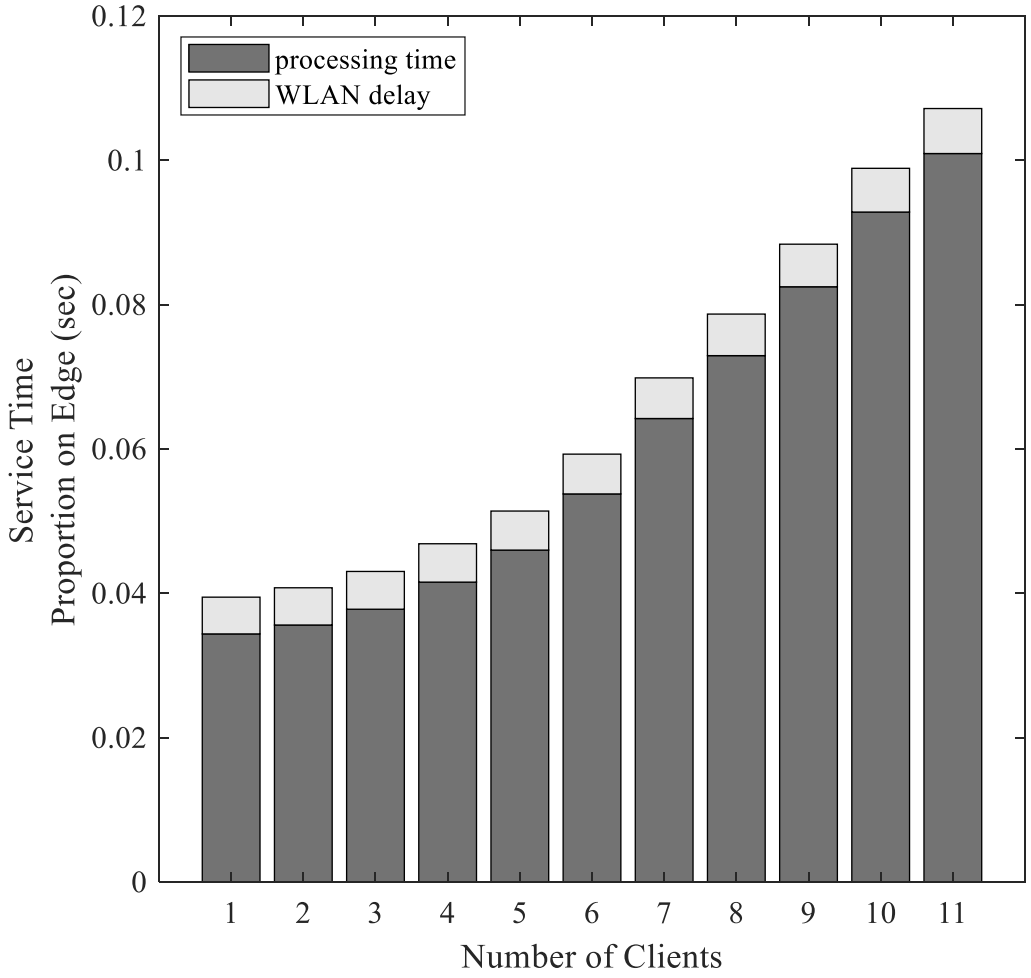
Server Side Statistics



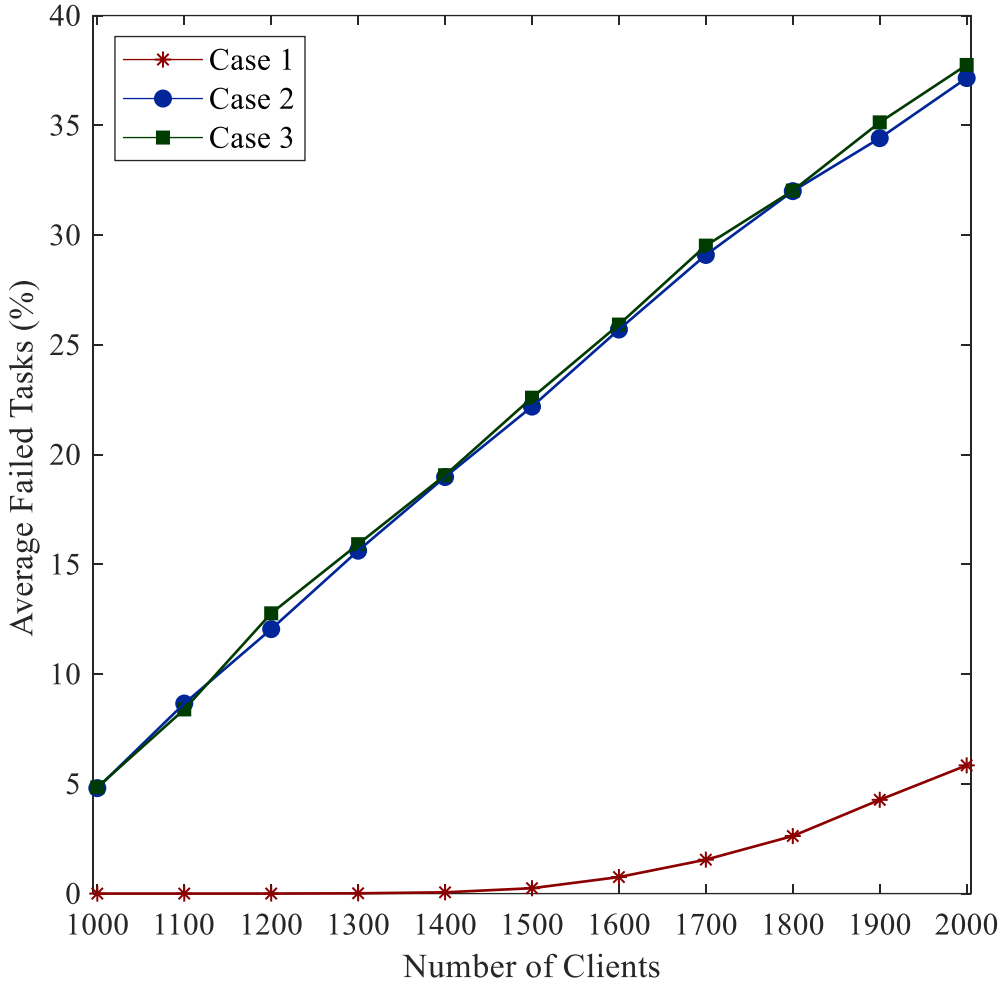




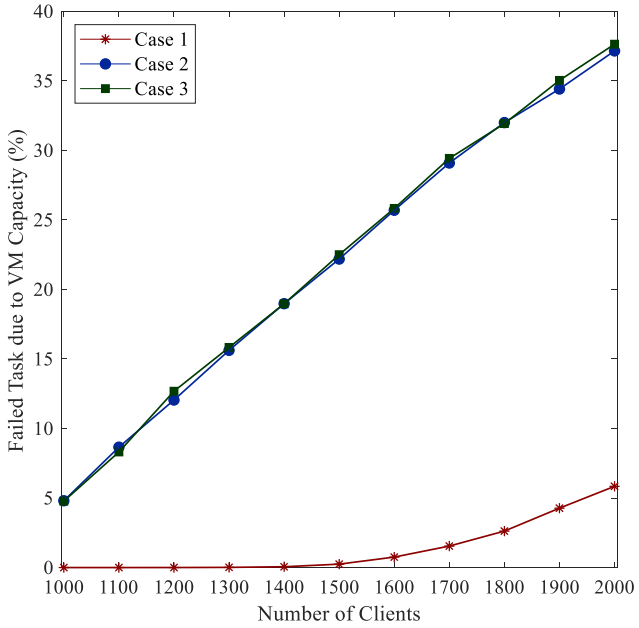
Proportion of Service Time Values

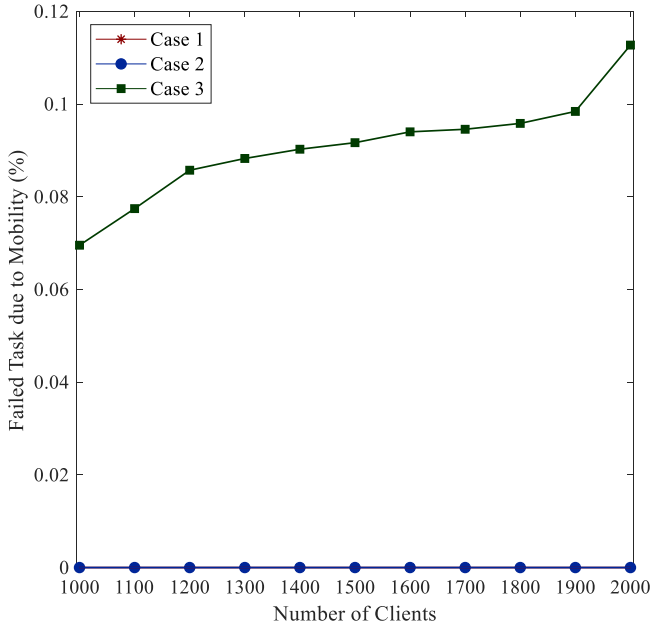


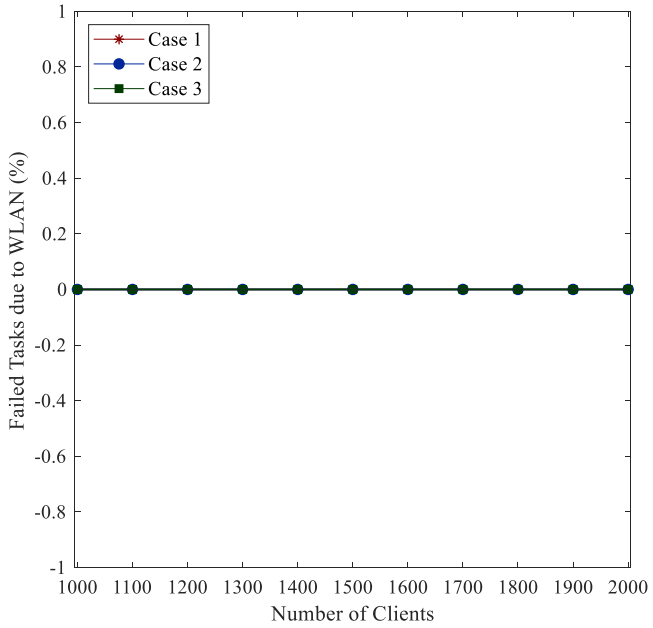
Average Failed Tasks



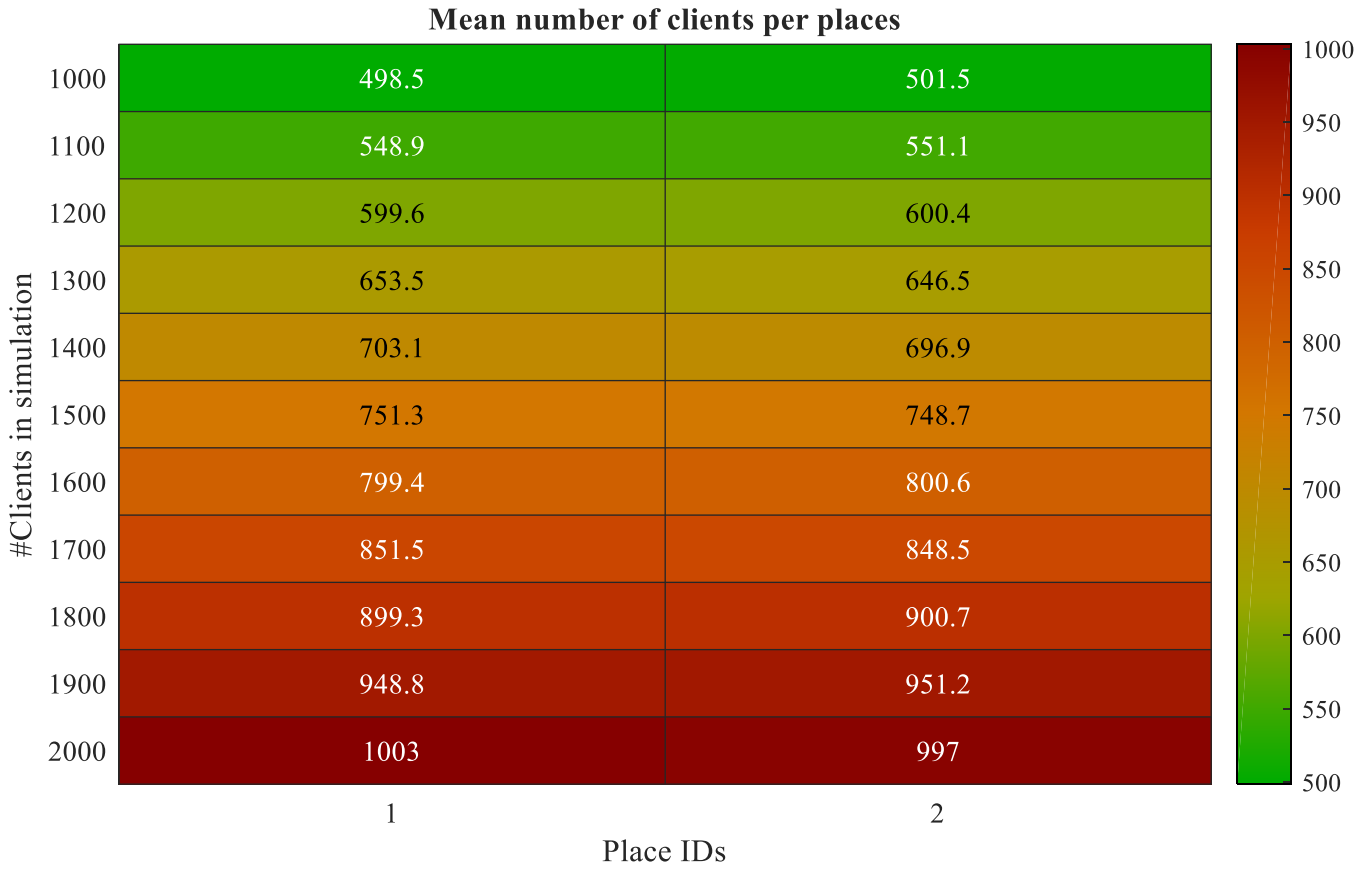
Task Failure Reasons







Average Number of Clients on the Places



Questions

References

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