# Network Performance Evaluation with EdgeCloudSim

18.05.2021

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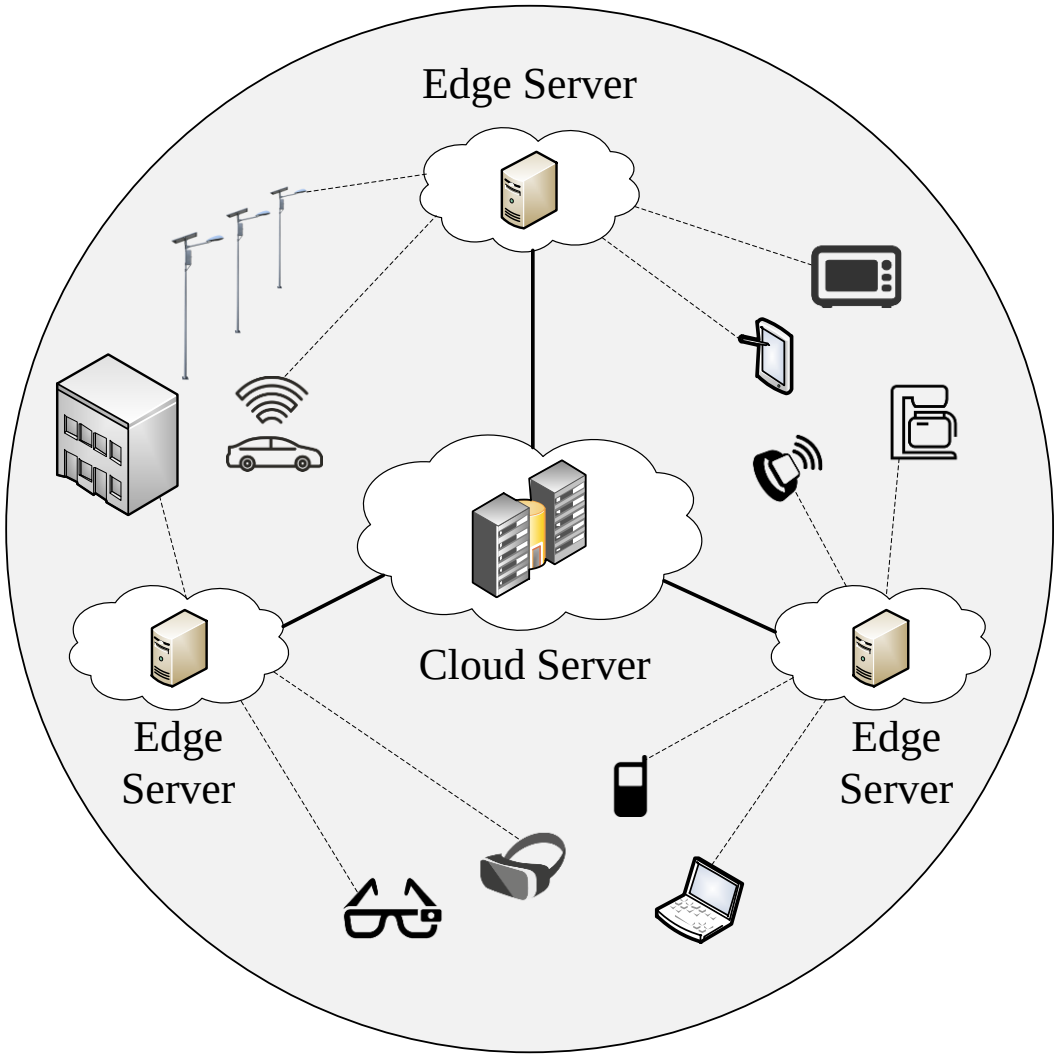
# Agenda

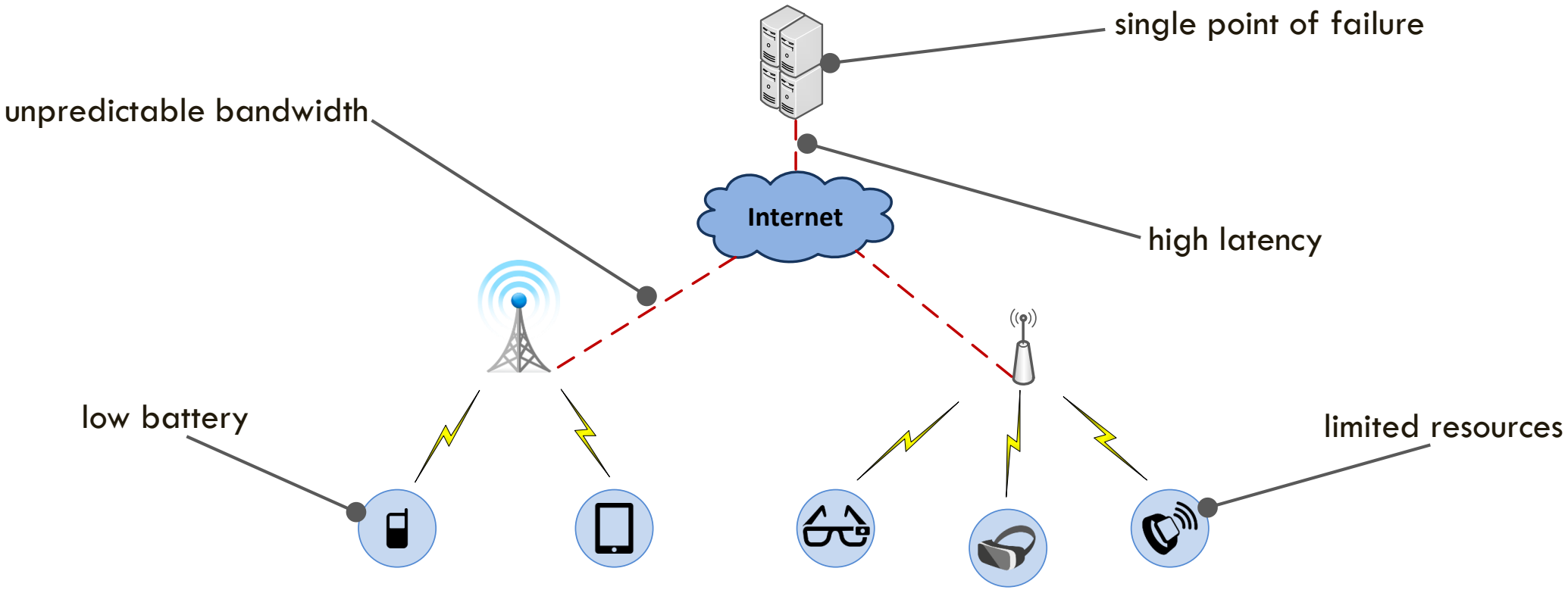
- Introduction to Edge Computing
- Challenges in Edge Computing Systems
- EdgeCloudSim
- Example Performance Evaluation Studies with EdgeCloudSim
  - Fuzzy Logic Based Workload Orchestrator
  - Machine Learning Based Workload Orchestrator
- A Network Performance Evaluation Case Study on EdgeCloudSim

# What is Edge Computing

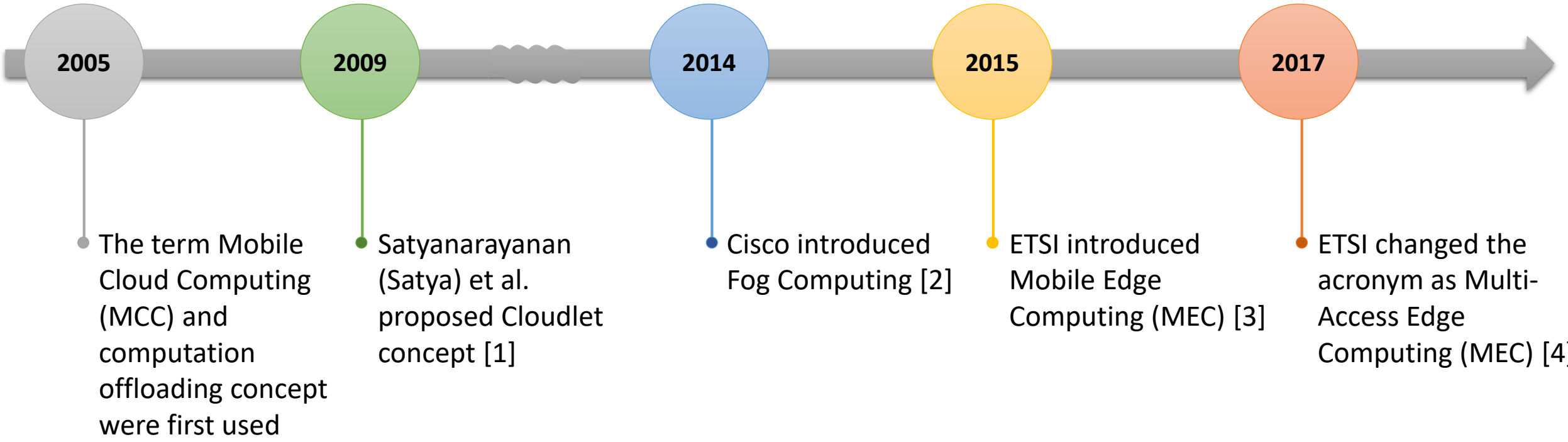



- Makes it possible to get services from nearby (edge) micro cloud server
- Data processing and storage are moved from the mobile device
- Complex operations can be executed on the edge server instead of local execution on the mobile devices

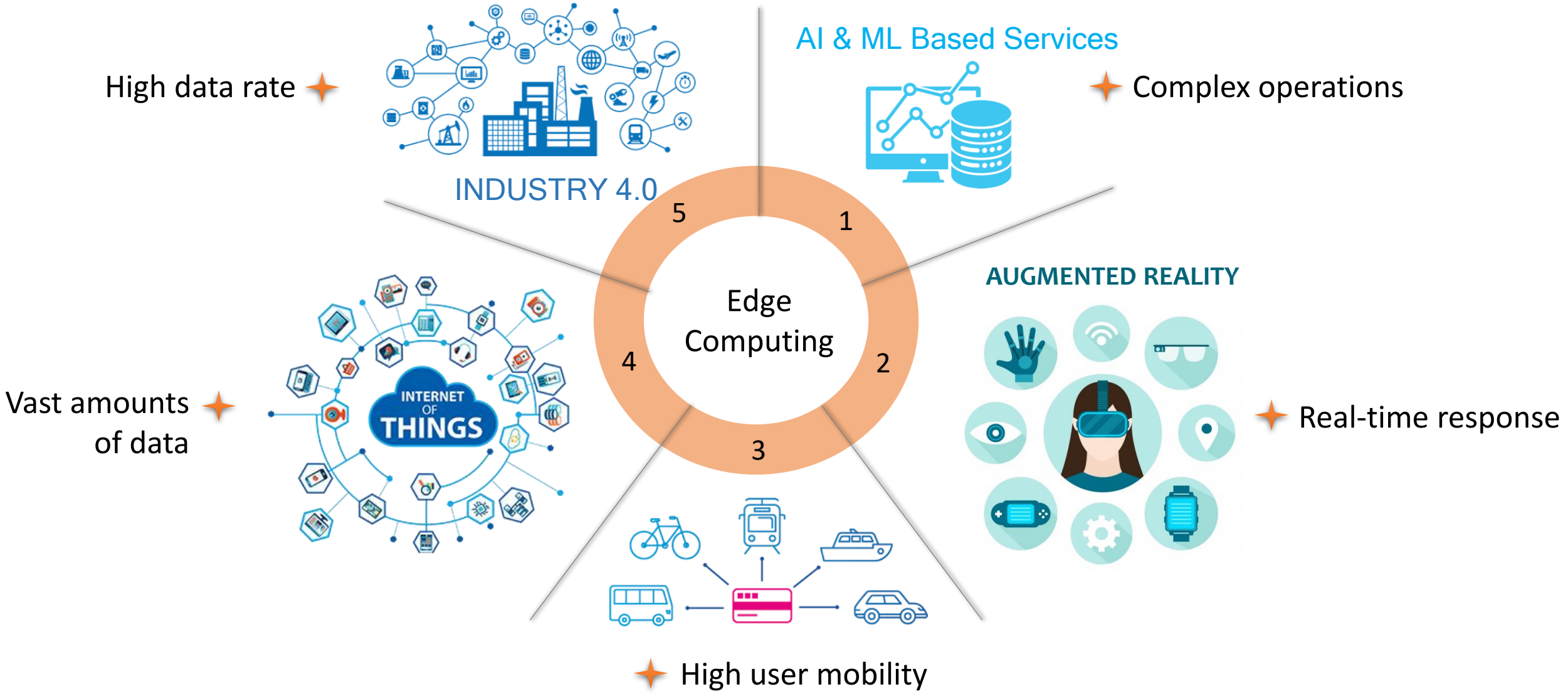
# Benefits of Edge Computing



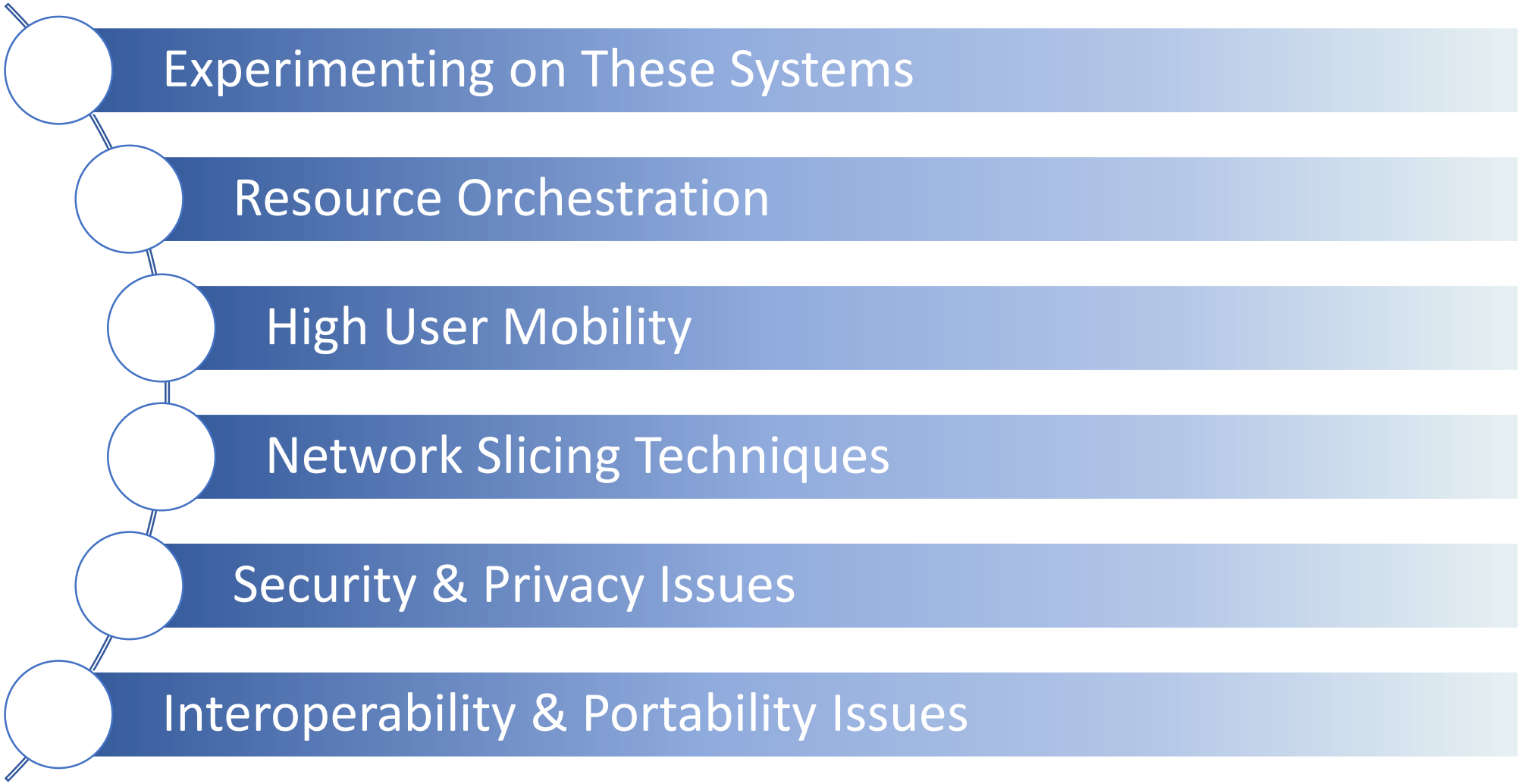
# The Evaluation of Edge Computing



# 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
- Provides a simu ...os
- EdgeCloudSim ...alities
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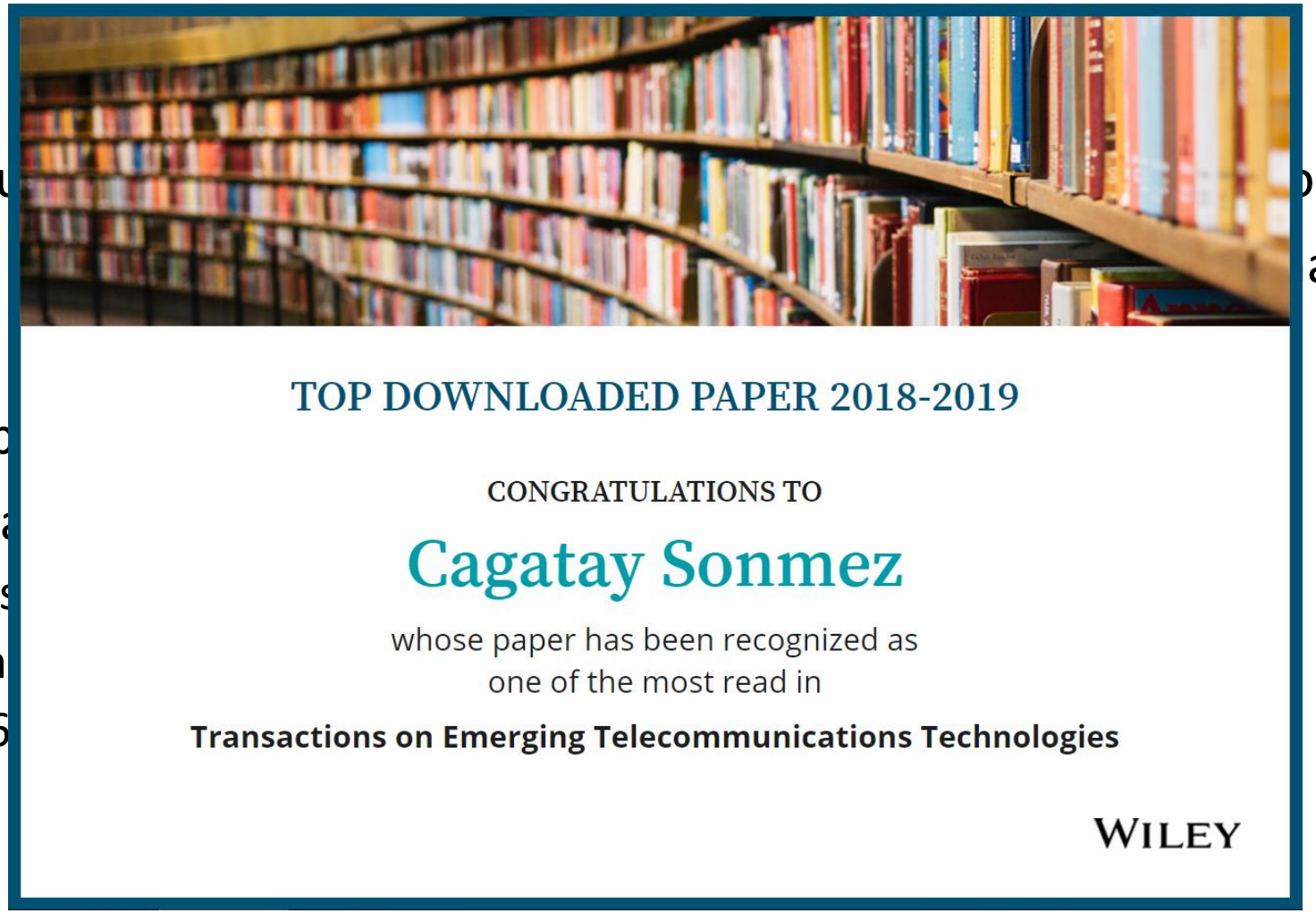
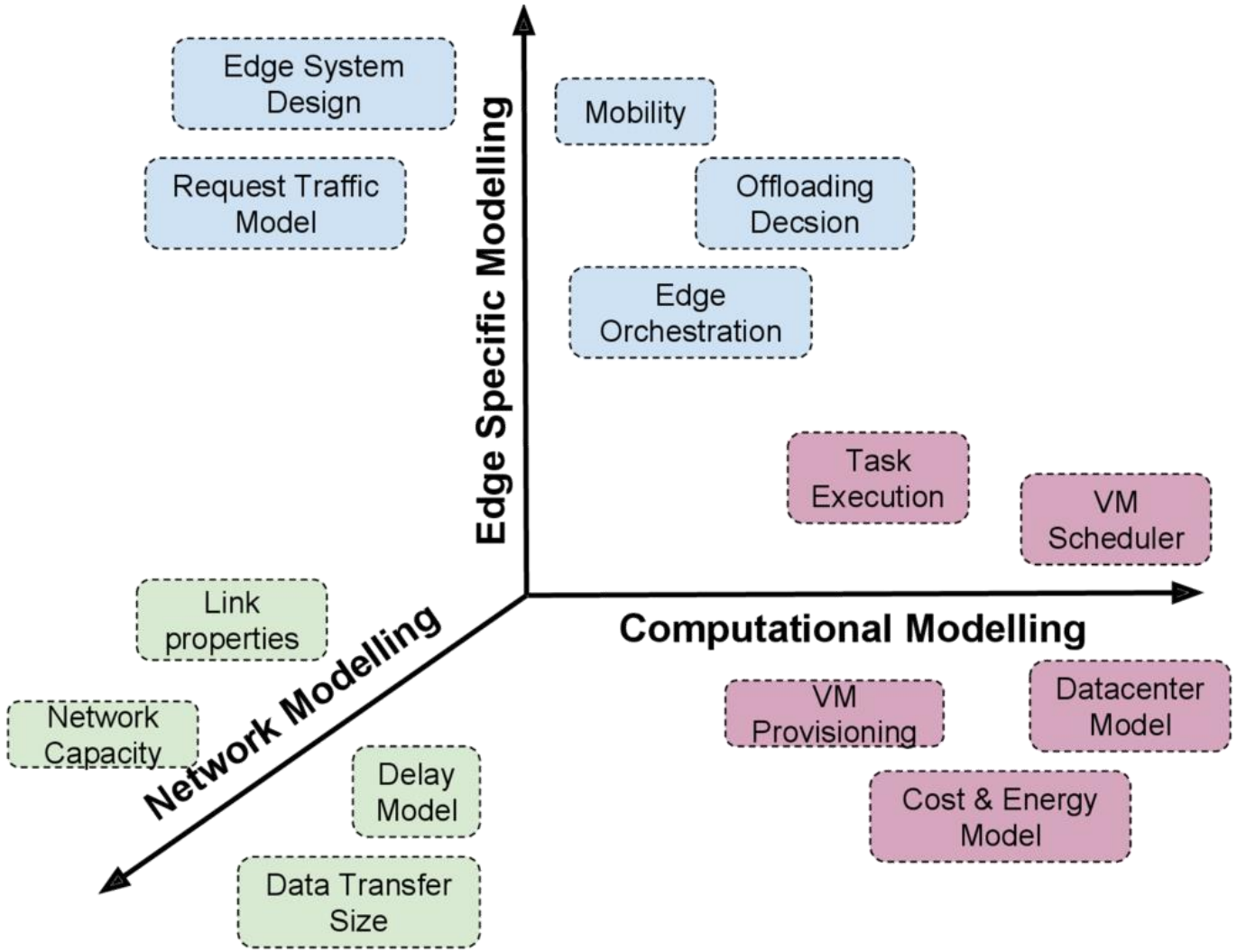
  - A discussion
  - More than 6



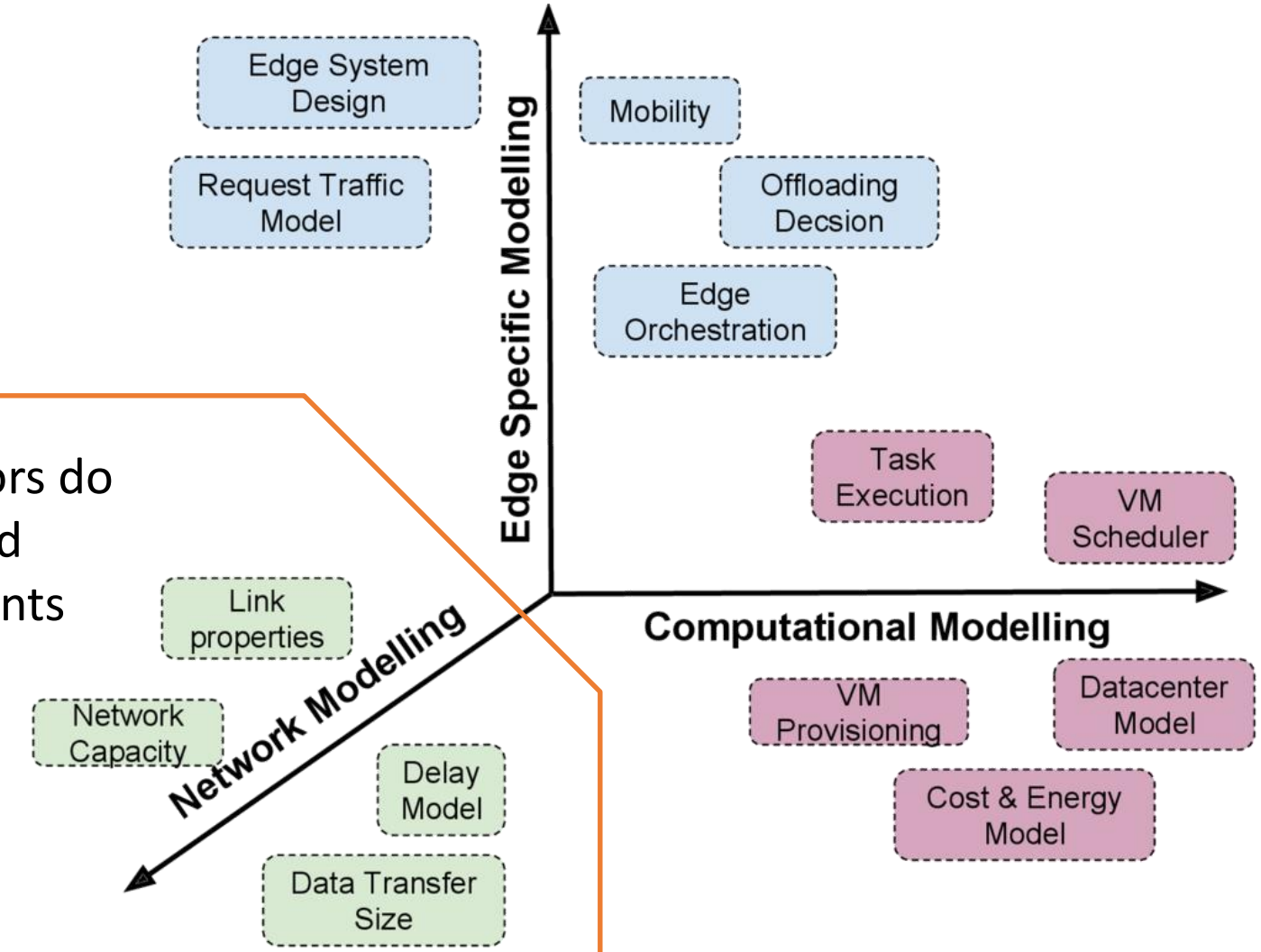
# Motivation of Developing a Simulator

- **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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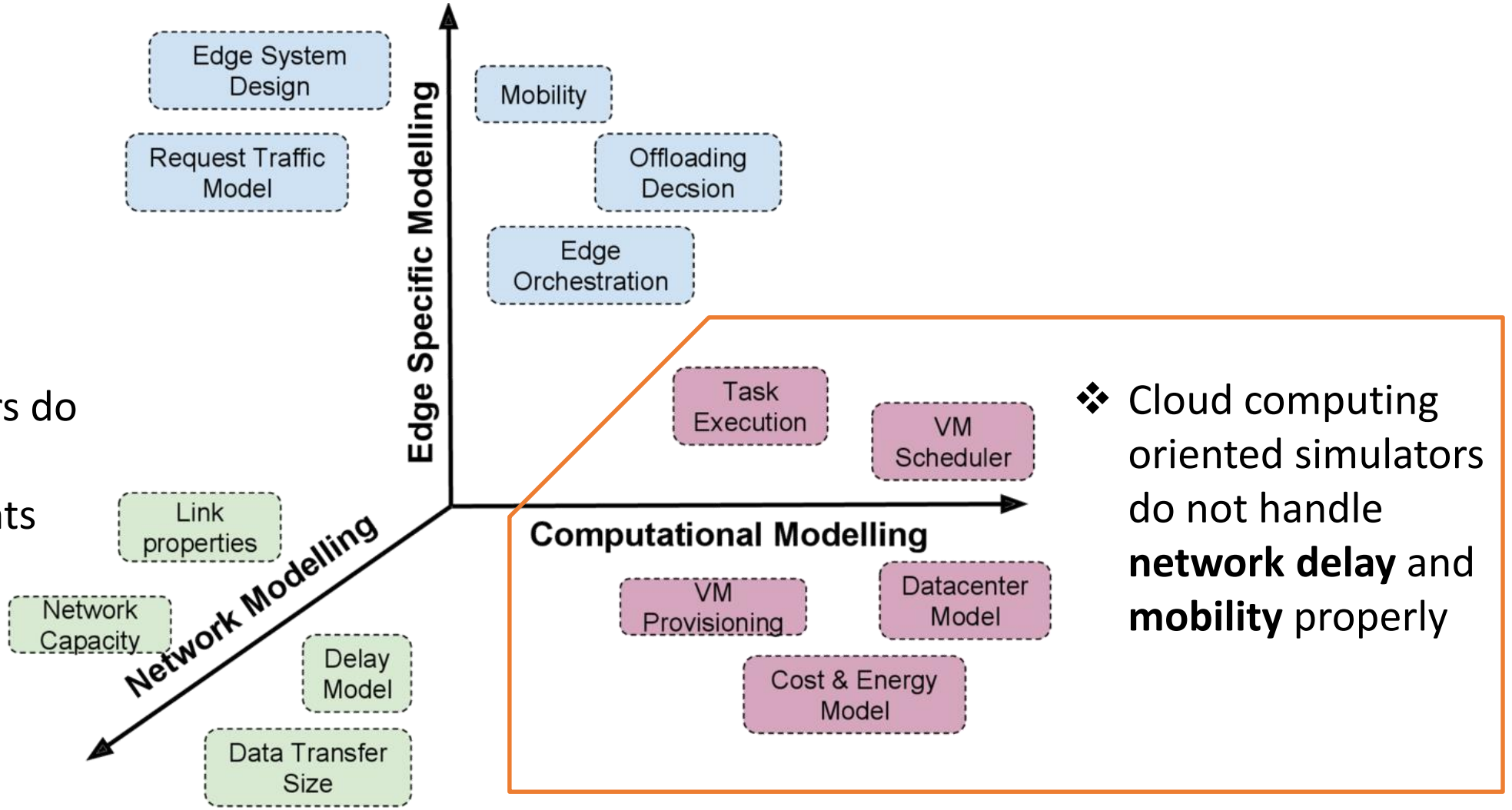
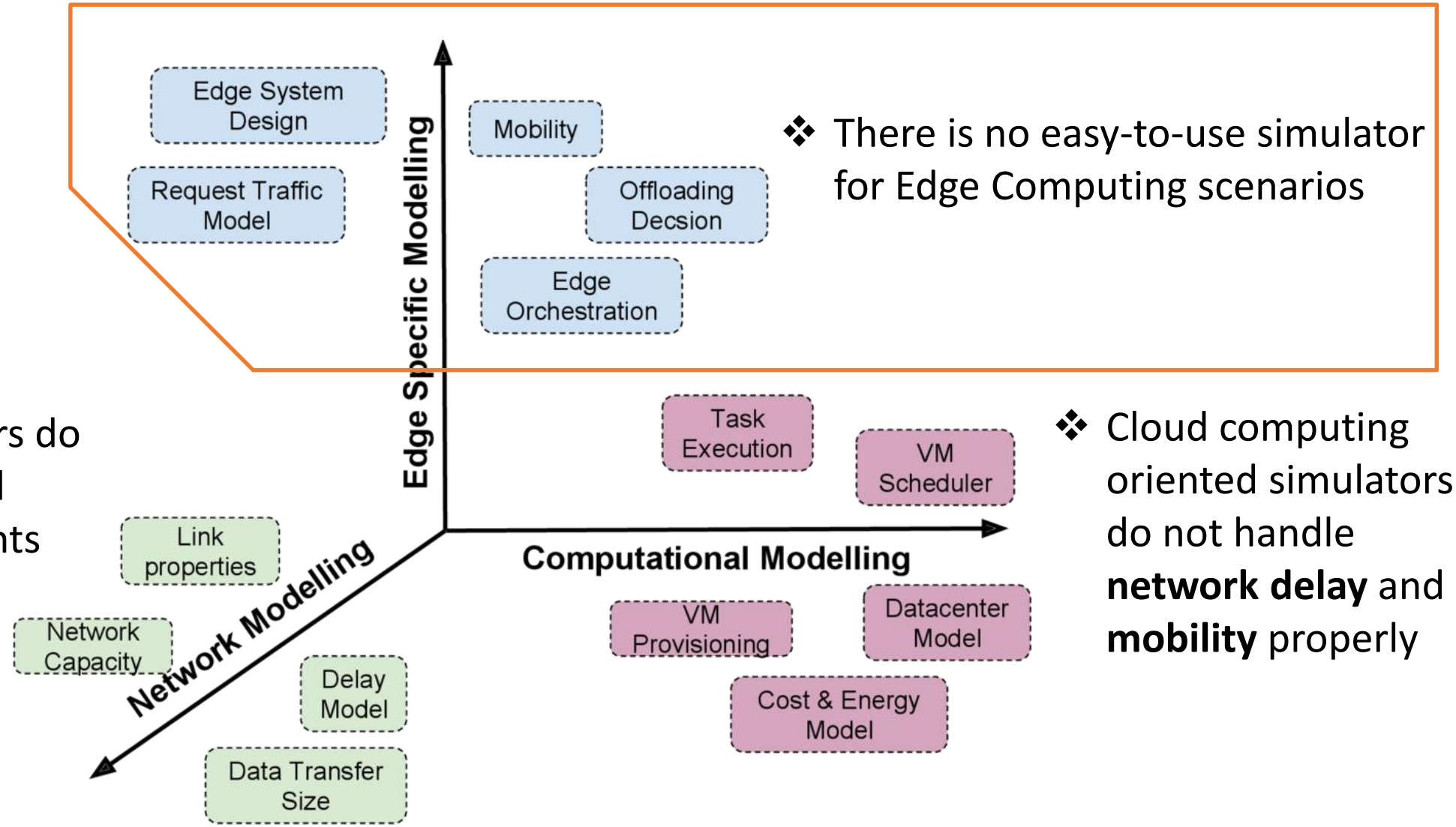



- Cloud computing oriented simulators do not handle **network delay** and **mobility** properly

# Motivation of Developing an Edge Comp. Sim.

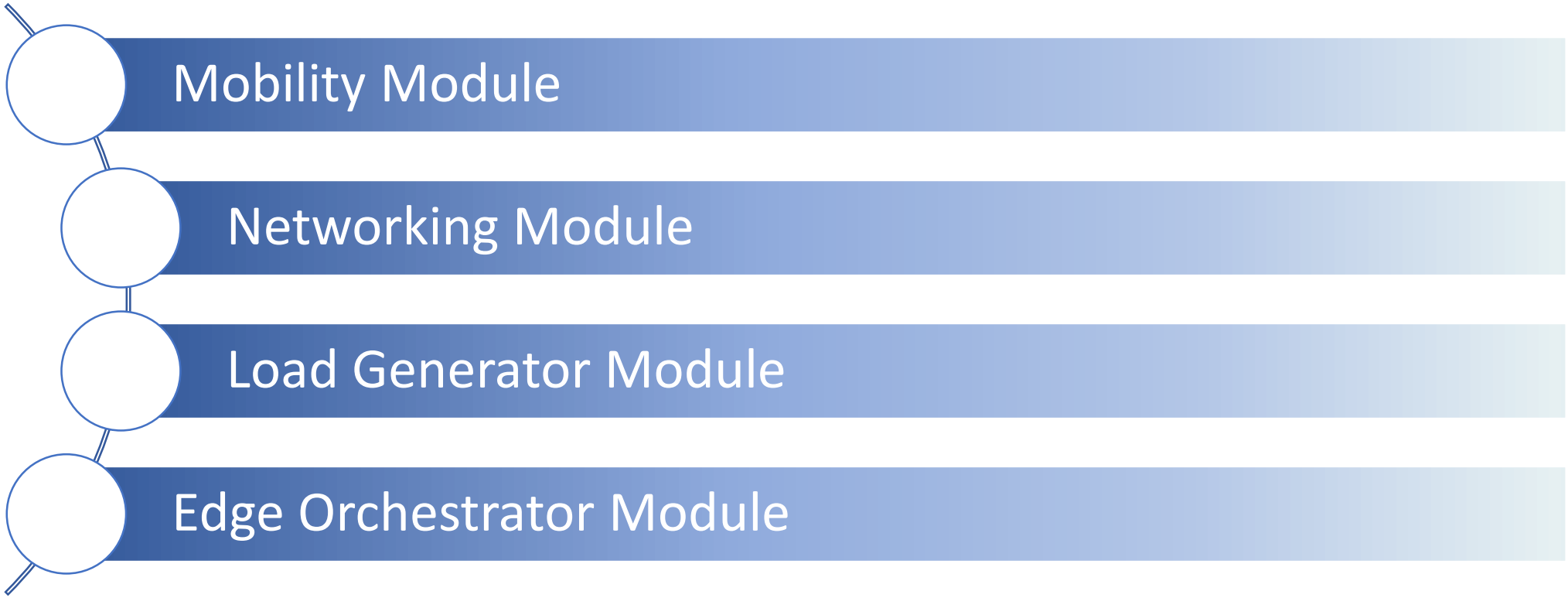



❖ There is no easy-to-use simulator for Edge Computing scenarios

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

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

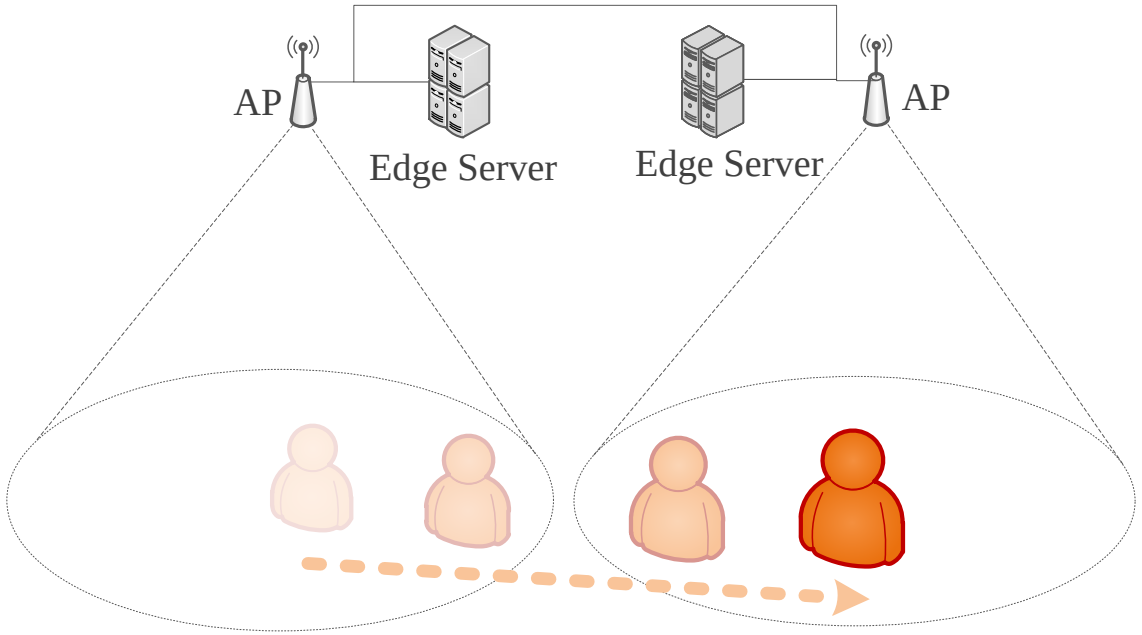
# EdgeCloudSim Core Modules



# EdgeCloudSim Core Modules cont.

## Mobility Module

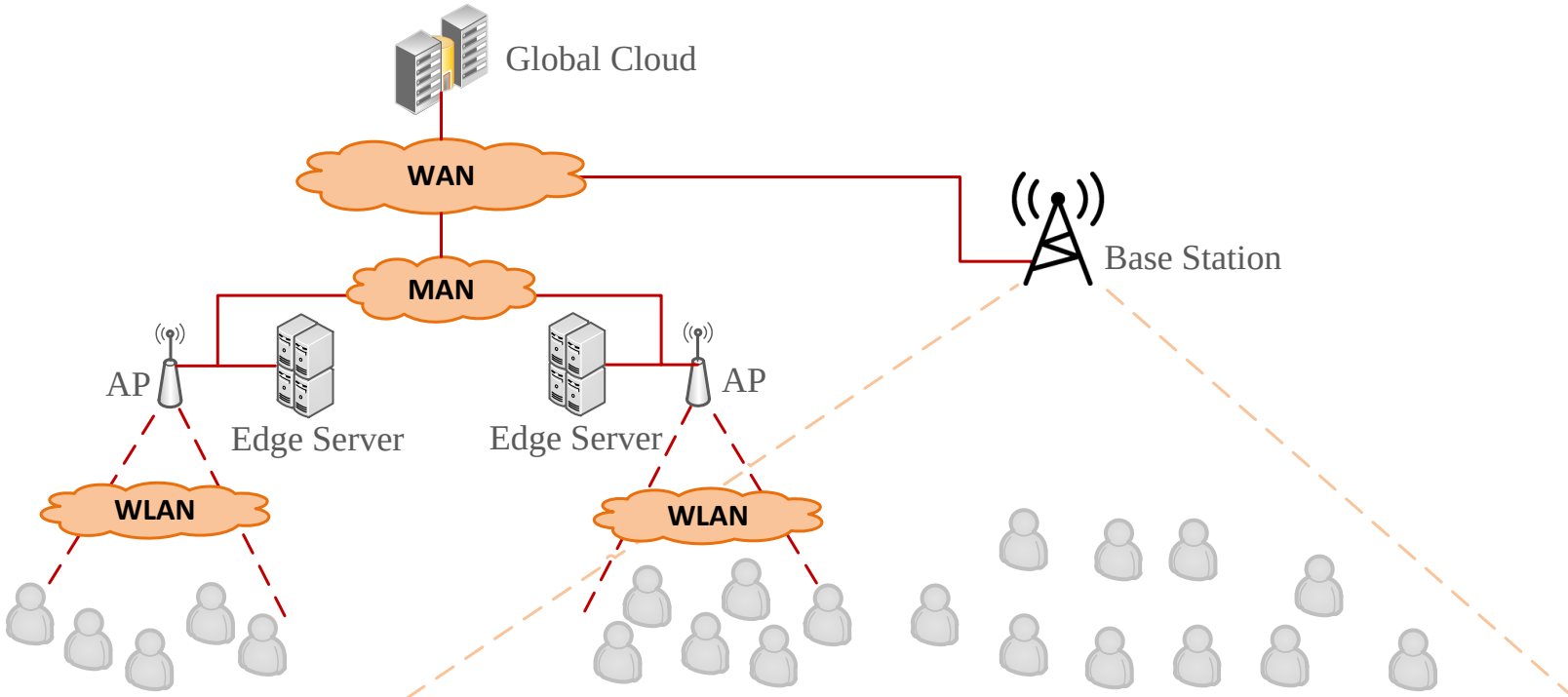
- Manages the location of edge devices and clients



# EdgeCloudSim Core Modules cont.

## Networking Module

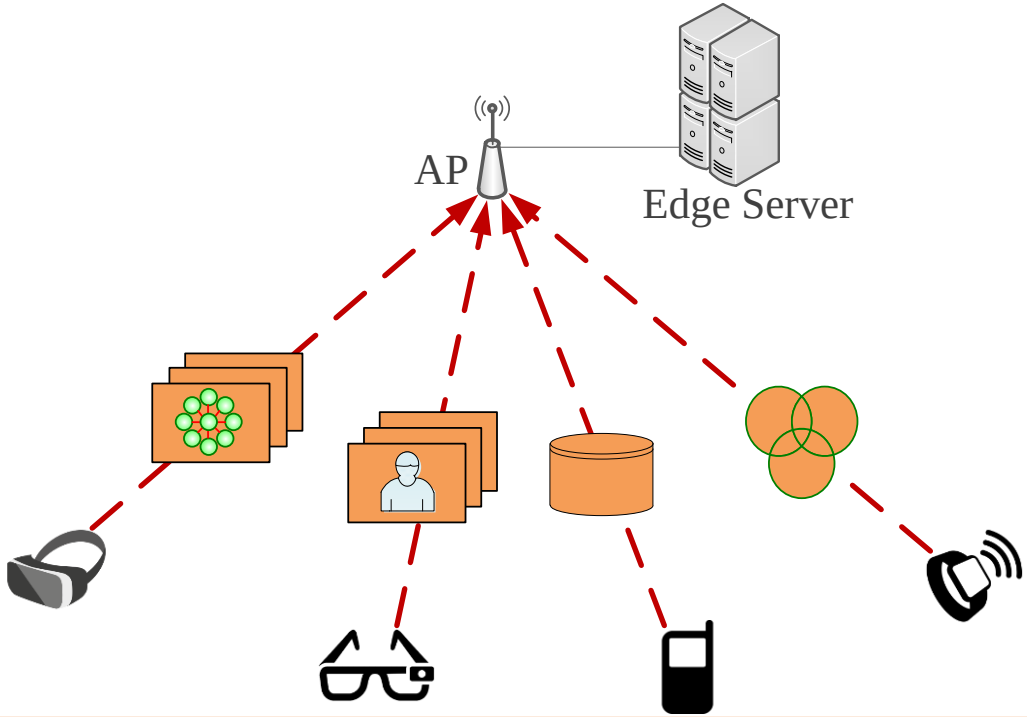
- Adds link delays between the network components



# EdgeCloudSim Core Modules cont.

## Load Generator Module

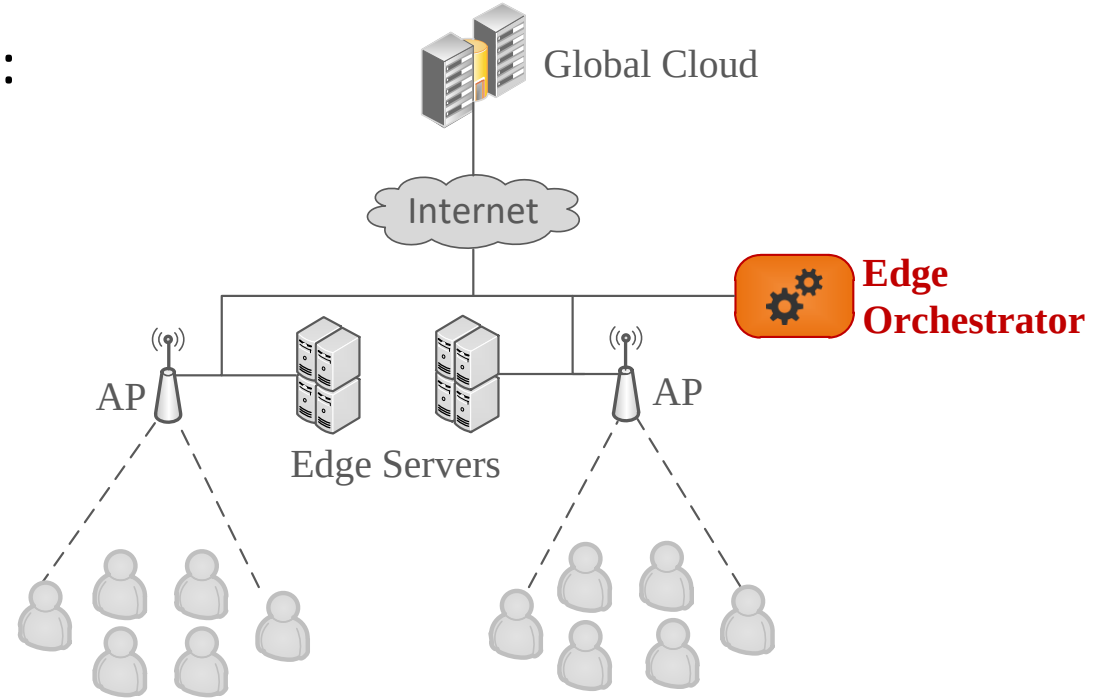
- Generates tasks based on the simulated scenario



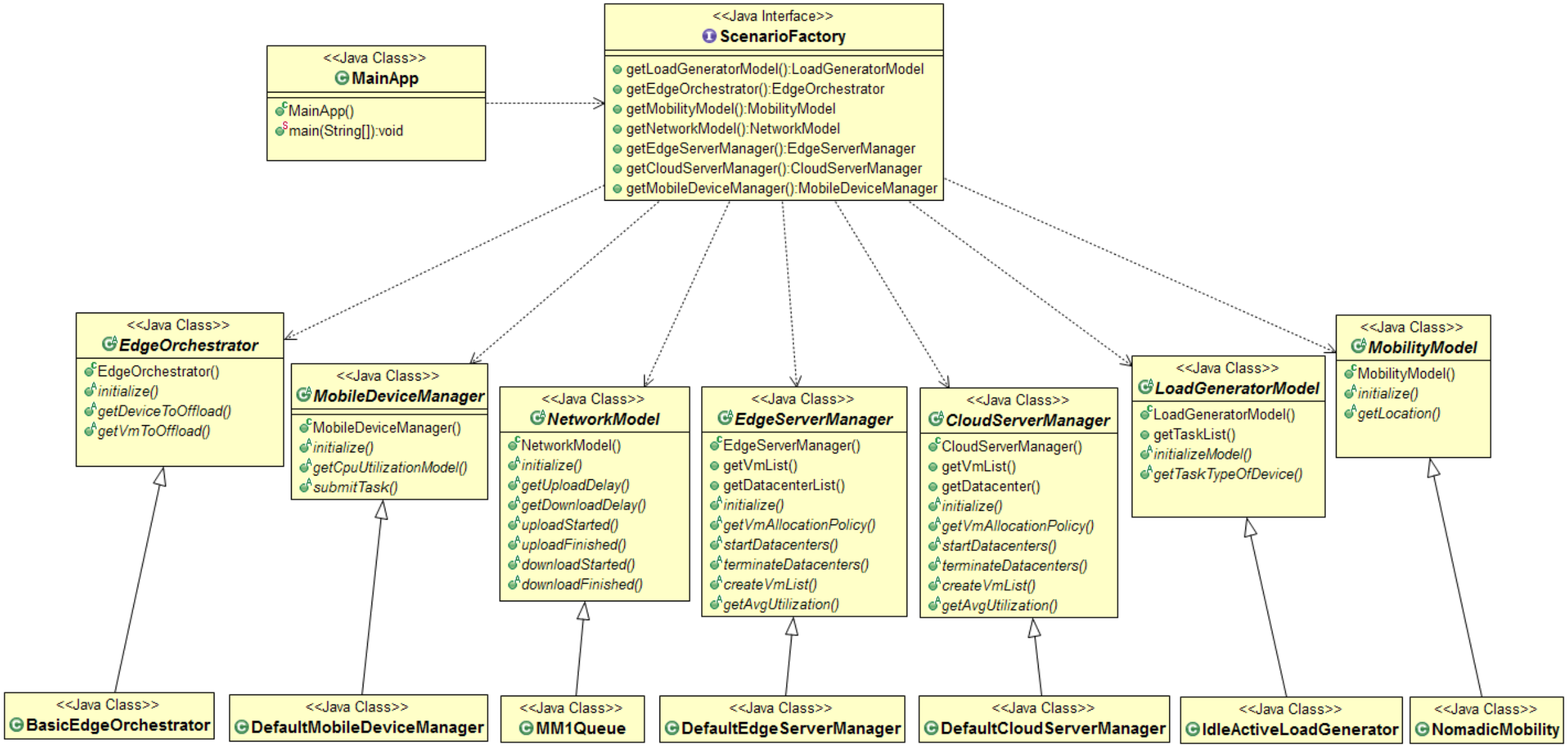
# EdgeCloudSim Core Modules cont.

## 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

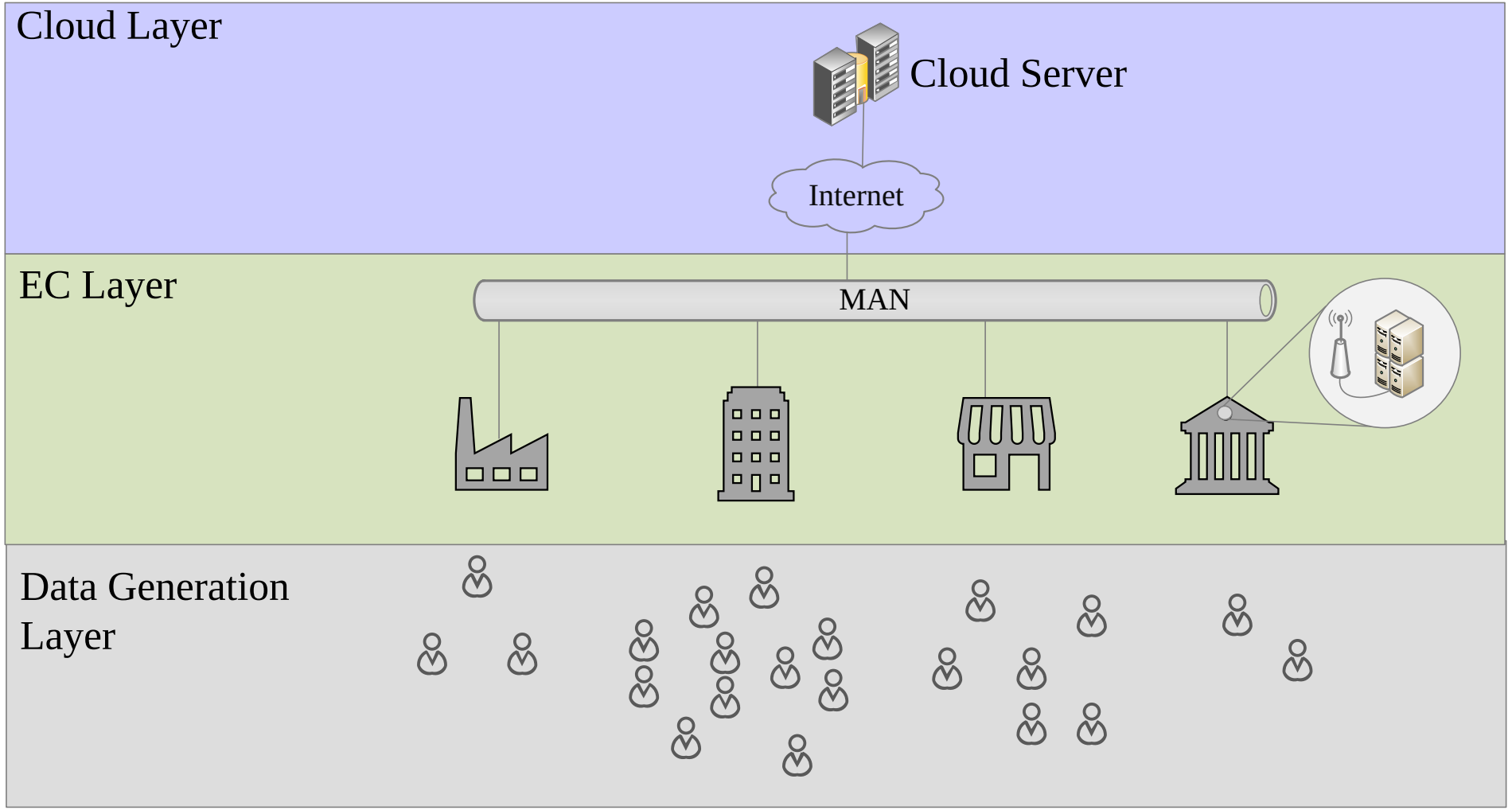
# Publications using EdgeCloudSim

- ✓ 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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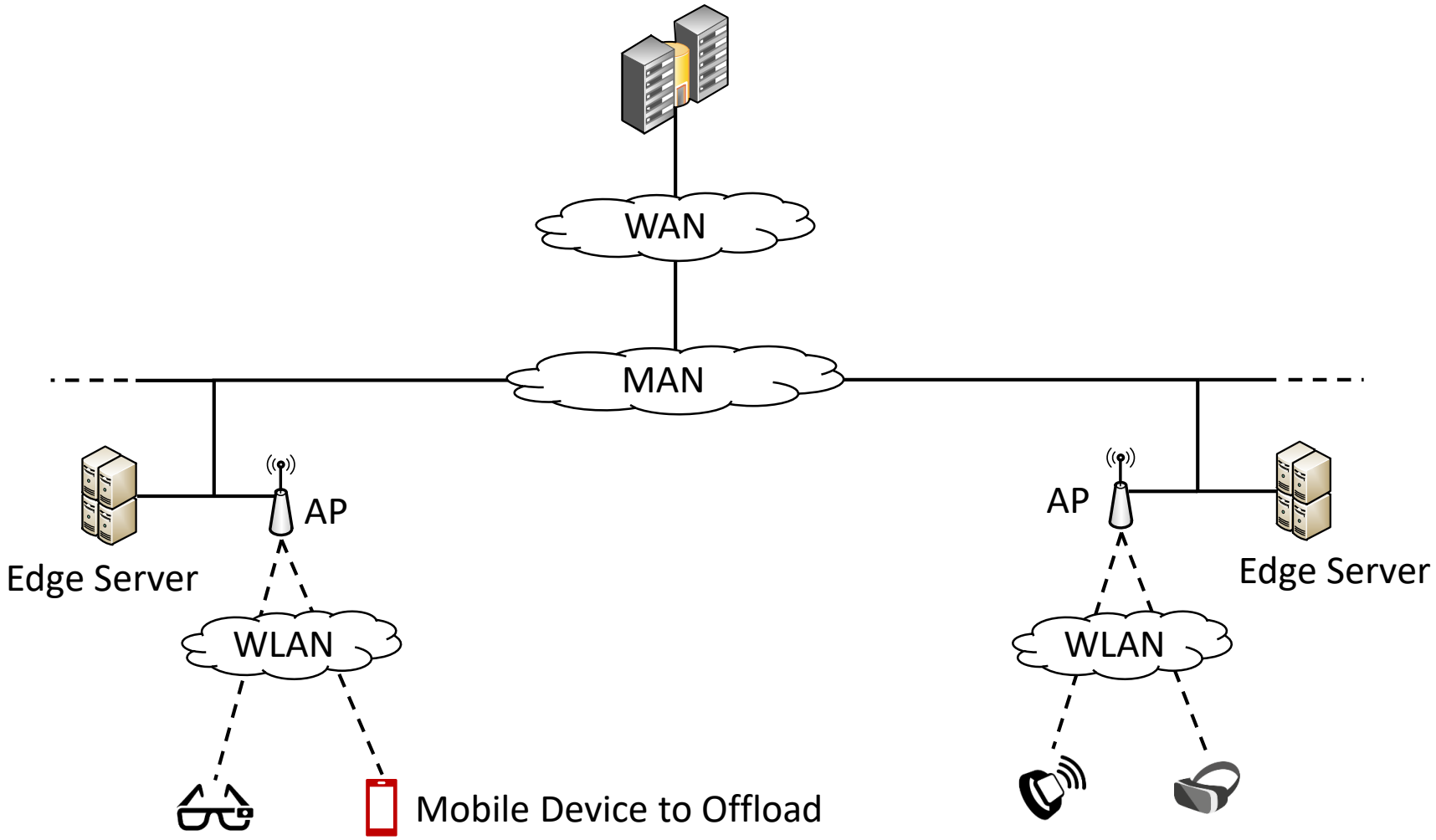

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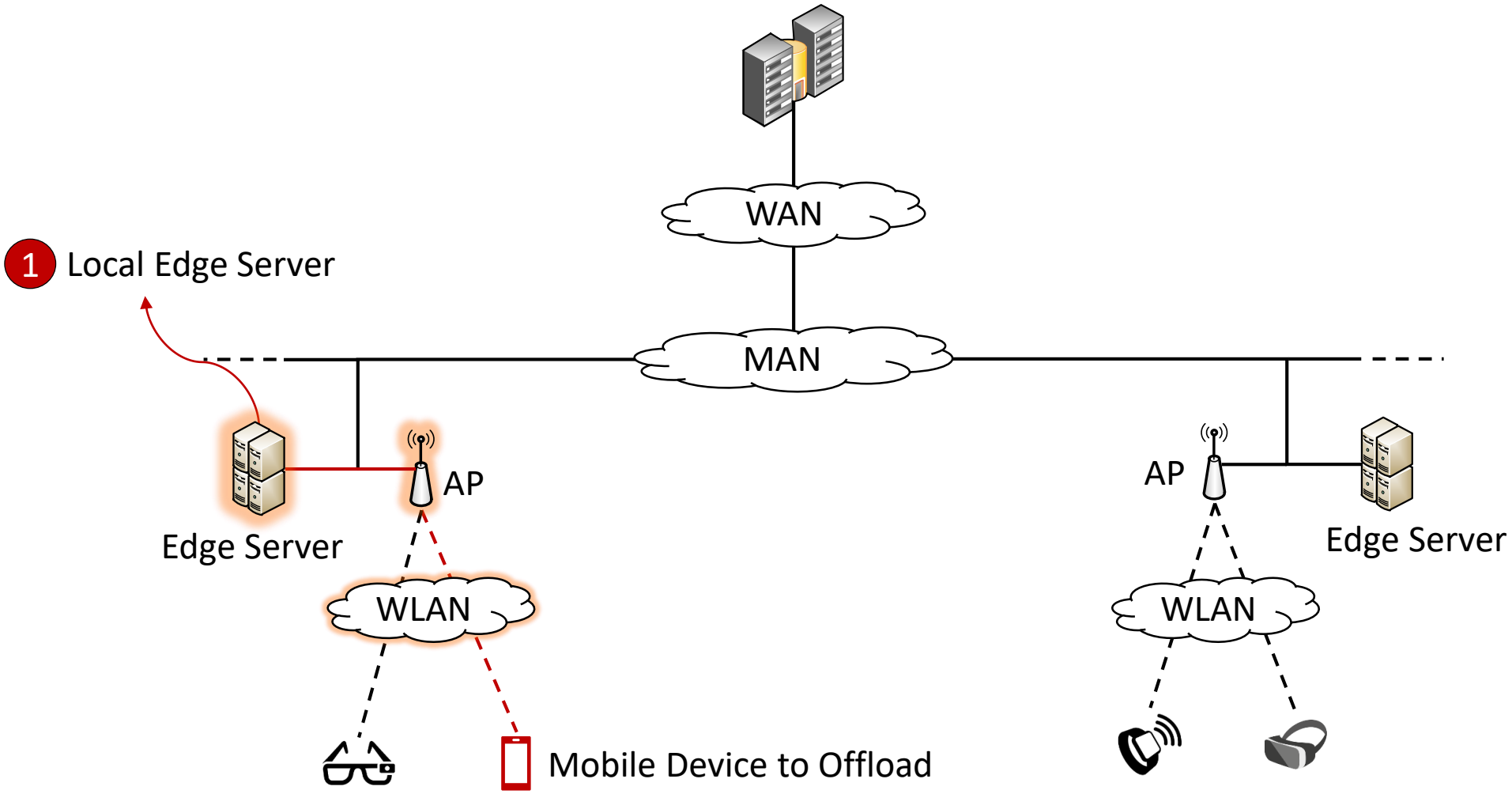

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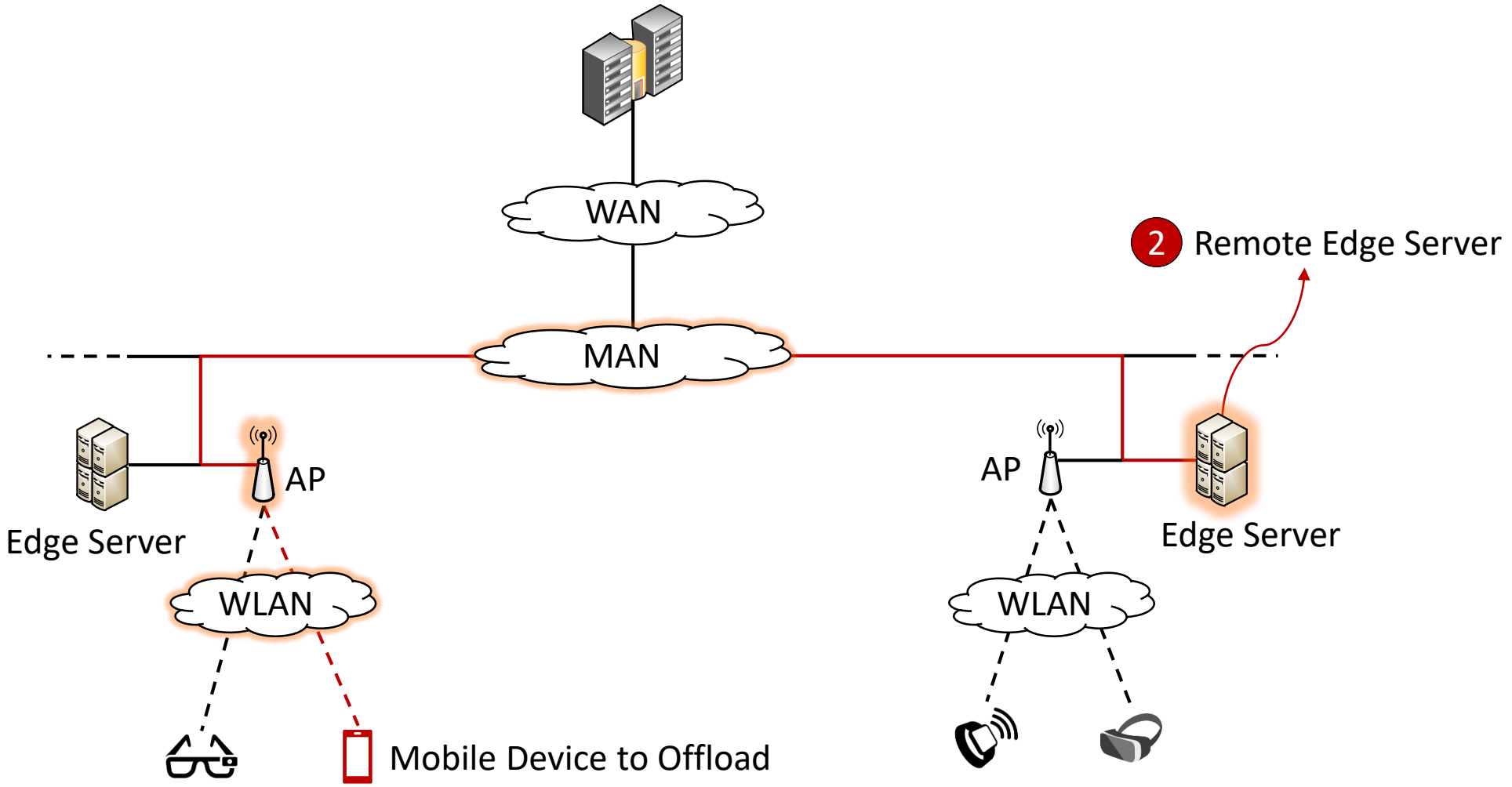

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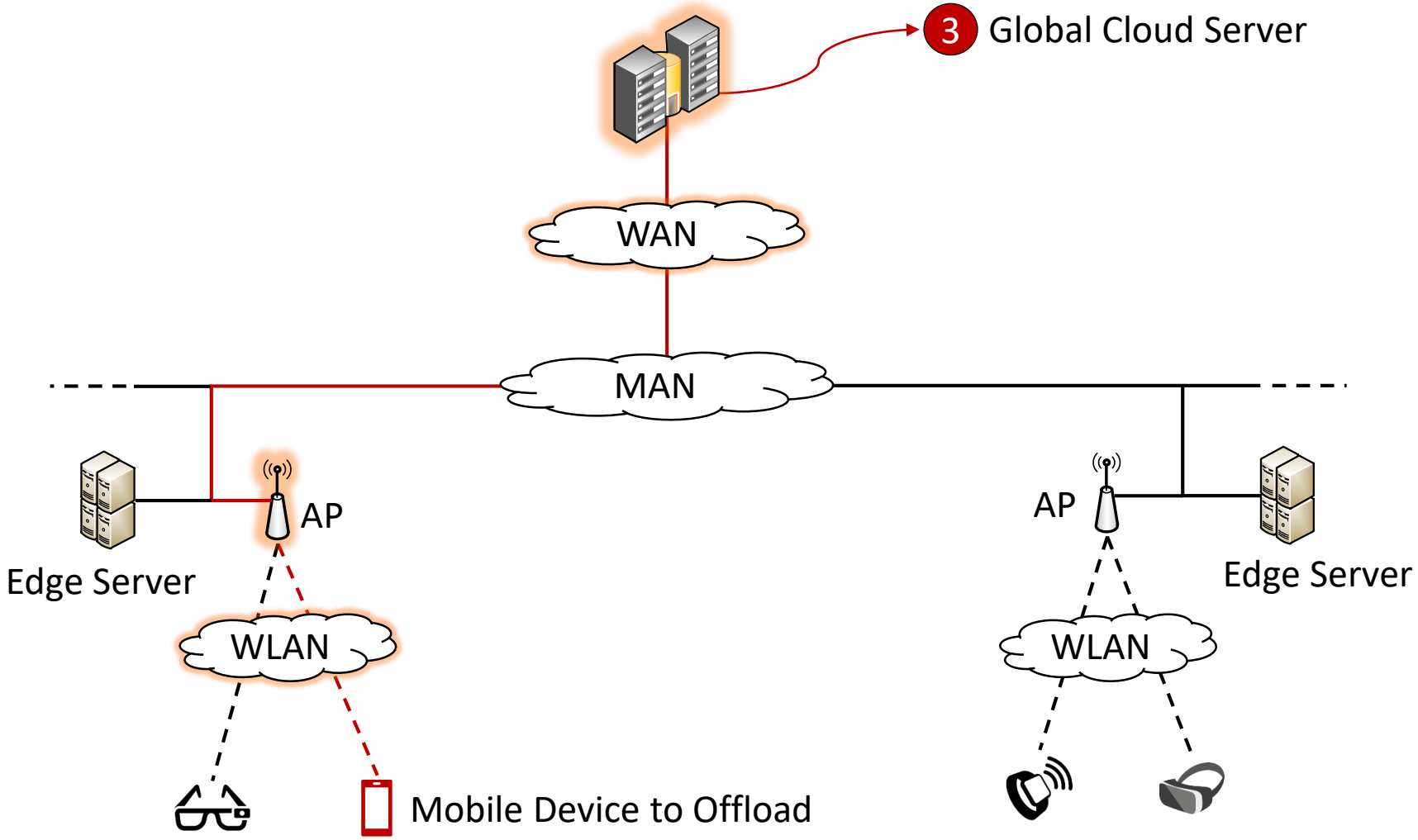

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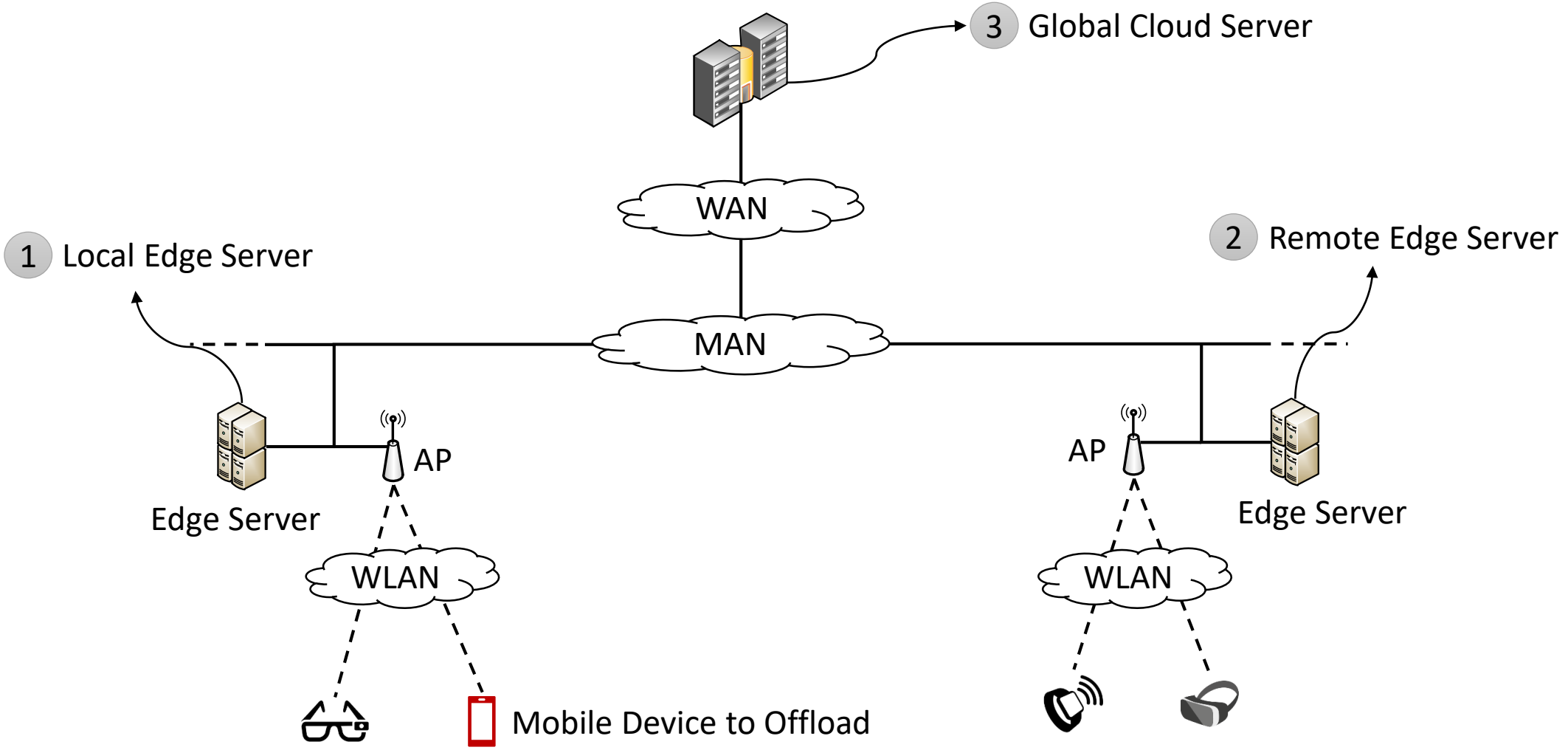
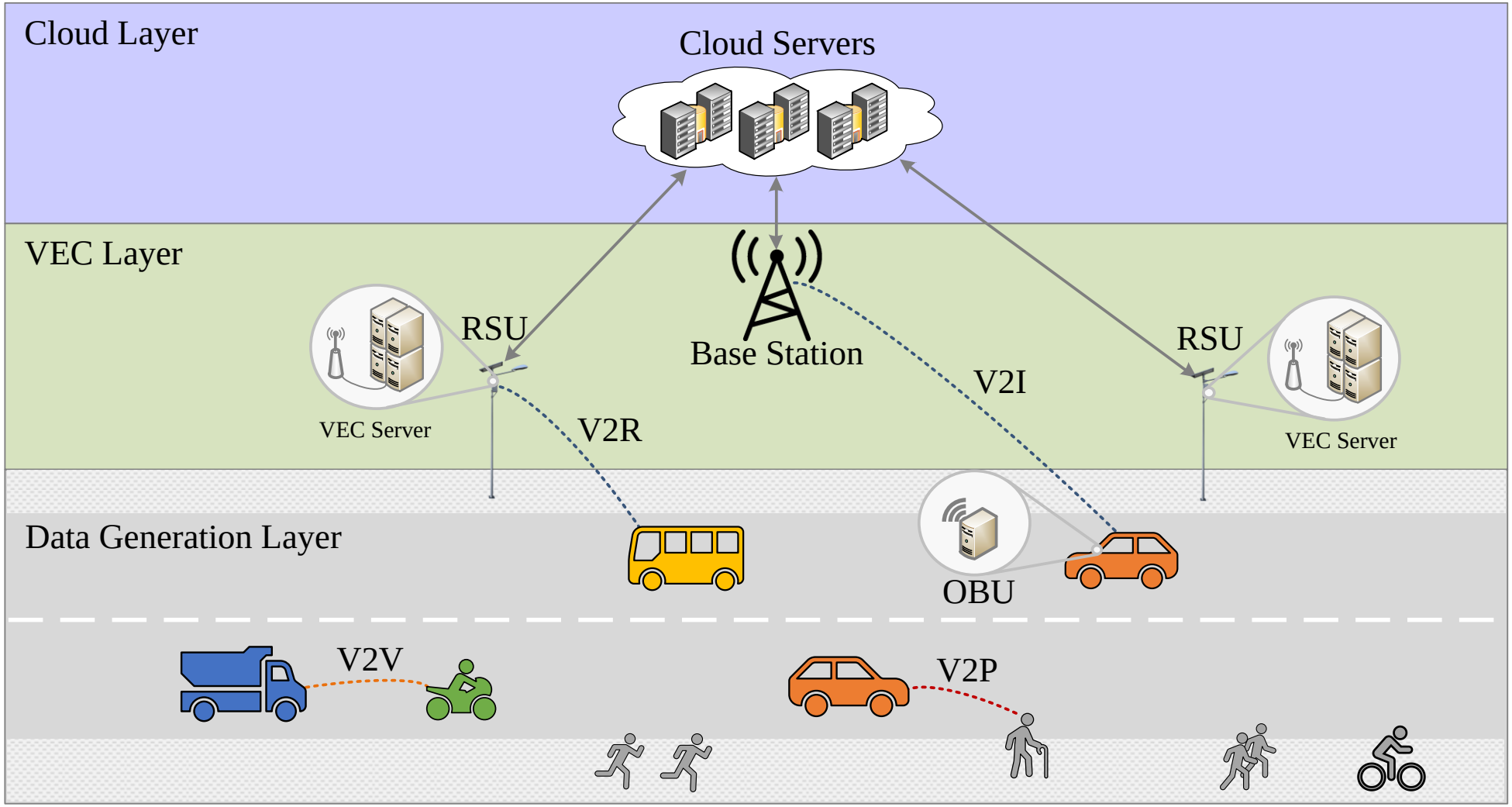



# Machine Learning Based Workload Orchestrator

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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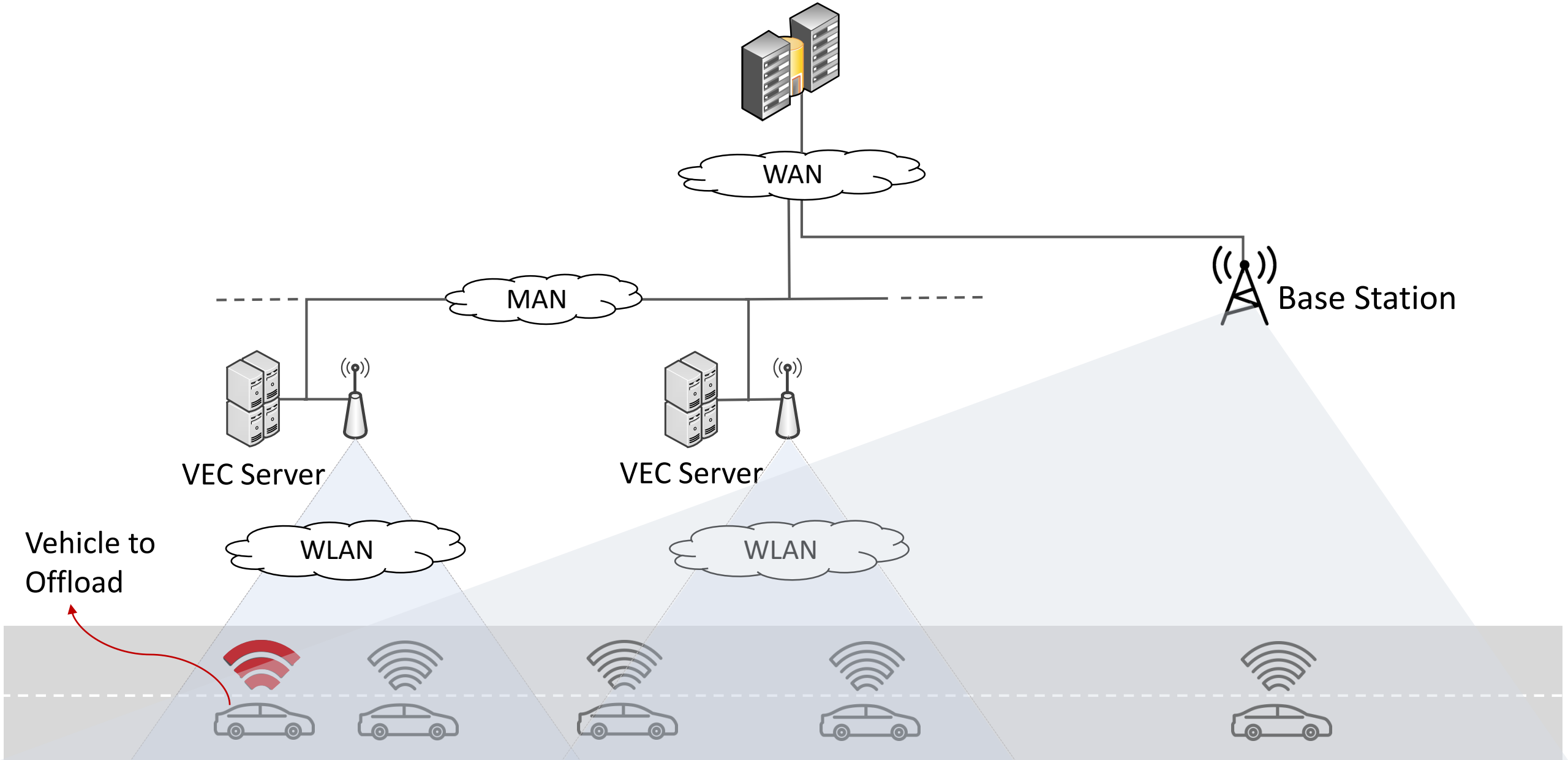

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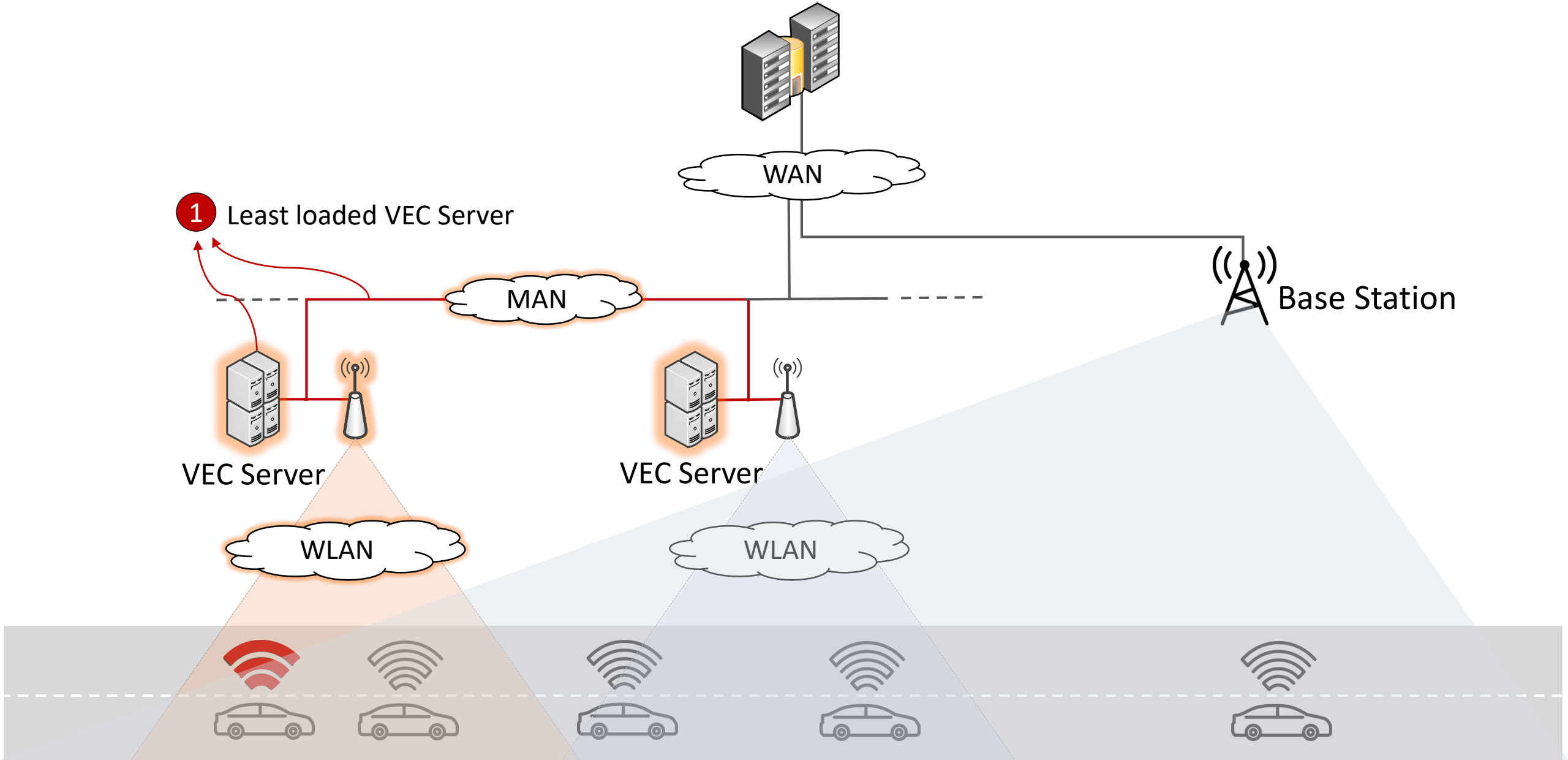

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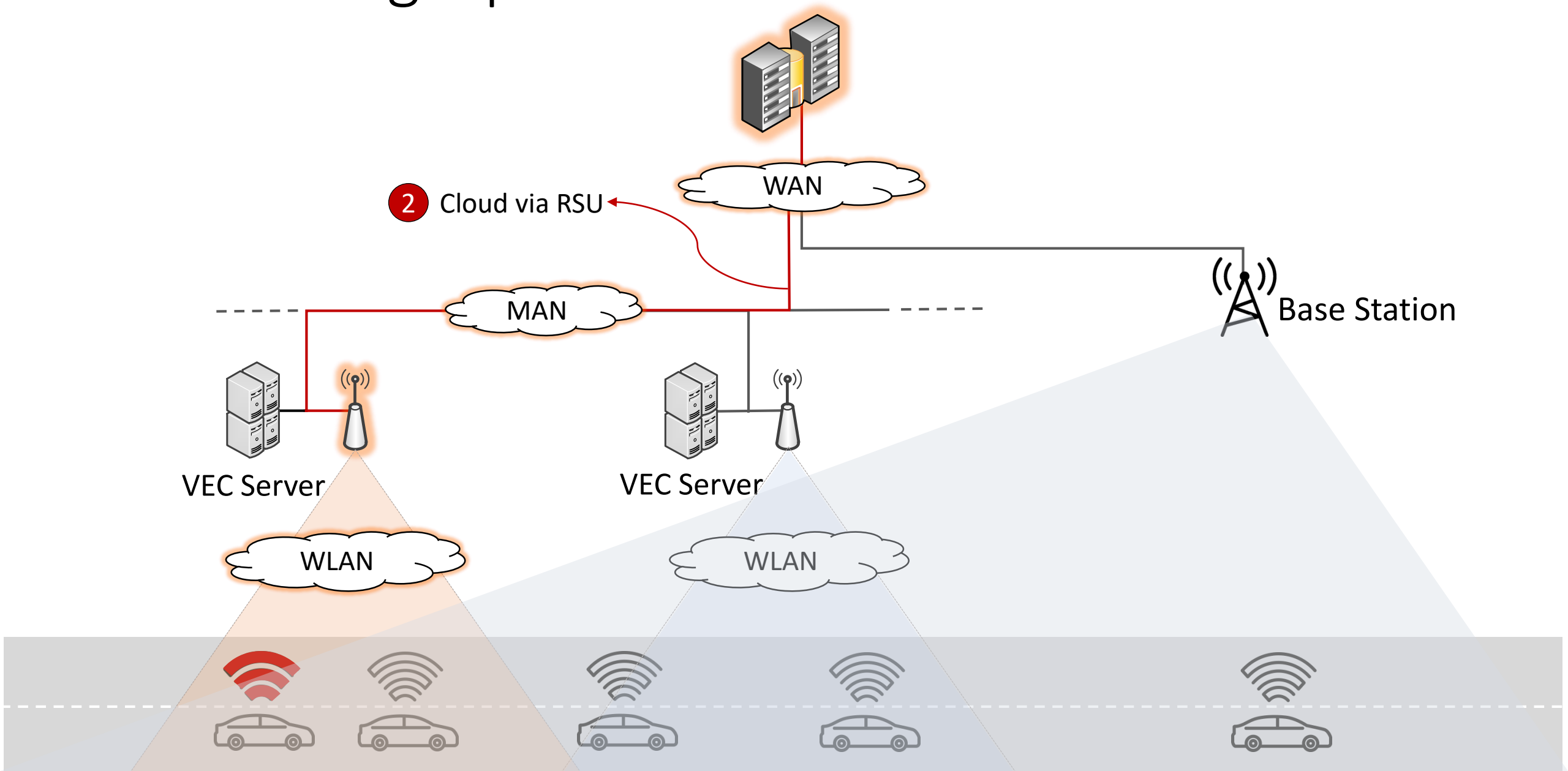

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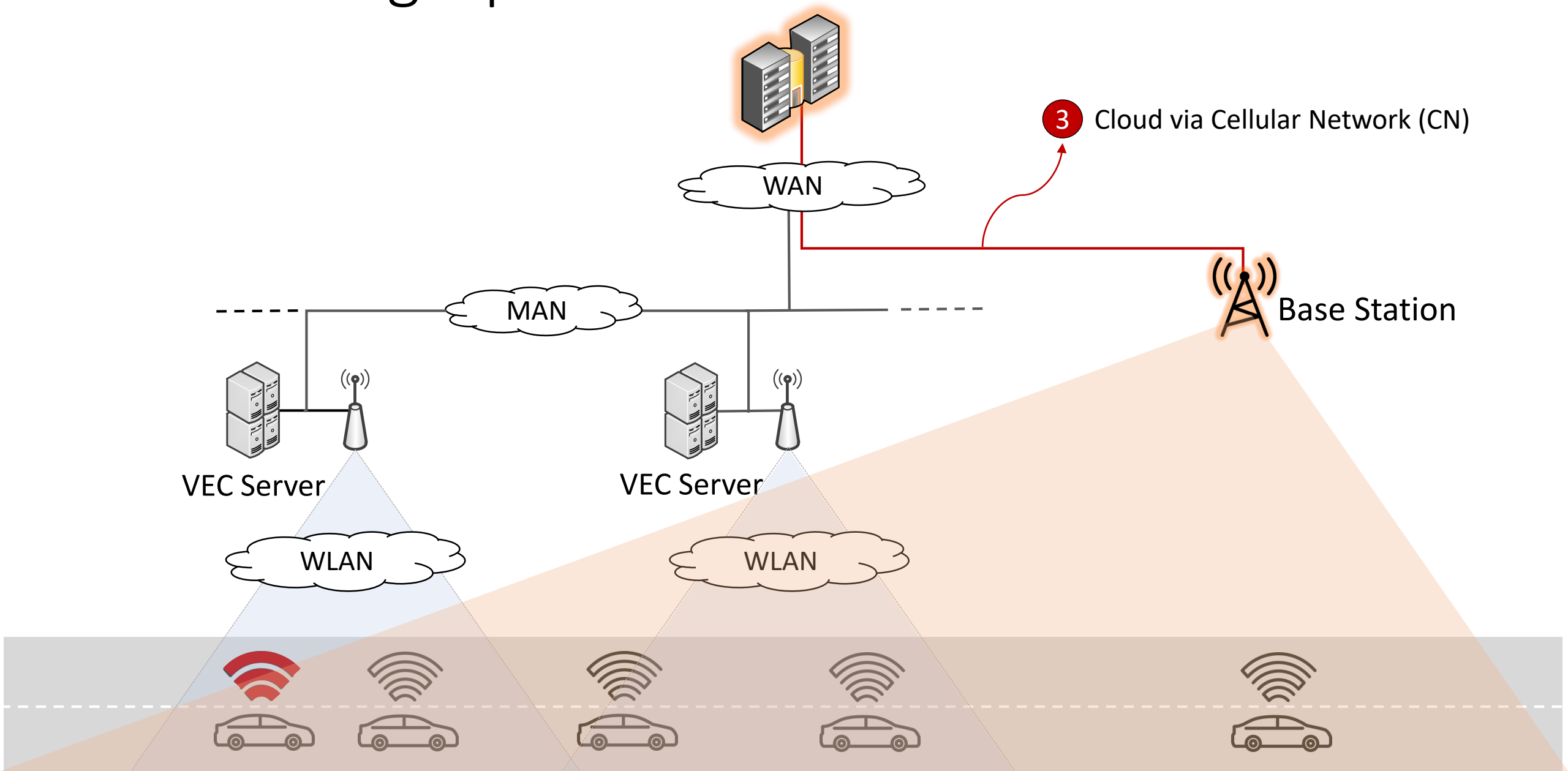

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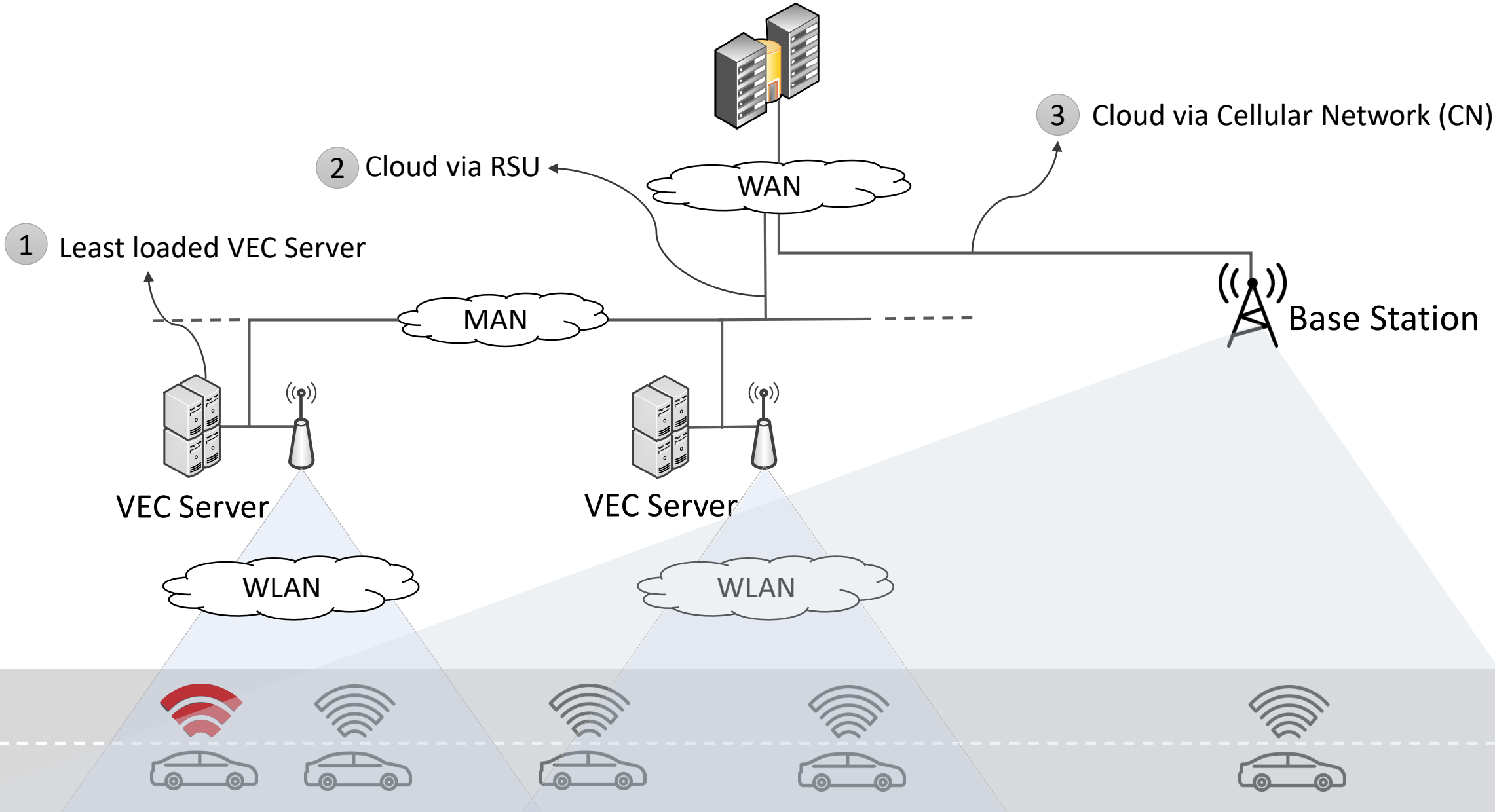
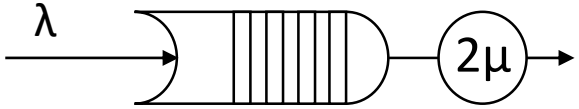


# Case Study with EdgeCloudSim

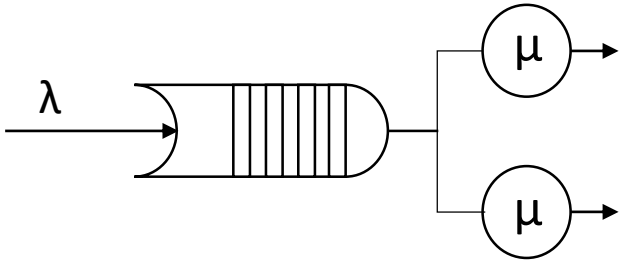
Network Performance Evaluation of Different Scenarios

# Which One Provides the Best Network Delay?

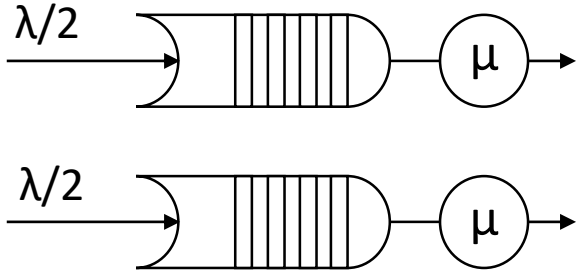
**Case 1**




**Case 2**




**Case 3**



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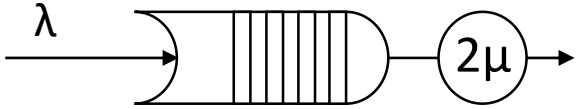
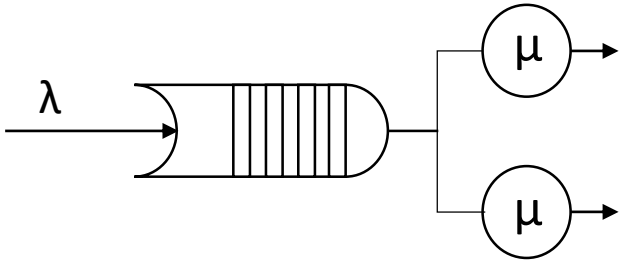


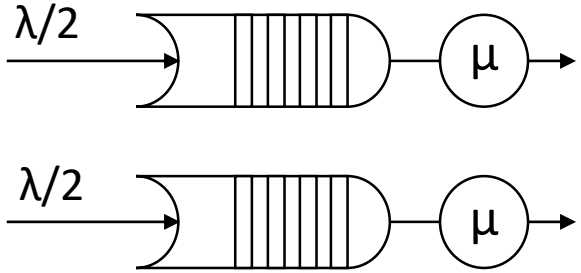

**M/M/1 Queue**

**Case 2**




**M/M/2 Queue**

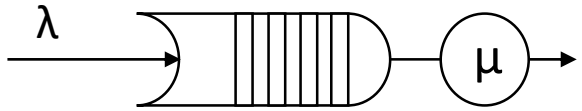
**Case 3**




**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



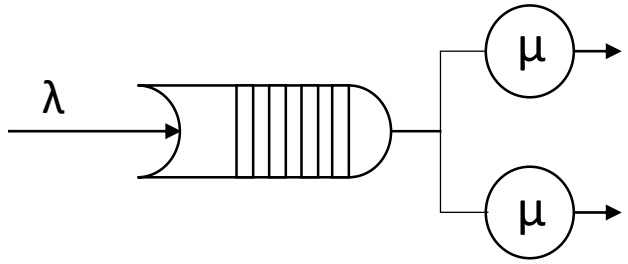

- Response time $E(T) = \frac{1}{\mu - \lambda}$ , $\mu > \lambda$

rate of the traffic (p/s)

capacity/packet length (p/s)

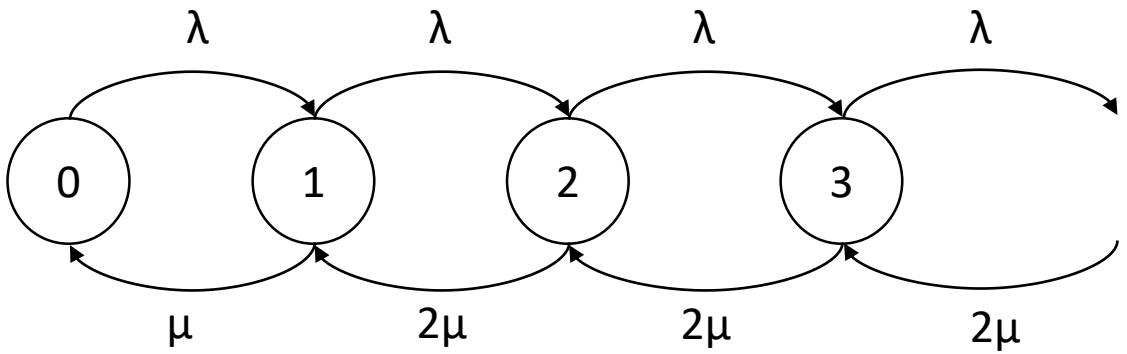
# Case 2: M/M/2 Queue

- 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.




$$P_0 \lambda = P_1 \mu$$

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

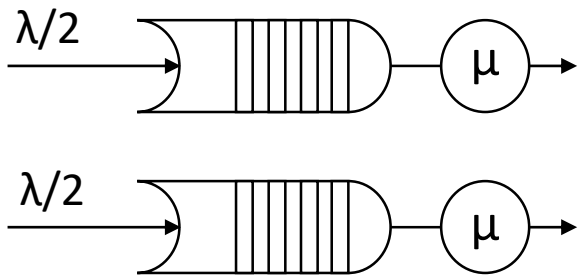
$$P_n (\lambda + 2\mu) = P_{n-1} \lambda + P_{n+1} 2\mu$$

$$\Sigma P_n = 1$$

After some math…

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

# Case 3: Two Parallel M/M/1 Queue

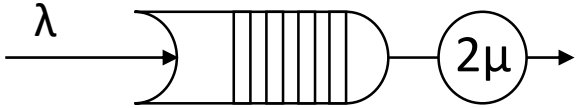



$$E(T) = \frac{1}{\mu - \lambda/2} \times 2$$

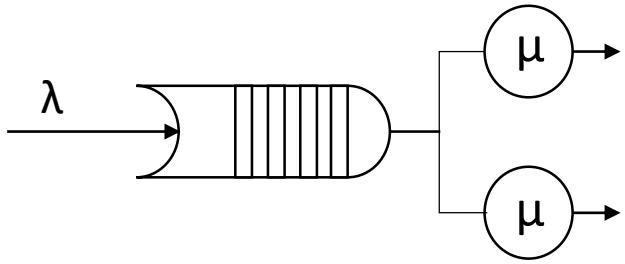
$$E(T) = \frac{4}{2\mu - \lambda}$$

# Expected Network Delay for All Cases

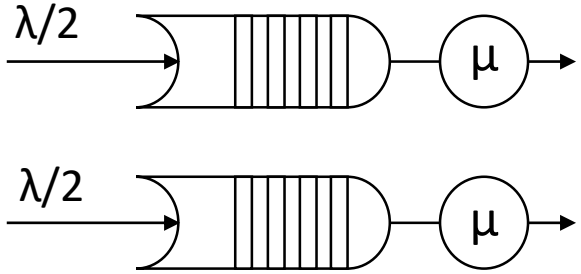
**Case 1**




**Case 2**




**Case 3**

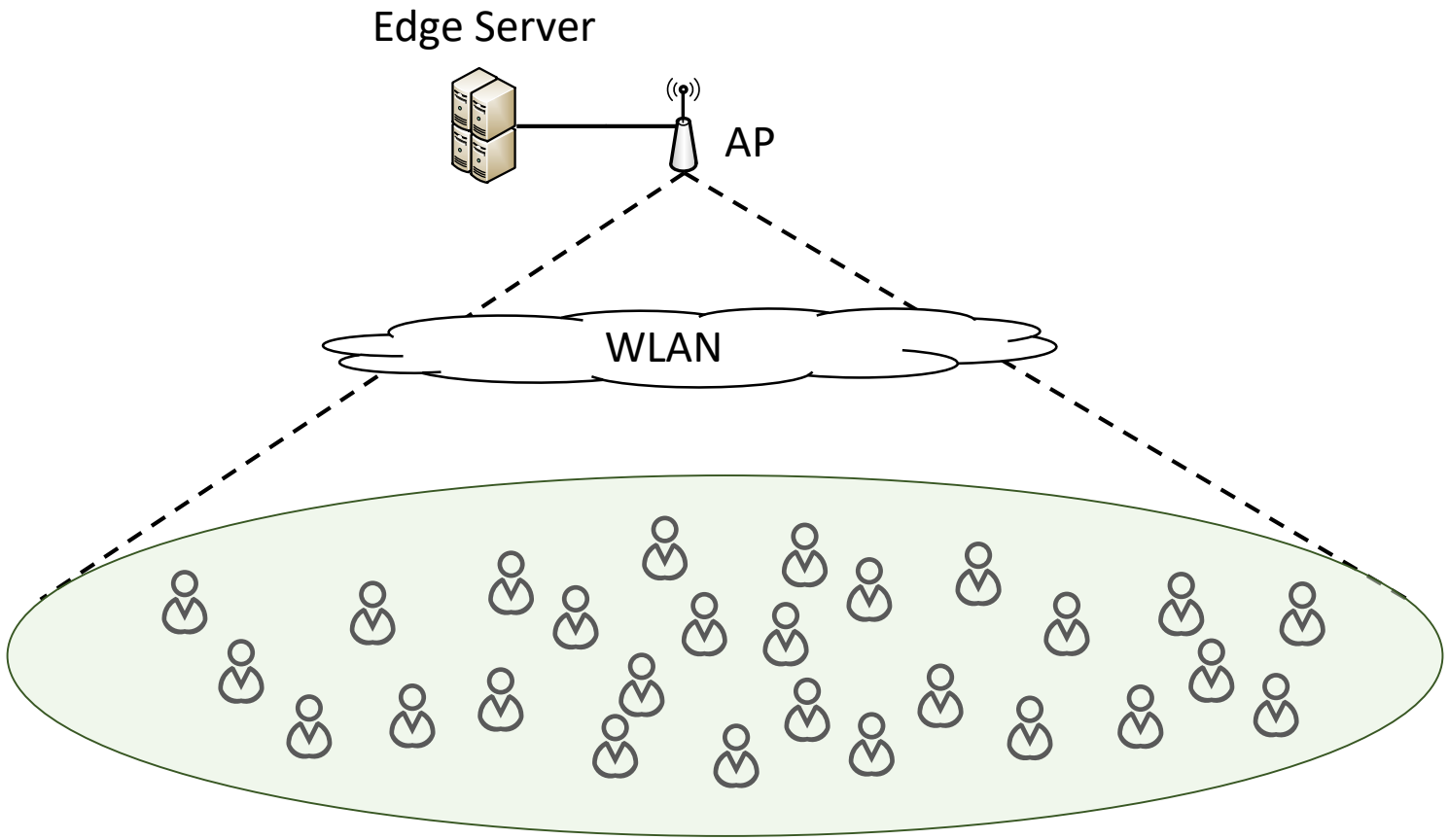



$$E(T) = \frac{1}{2\mu - \lambda} < E(T) = \frac{4\mu}{(2\mu - \lambda)(2\mu + \lambda)} < E(T) = \frac{4}{2\mu - \lambda}$$

# Simulation Study on EdgeCloudSim

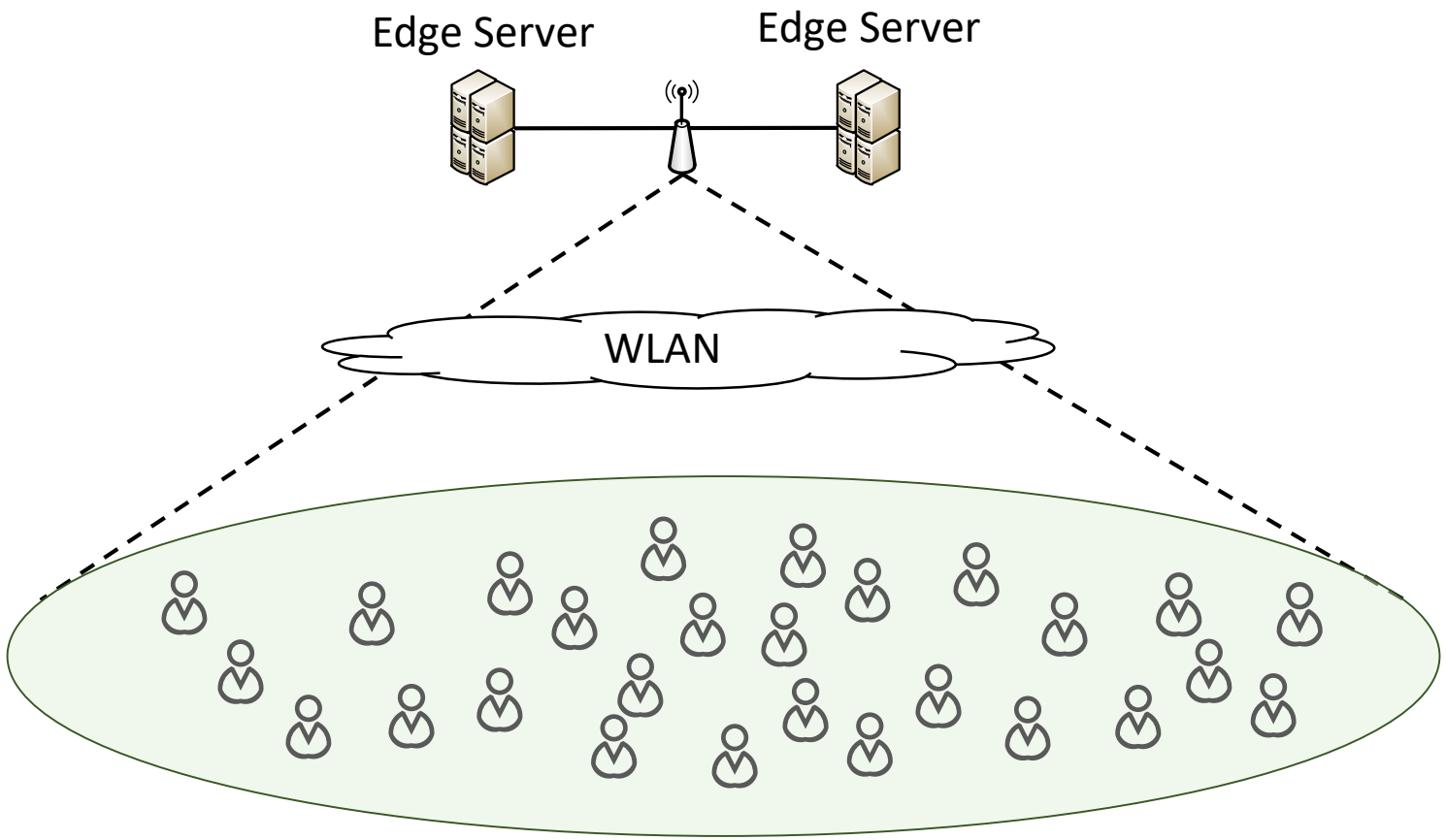
- Three cases are implemented on EdgeCloduSim
- An environment with 1000 to 2000 mobile clients is simulated
- Clients are utilizing an application that generates task according to a Poisson process
- Important simulation parameters are provided in the following slides
- You can find the source code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

# Implementation of Case1



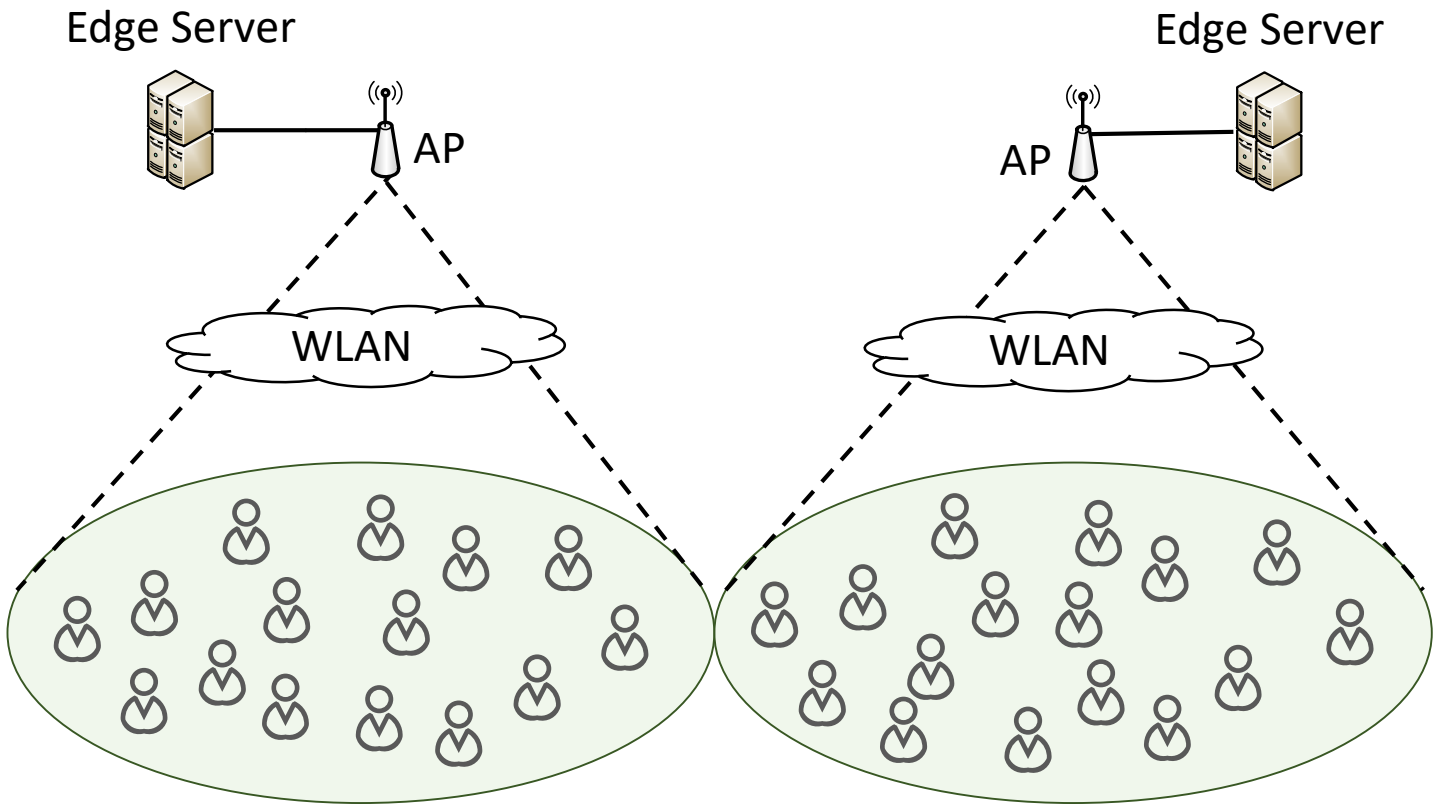

| Parameter | Value |
|---|---|
| WLAN Bandwidth | 100 Mbps |
| Number of Core Edge Server | 4 |
| Capacity of Edge Server | 20 GIPS |

# 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 on VM | 2 |
| Capacity of VM | 10 GIPS |

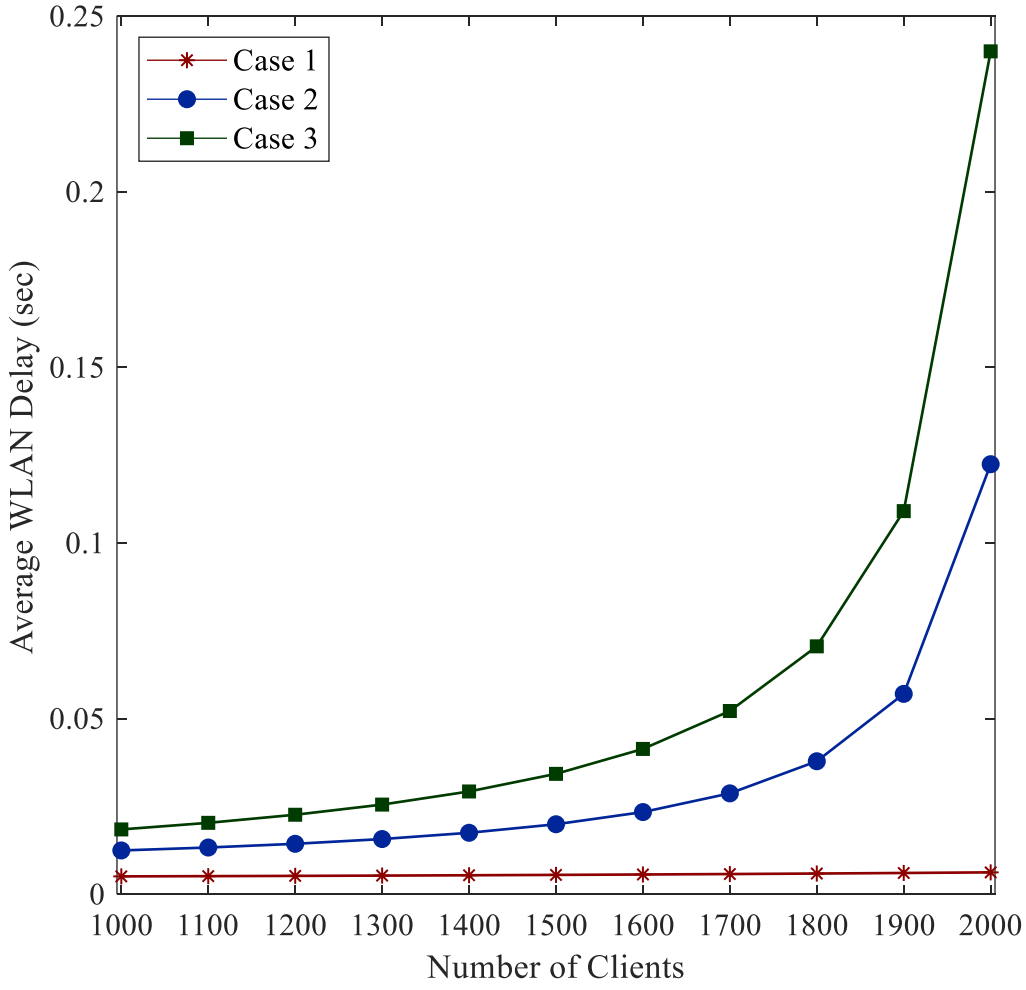
# Application Used in Simulations

| 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 |

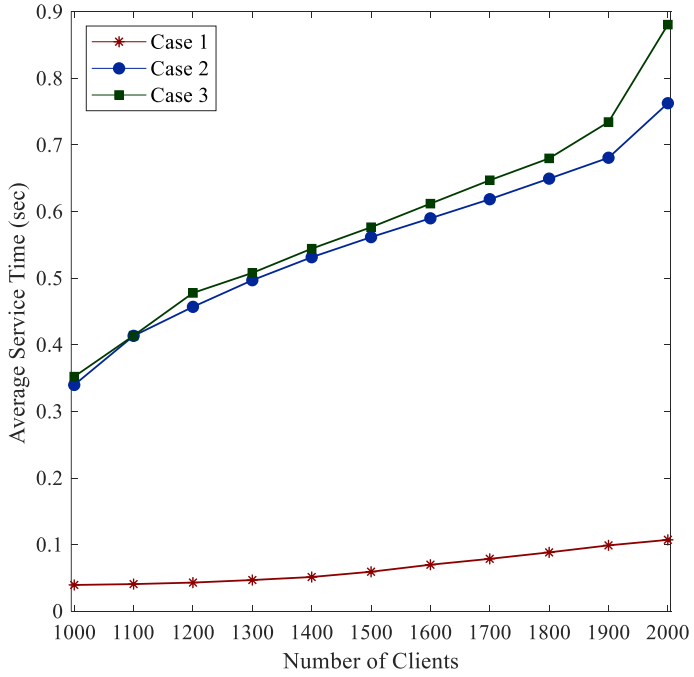
# Simulation Parameters

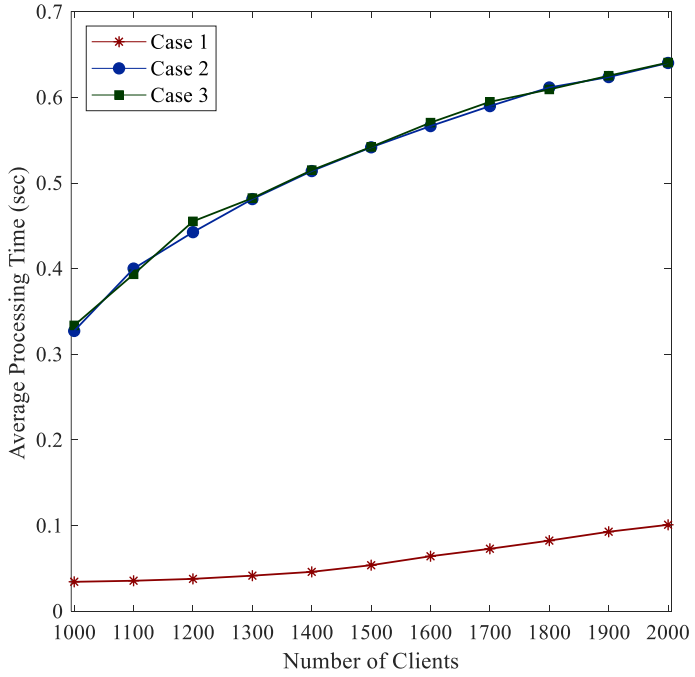
| Parameter | Value |
|---|---|
| Simulation Time | 30 minutes |
| Warm-up Period | 5 minutes |
| Number of repetition | 25 |
| Mobility Model | Nomadic Mobility |
| Number of Mobile Clients | 1000 to 2000 |
| Length of the Simulated Area | 6 KM |

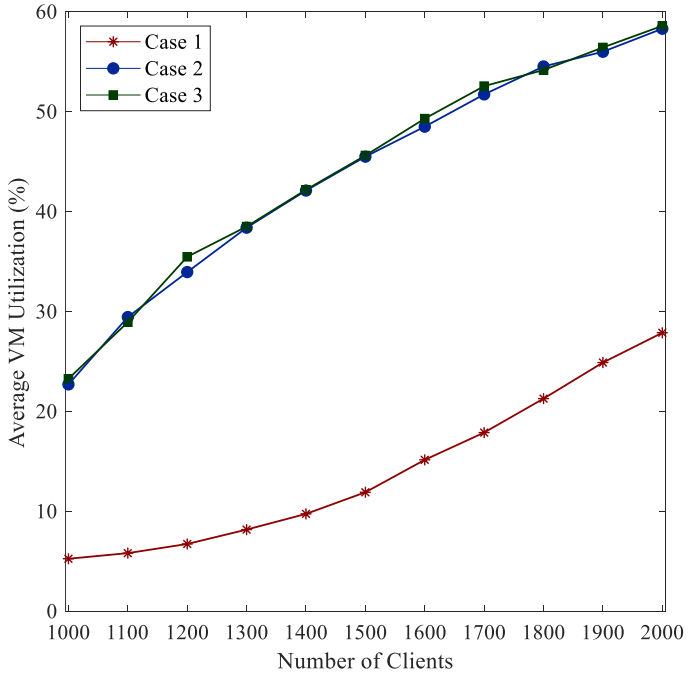
# Average WLAN Delay



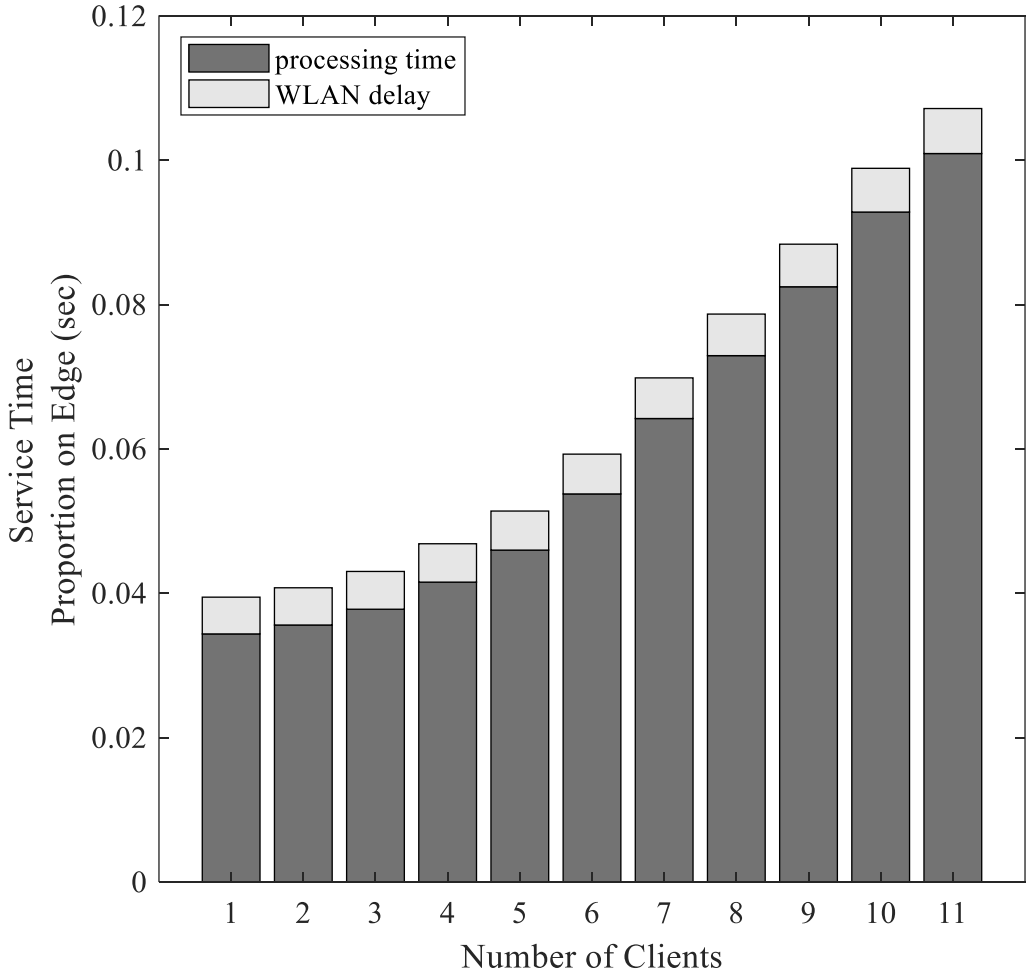
# Server Side Statistics



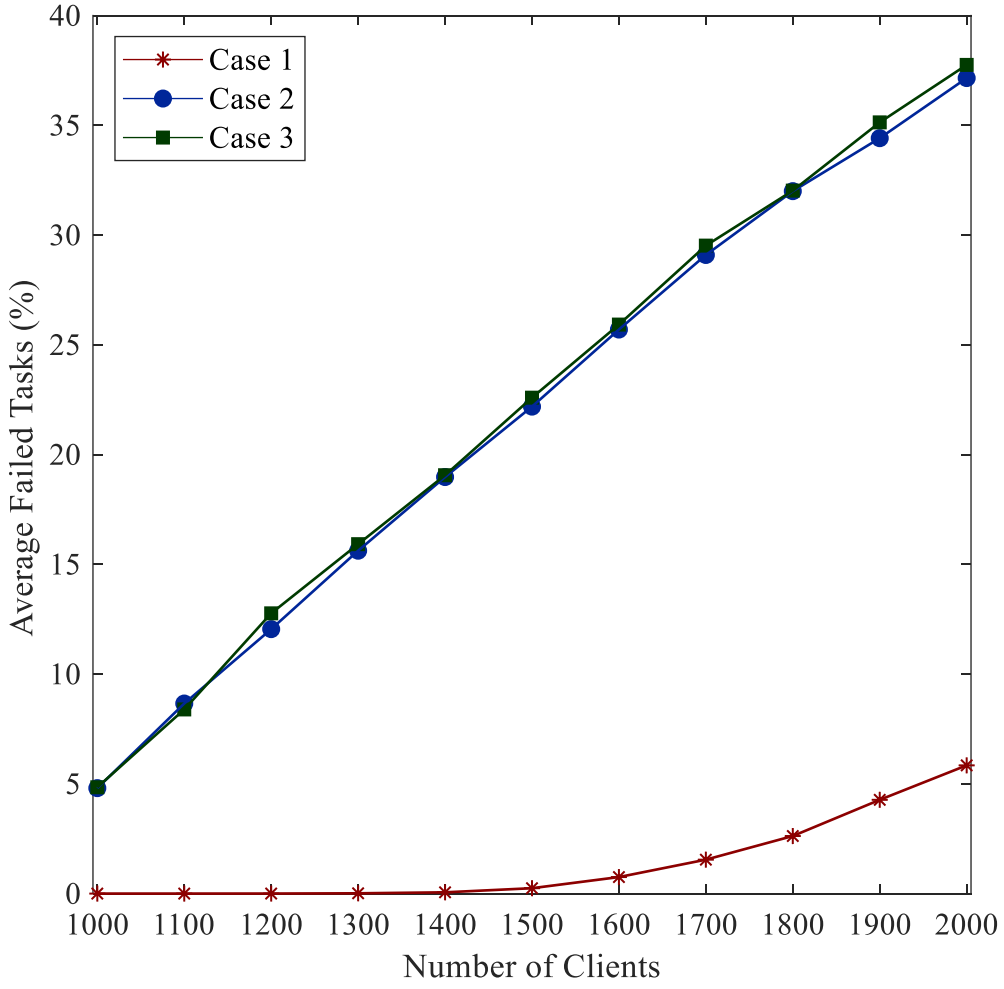



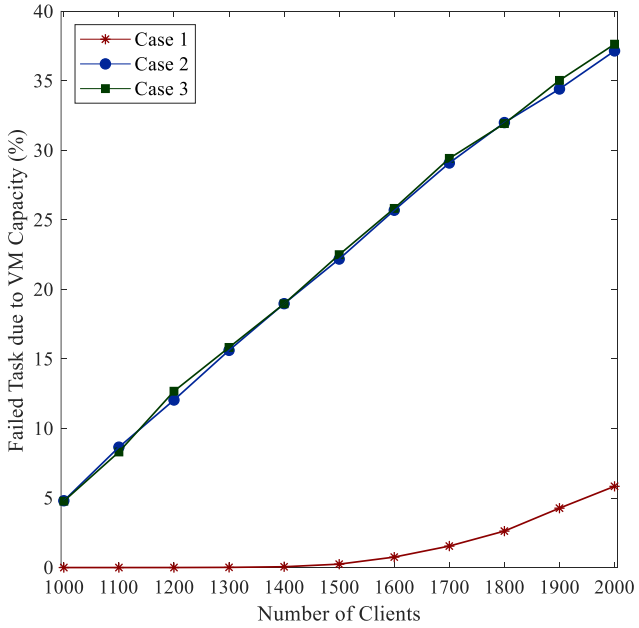
# Proportion of Service Time Values

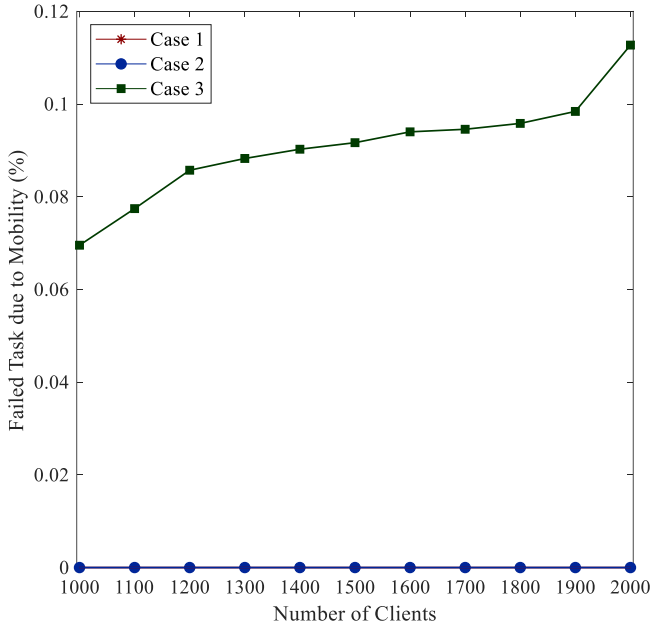


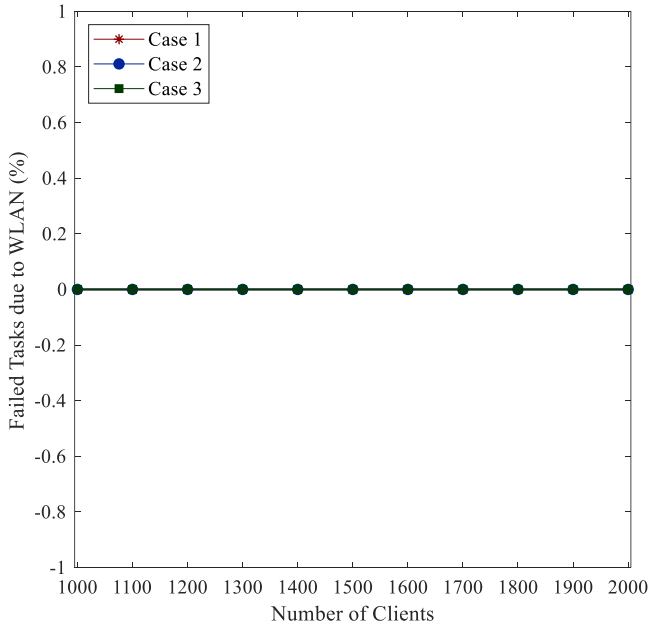
# Average Failed Tasks



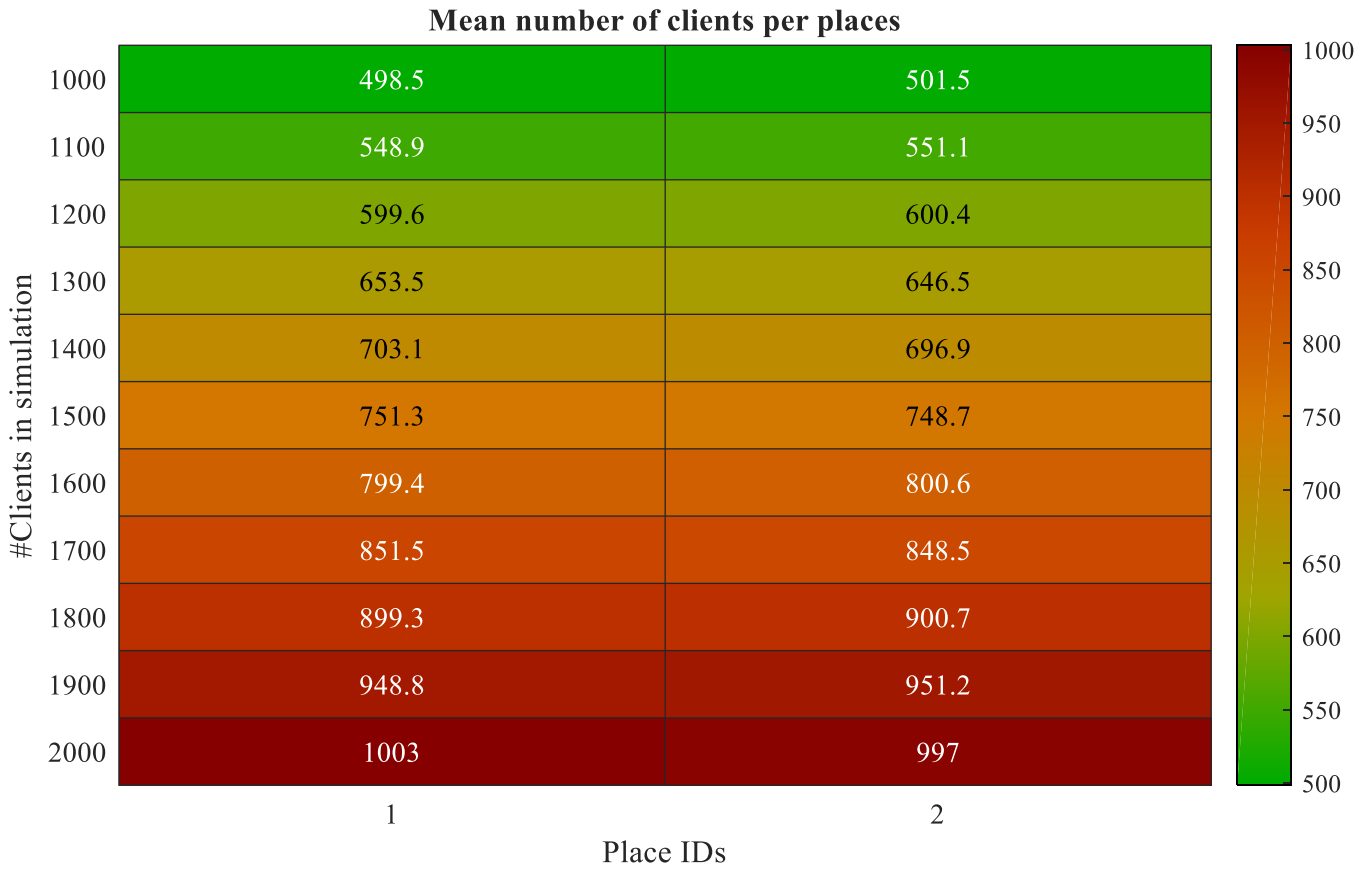
# Task Failure Reasons



# Average Number of Clients on the Places



# Questions

# References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