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Application-aware Traffic Redirection: A Mobile Edge Computing Implementation toward Future 5G Networks

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Outline

- Motivation and Background
- Design and Implementation
- Performance Evaluation
- Conclusions and Future Work

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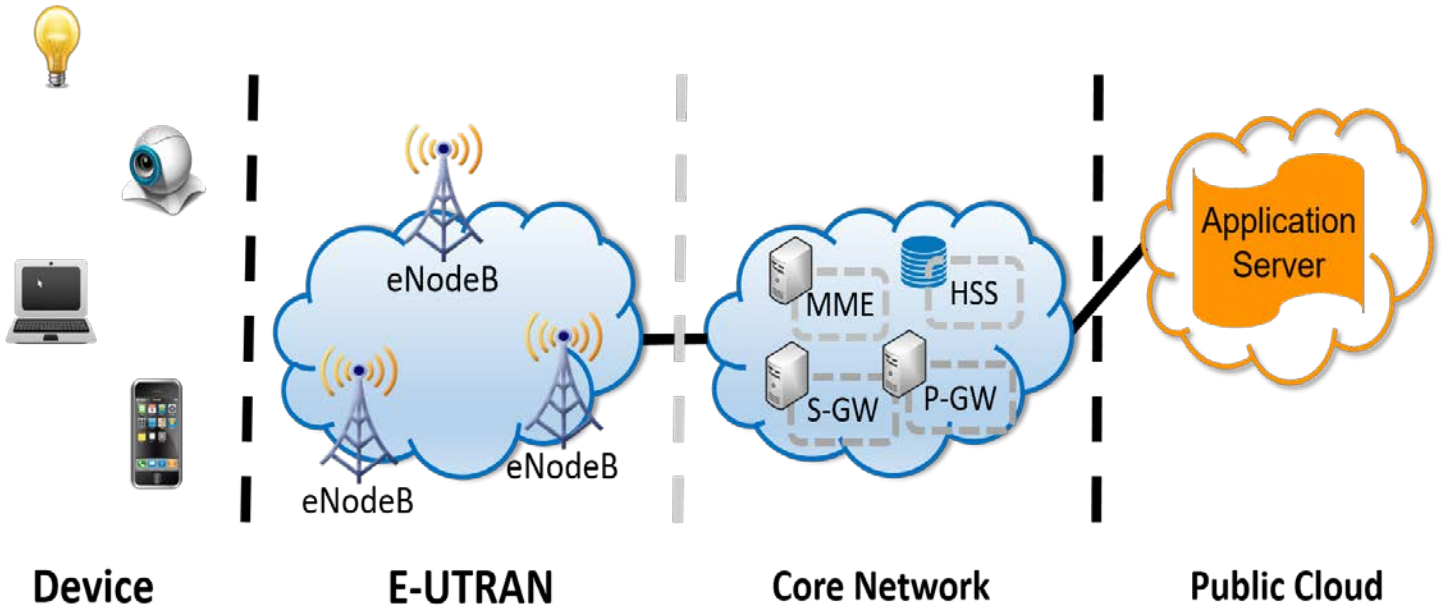
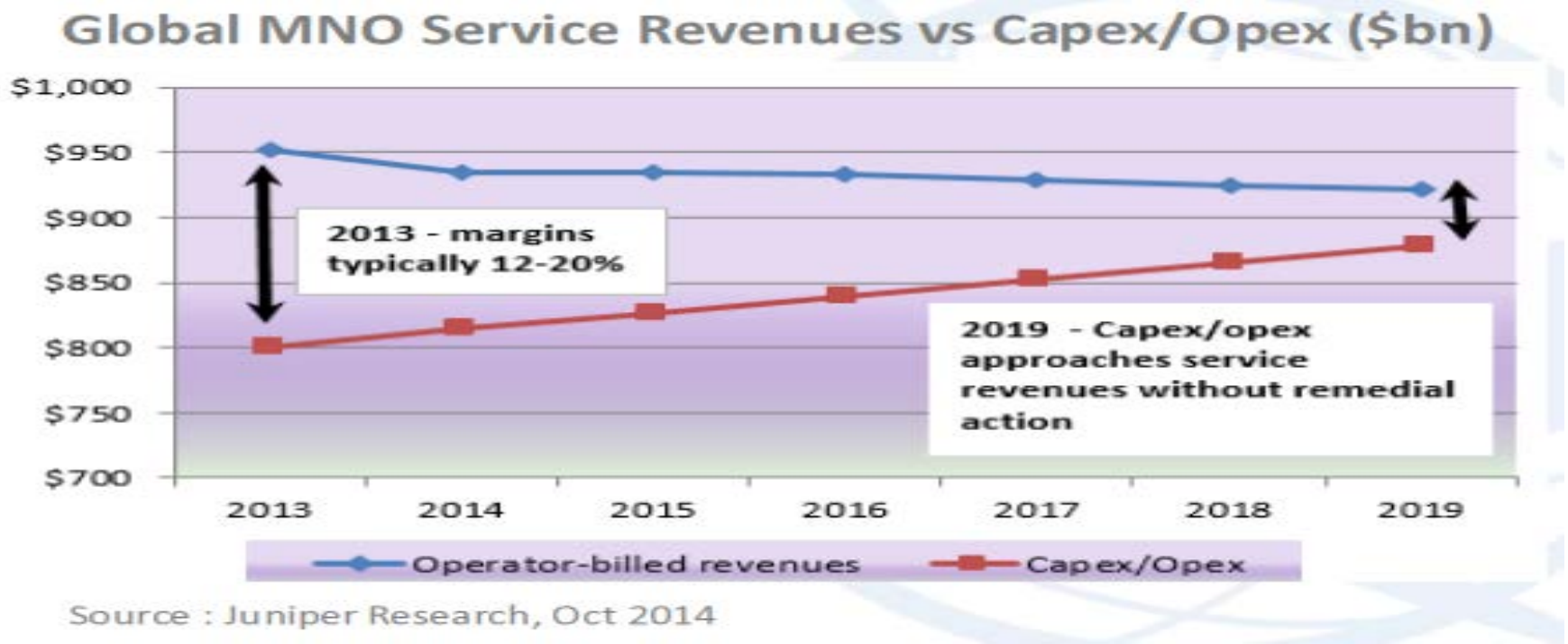
Mobile Communication Network

- Mobile devices and Mobile traffic:
  - Tremendous growth during the last decade.
- Mobile Network Operators (MNOs)
  - Facing enormous pressure on backhaul networks.
- Mobile Cloud Computing (MCC)
  - Long propagation delays and high bandwidth consumption.



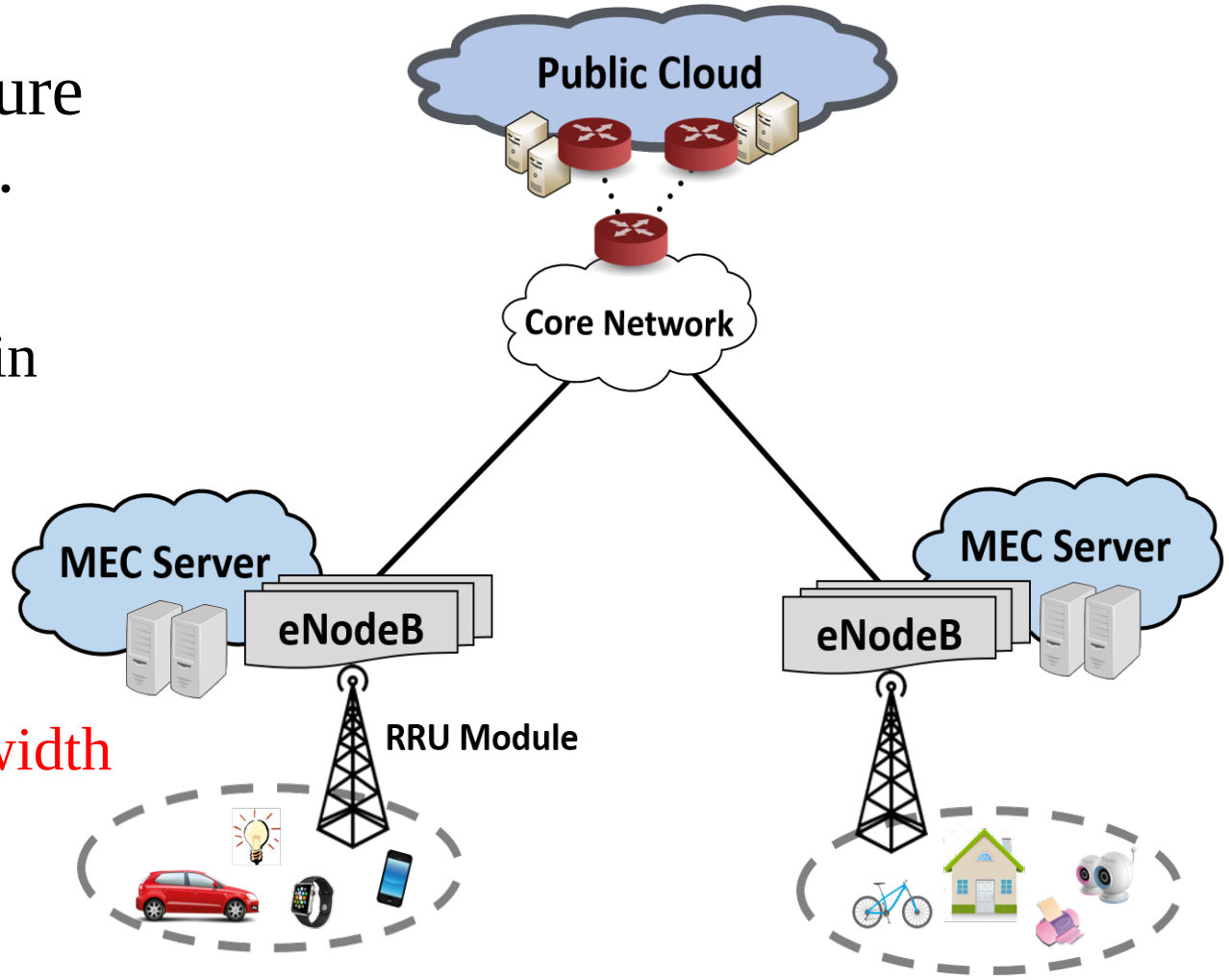
Pressure on Mobile Network Operator

- Mobile operators are facing cases where network cost may exceed revenues if no remedial actions are taken.
- Upgrading the network equipment is a heavy burden for MNOs.



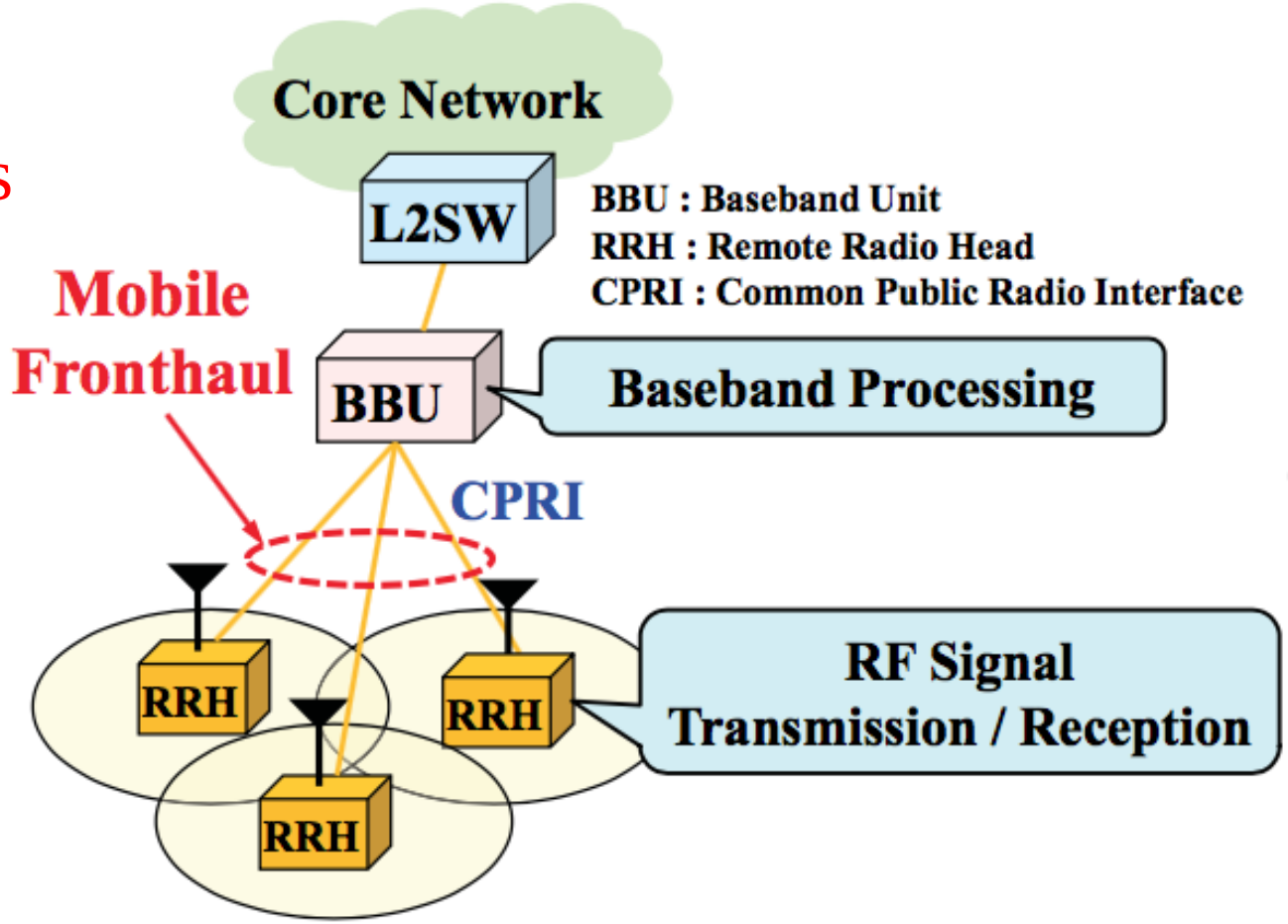
Mobile Edge Computing

- Design a proper network architecture to handle huge amounts of traffics.
- Mobile Edge Computing (MEC)
  - Provides cloud and IT services within the close proximity of mobile subscribers.
- Many organizations and individuals will benefit from
  - Reduced network latency and bandwidth consumption.



5G Cloud-RAN Architecture

- A centralized, cloud computing-based architecture for radio access networks
  - Let numbers of remote RRH connect to a centralized BBU pool
  - A dynamic shared resource allocation and support of **multi-vendor, multi-technology** environments
- Better performance & Lower cost



OAI: OpenAirInterface

- An **EURECOM** software project to advance wireless innovation of 3GPP cellular networks for the future 5G wireless network design
  - Based on initial work from EUROCOM
  - Managed by the OpenAirInterface™ Software Alliance (OSA)

- An **open source implementation** of fully real-time stack
  - Core network (EPC)
  - Access network (eNodeB/BBU pool)
  - User equipment (UE)

OAI: OpenAirInterface

- Running on **general purpose processors**
  - Simplify network access, reduce cost, increase flexibility
  - Improve innovation speed and accelerate time-to-market for introduction of new services
  - To combine with cloud and virtualization technology, like SDN, NFV, VM, container, etc.

- OAI has become one of the evolutionary paths towards 5G

Contributions

- Build up a prototype of **Mobile Edge Computing solution** in a 5G Cloud-RAN (**OpenAirInterface**).
- Propose a threshold-based application-aware **traffic redirection mechanism.**
- Performance evaluation of proposed mechanism based on our MEC prototype considering the **real application performance impact**.

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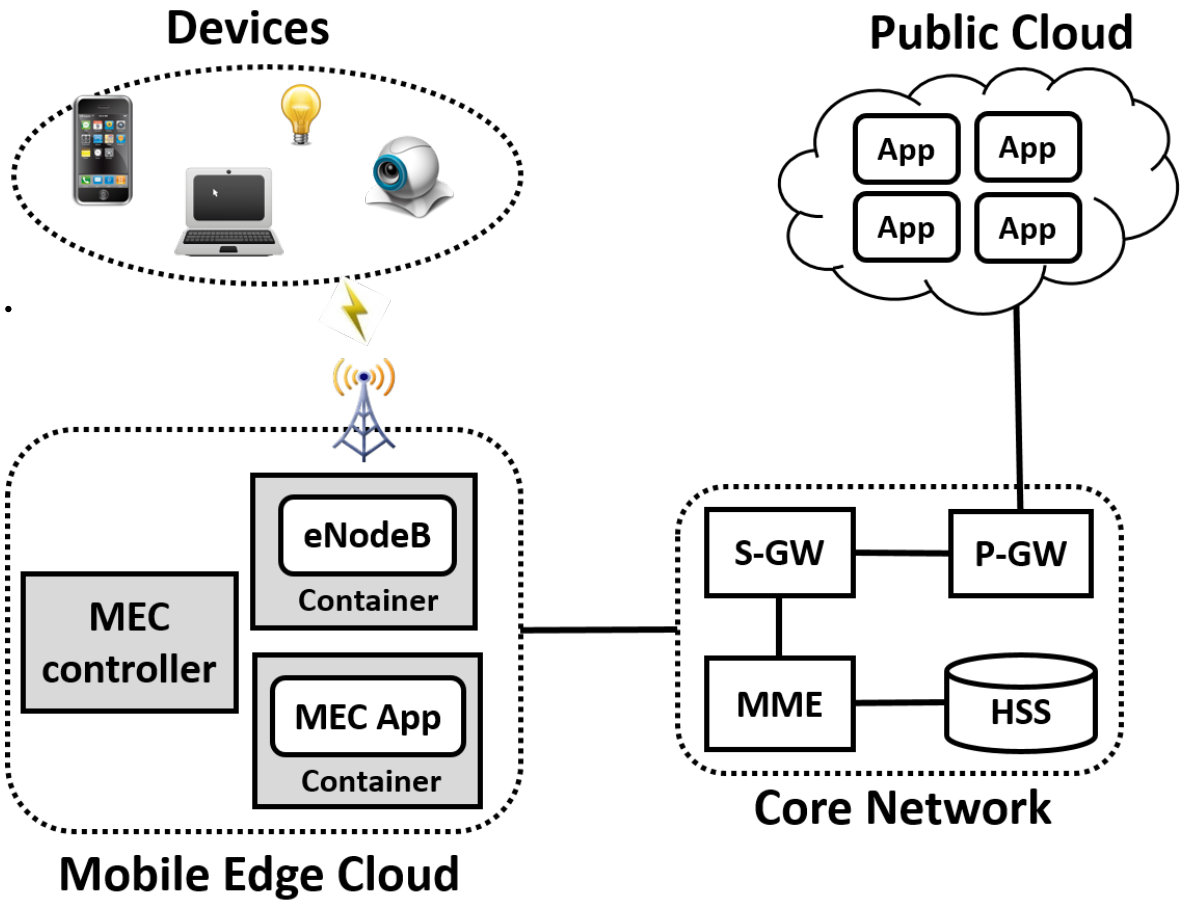
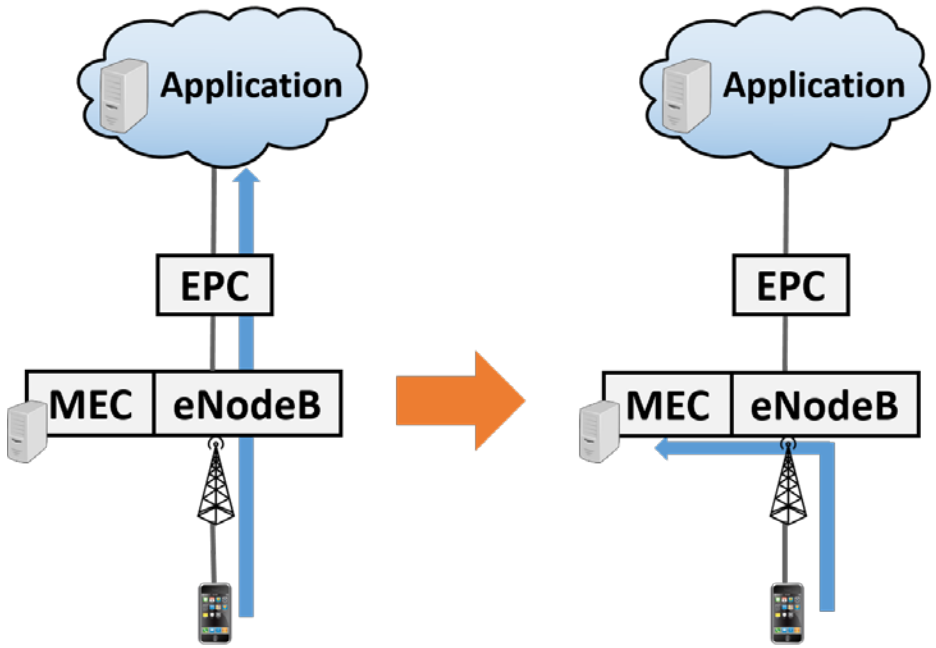
MEC Architecture

- UE:
  - LTE dongle
- Mobile Edge Cloud:
  - Container-based eNodeB (openairinterface5g).
  - MEC controller.
  - MEC application (Docker image).
- EPC (openair-cn):
  - MME + HSS
  - S/P-GW
- Cloud:
  - OpenStack, Amazon EC2

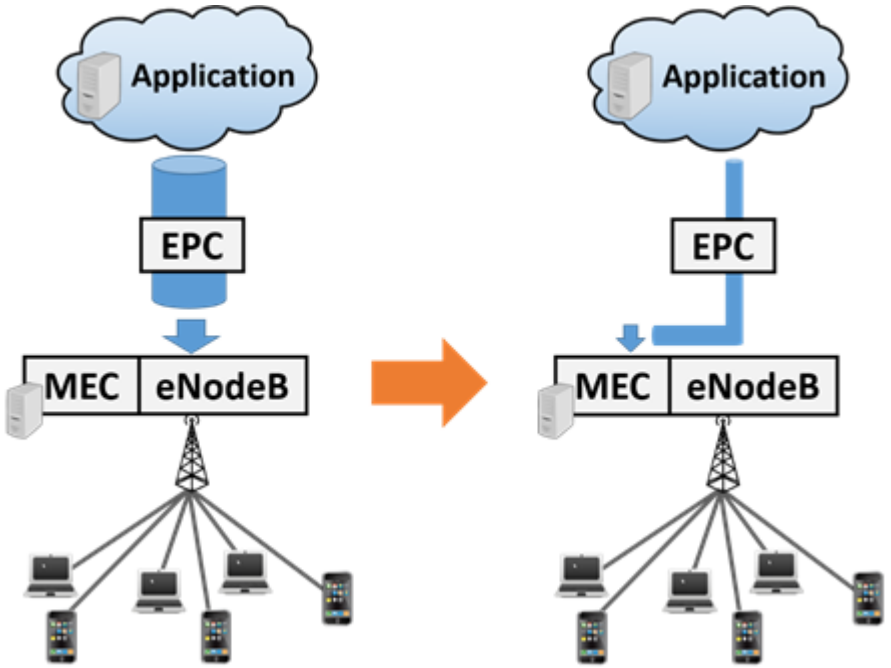


Use Cases

Reduce latency



Reduce bandwidth



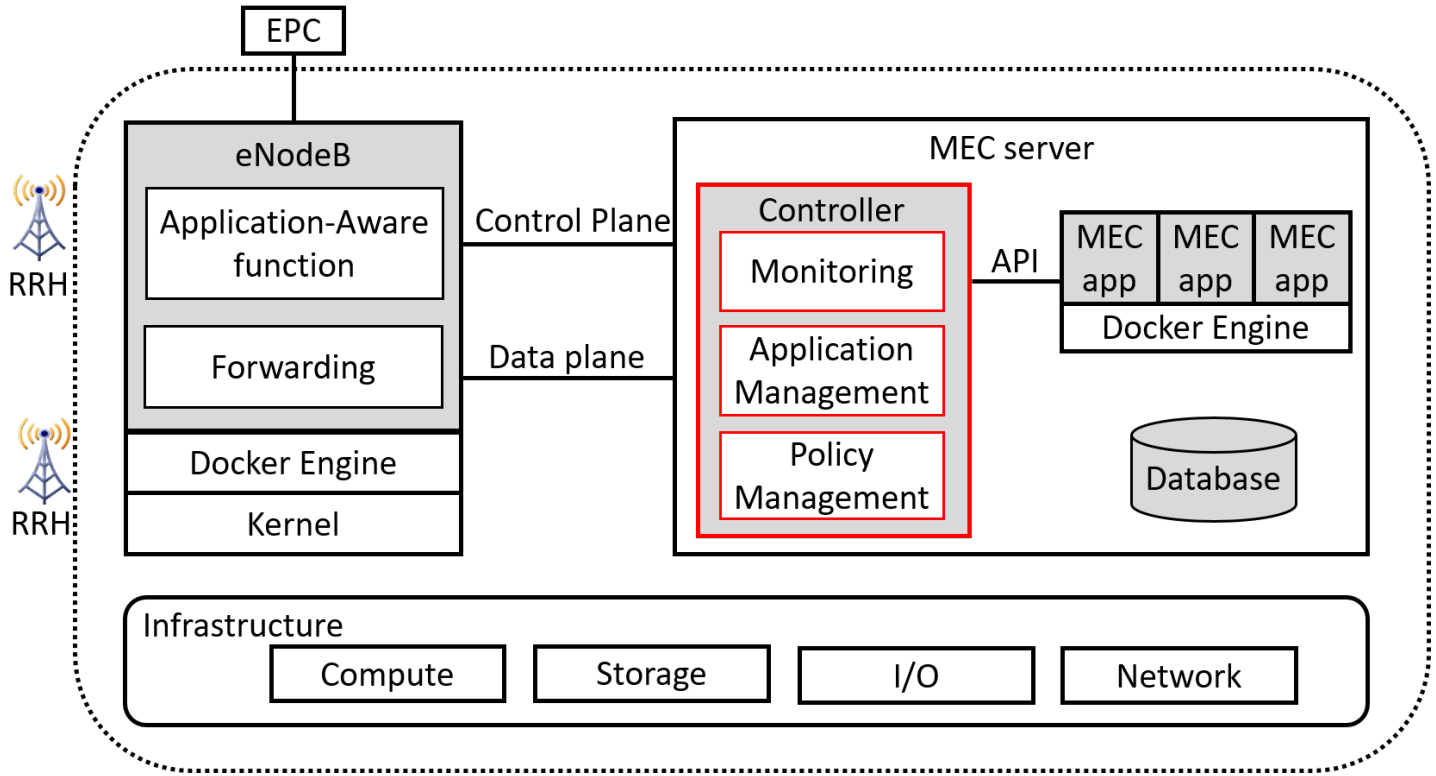
Redirection Method Overview

- Provide the traffic redirection without interrupting applications.
- Traffic is managed for a list of registered applications.
  - {IP/Port, threshold}
- Threshold-based policy:
  - Threshold: “throughput of each application” Mb/s
  - Lower threshold for low-latency requirement application.
  - Higher threshold for high-bandwidth consumption application.

Design and Implementation

The Components of Mobile Edge Cloud

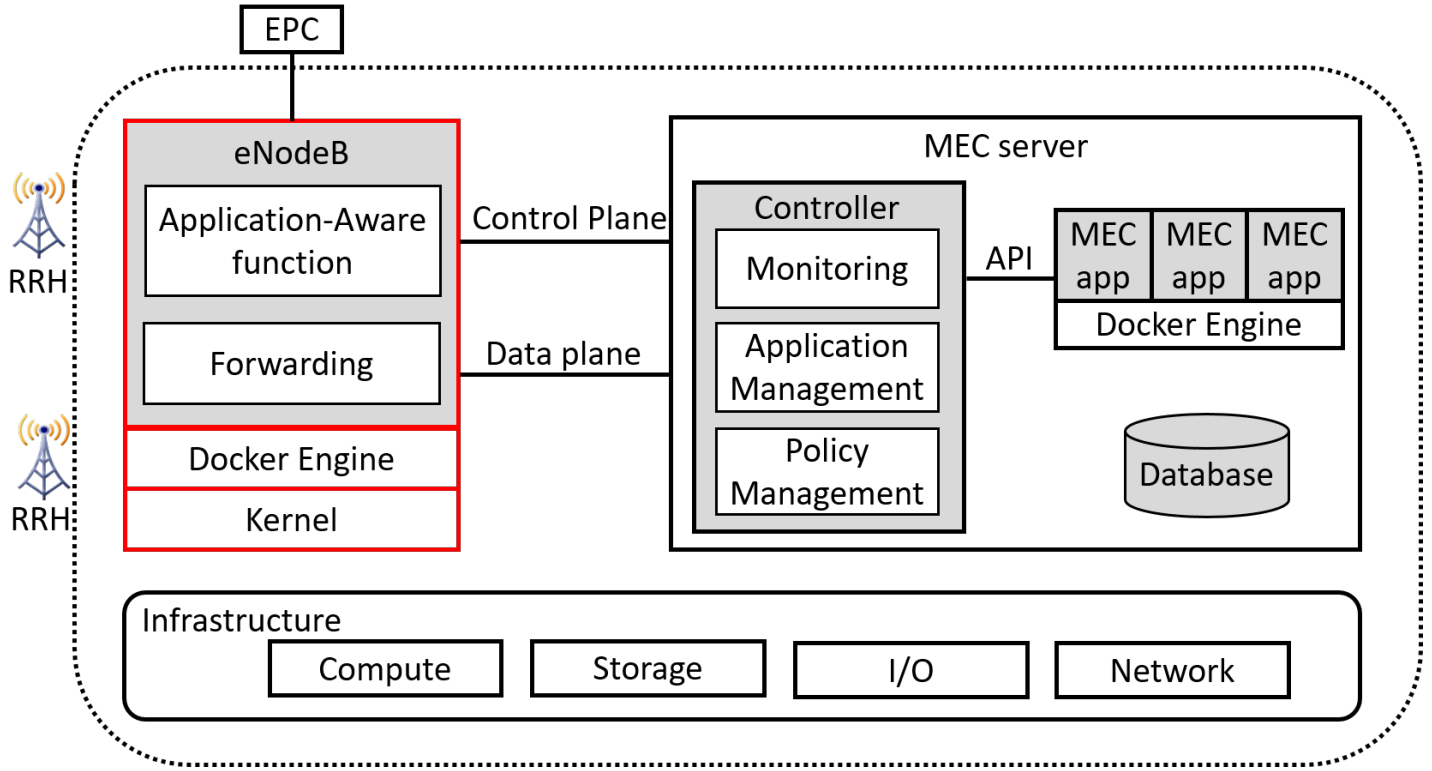
- MEC controller:
  - Monitoring
    - Monitor the throughput of each application.
  - Policy Management
    - Maintain the application list.
    - Trigger redirection procedure.
  - Application Management
    - Launch MEC application.
    - Release resource when application at idle for a long time.



Design and Implementation

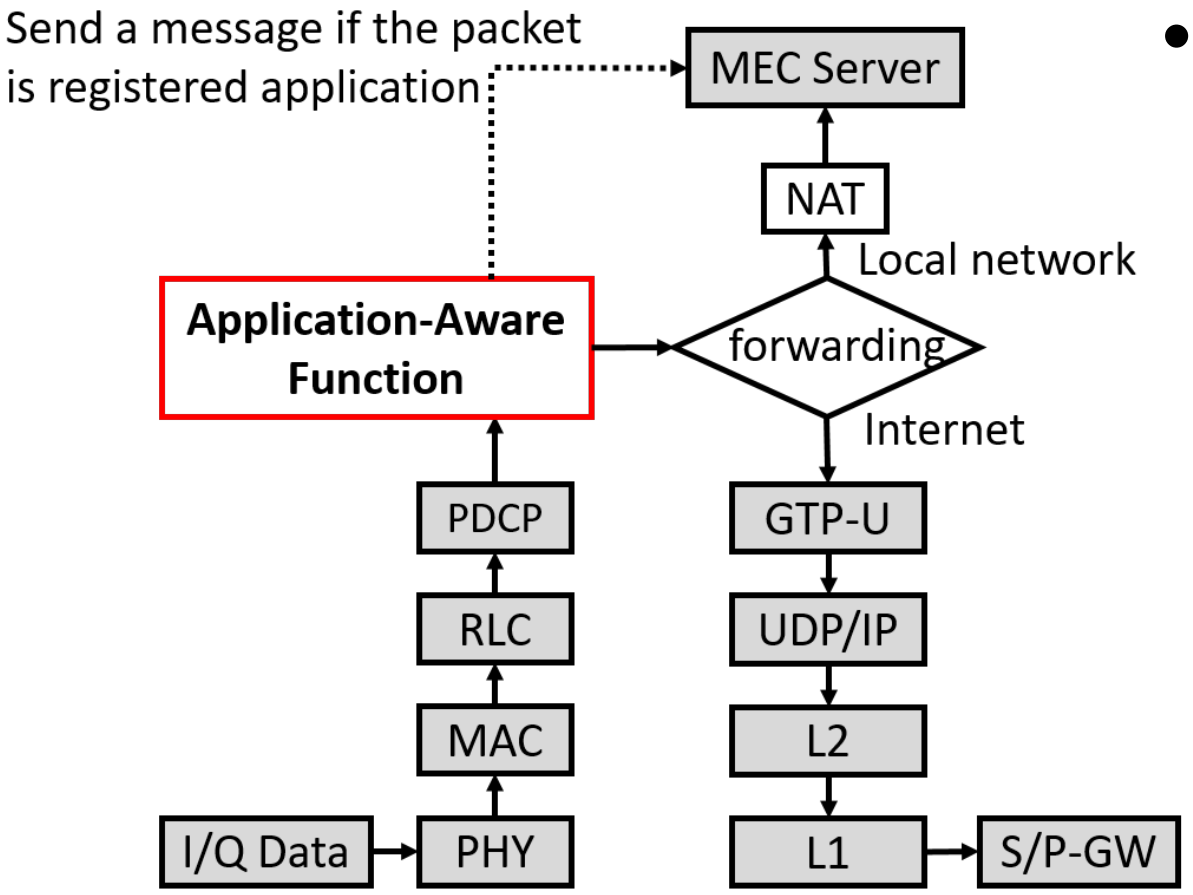
The Components of Mobile Edge Cloud

- Infrastructure:
  - General-purpose computer
- eNodeB:
  - Low-latency kernel
  - Containerization
  - Application-aware function
    - Inspect packet header against the policy
  - Forwarding component
    - Send packets to MEC server



Design and Implementation

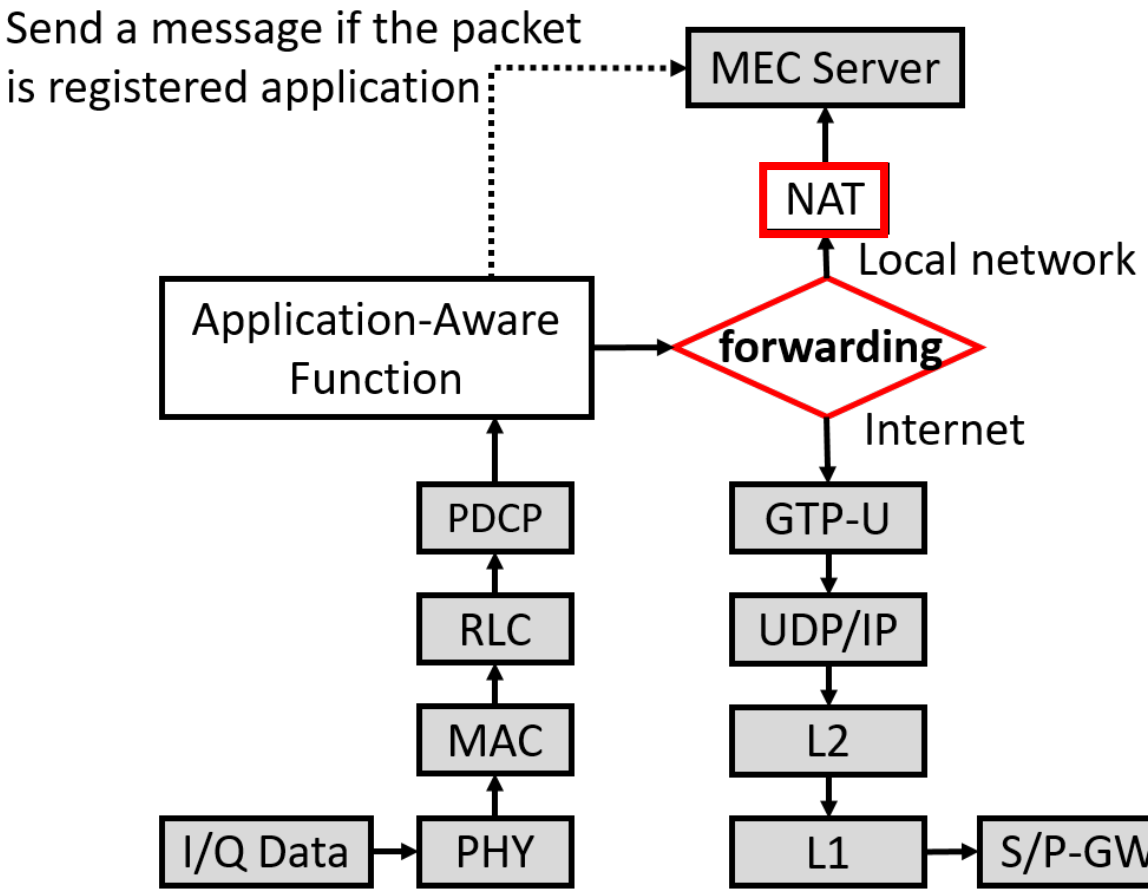
Application-aware in eNodeB



- Application-aware function:
  - Extract the destination ip address and port of packets by decomposing user packets.
  - Identify the application and check if it should be redirected.
  - Send a message to the MEC controller through the control plane if match the list.

Design and Implementation

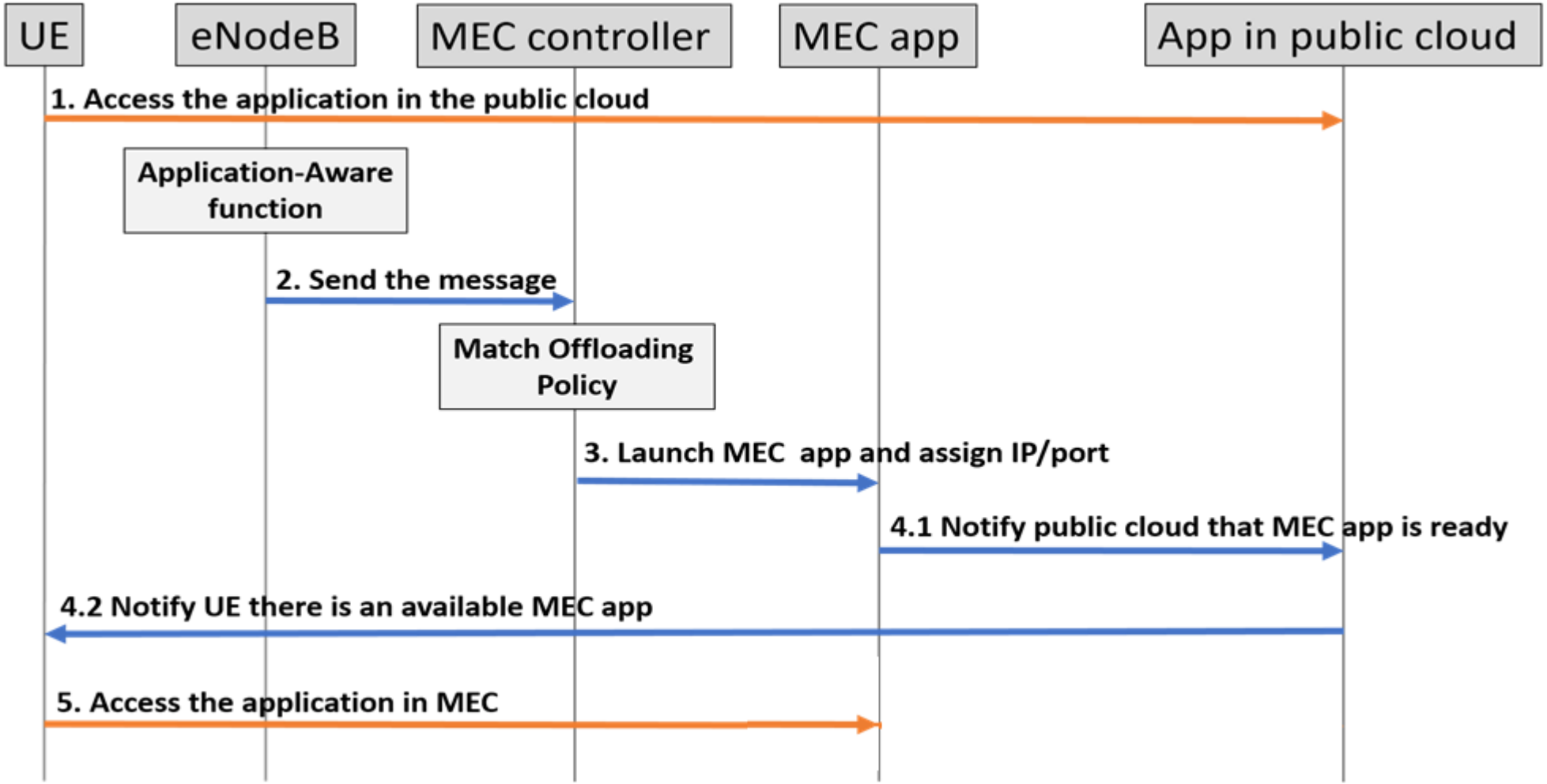
Application-aware in eNodeB



- Forwarding component:
  - There is no forwarding component between PDCP layer and GTP-U layer in the original eNodeB.
  - We use NAT to forward user packets to the local network

Design and Implementation

Traffic Redirection Workflow



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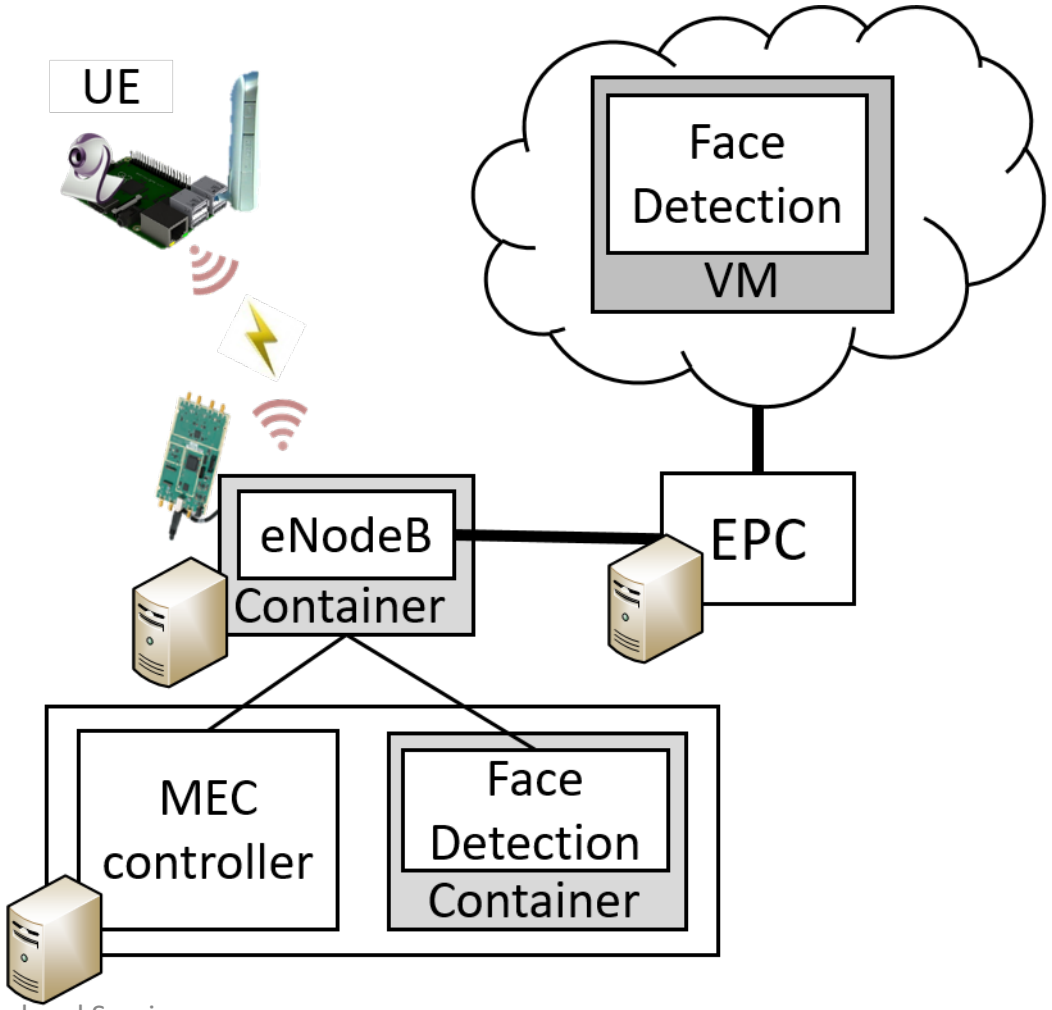
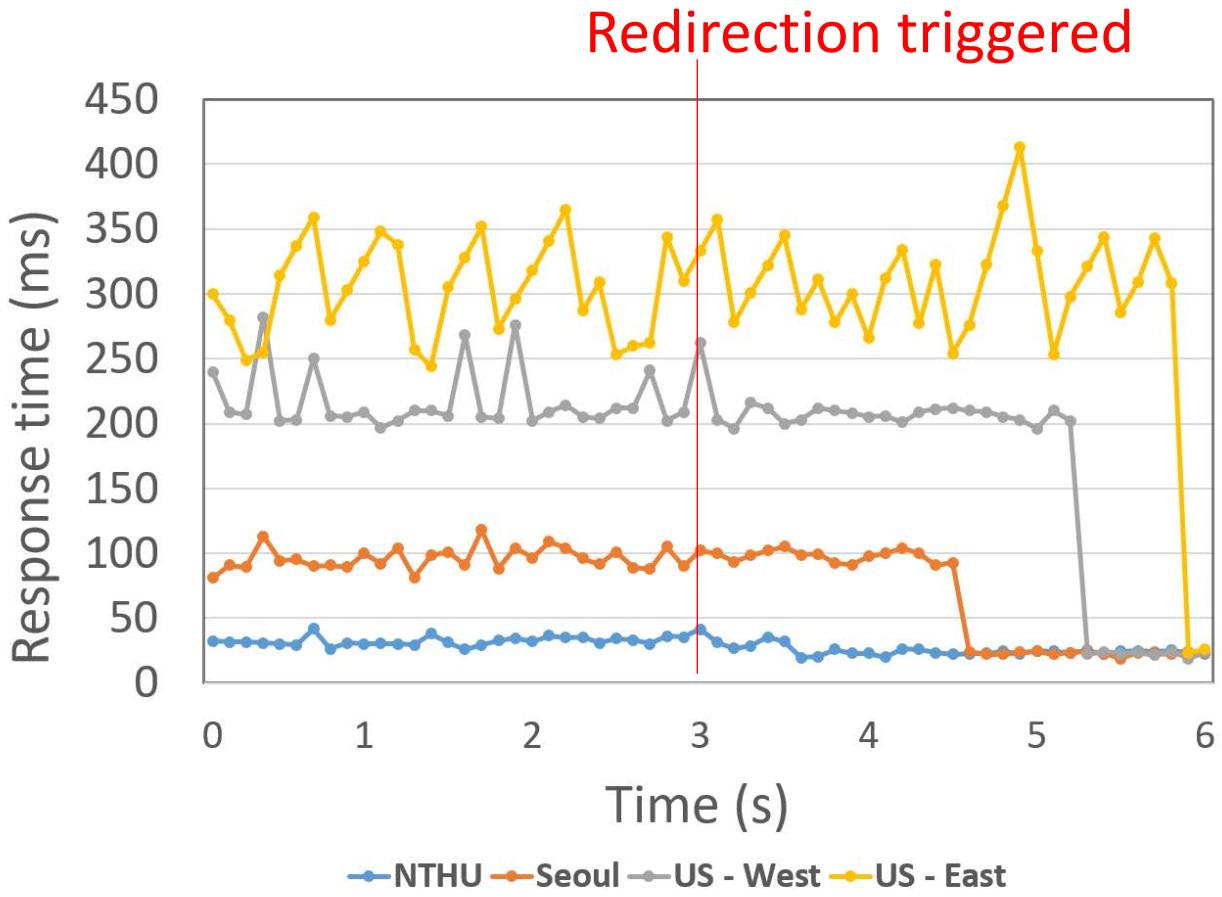
Experimental Environment

- Application:
  - **Face detection**.
- UE:
  - Raspberry pi with camera and LTE dongle.
  - Send photos to application.
- MEC server、eNodeB、EPC:
  - AMD A10-7850K APU at 3.7GHz
  - Ubuntu 14.04 with low-latency kernel 3.19.
- Cloud
  - Local host using OpenStack
  - AWS EC2: Seoul, US west, US east



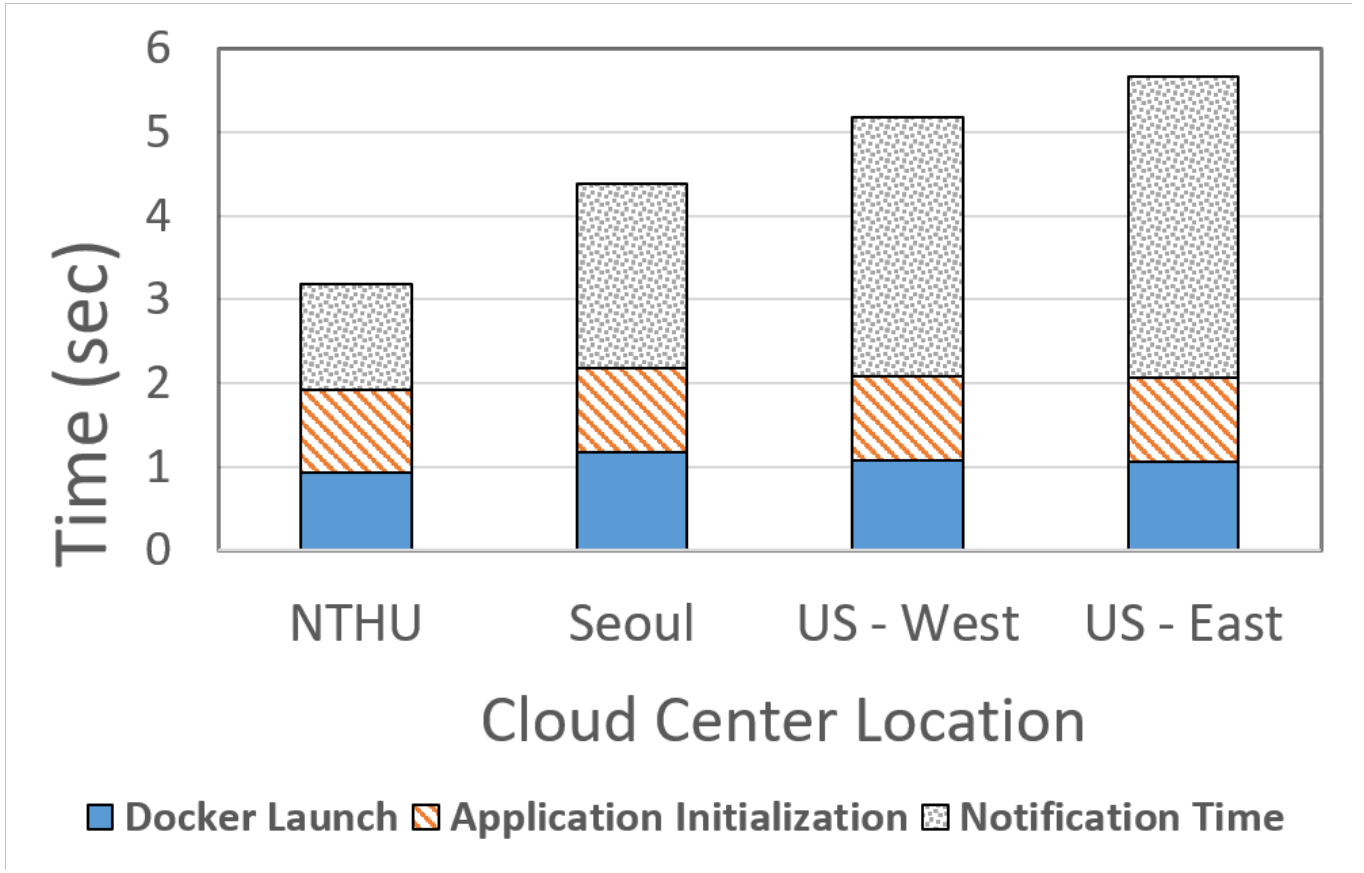
Application Response Time

- Image resolution = 1920 x 1080 pixels
- Frame Per Second = 10 FPS
- Threshold = 0.1 Mb/s
- Latency delay depends on location of public cloud.
- Significantly decrease in response time of application.
- Takes 3.5~6 seconds to finish the traffic redirection procedure.



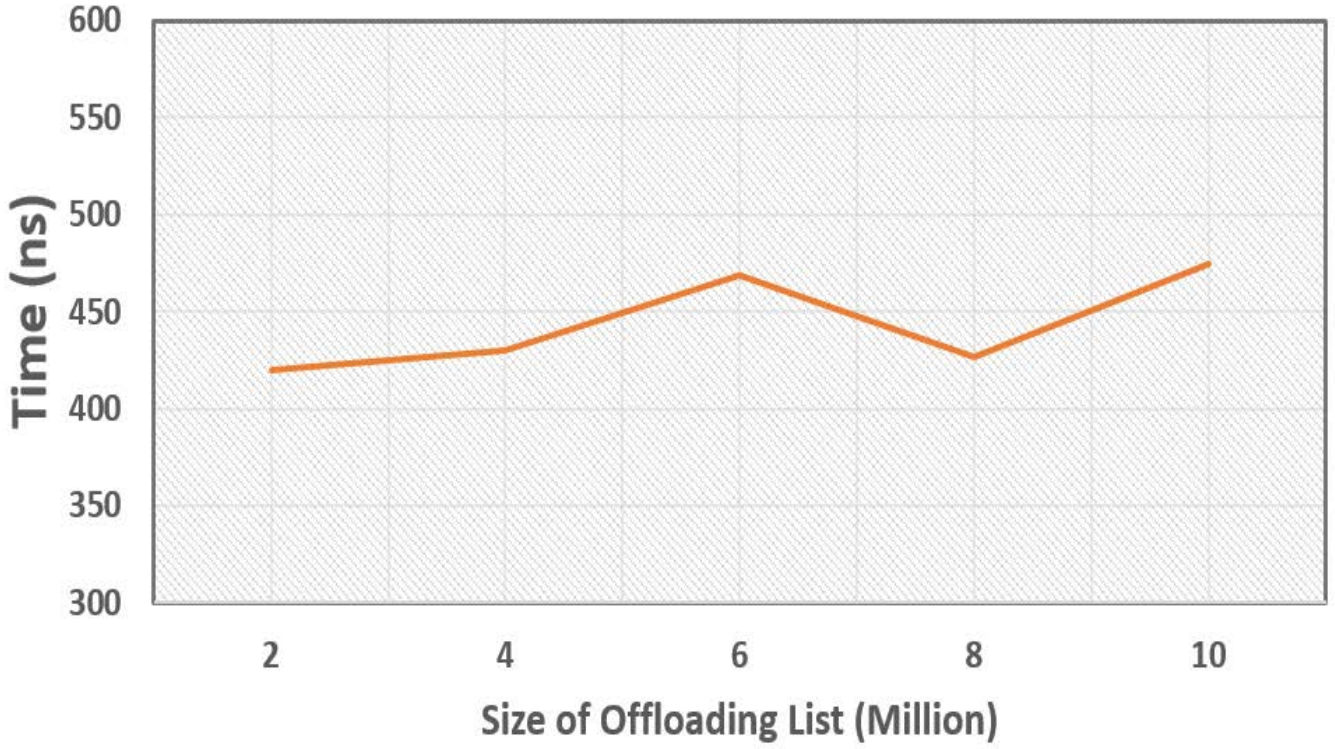
Redirection Time Breakdown

- Docker launch time
  - A constant.
- Initialization of application
  - Depend on each application.
  - In our experiment, it takes 1 sec.
- Notification time
  - Depend on the distance from UE to public cloud.



Application-Aware Decision Time Overhead

- The time of application-aware function on each packet takes around 450 ns.
- As the size of offloading list increases, the function time do not increase obviously.



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Conclusions and Future Work

- **Contributions:**
  - We are the first work to realize the concept of **MEC on OAI (5G C-RAN platform)**.
  - We also propose a threshold-based traffic **redirection mechanism**.
  - Furthermore, our **performance evaluation** of proposed mechanism shows that it can reduce the latency of user application and the throughput consumption of backhaul network.
- **Future work:**
  - Study workload characteristics to design more performance driven redirection policy or bandwidth sharing allocation algorithm