5G Mobile Platform with P4-enabled Network Slicing and MEC

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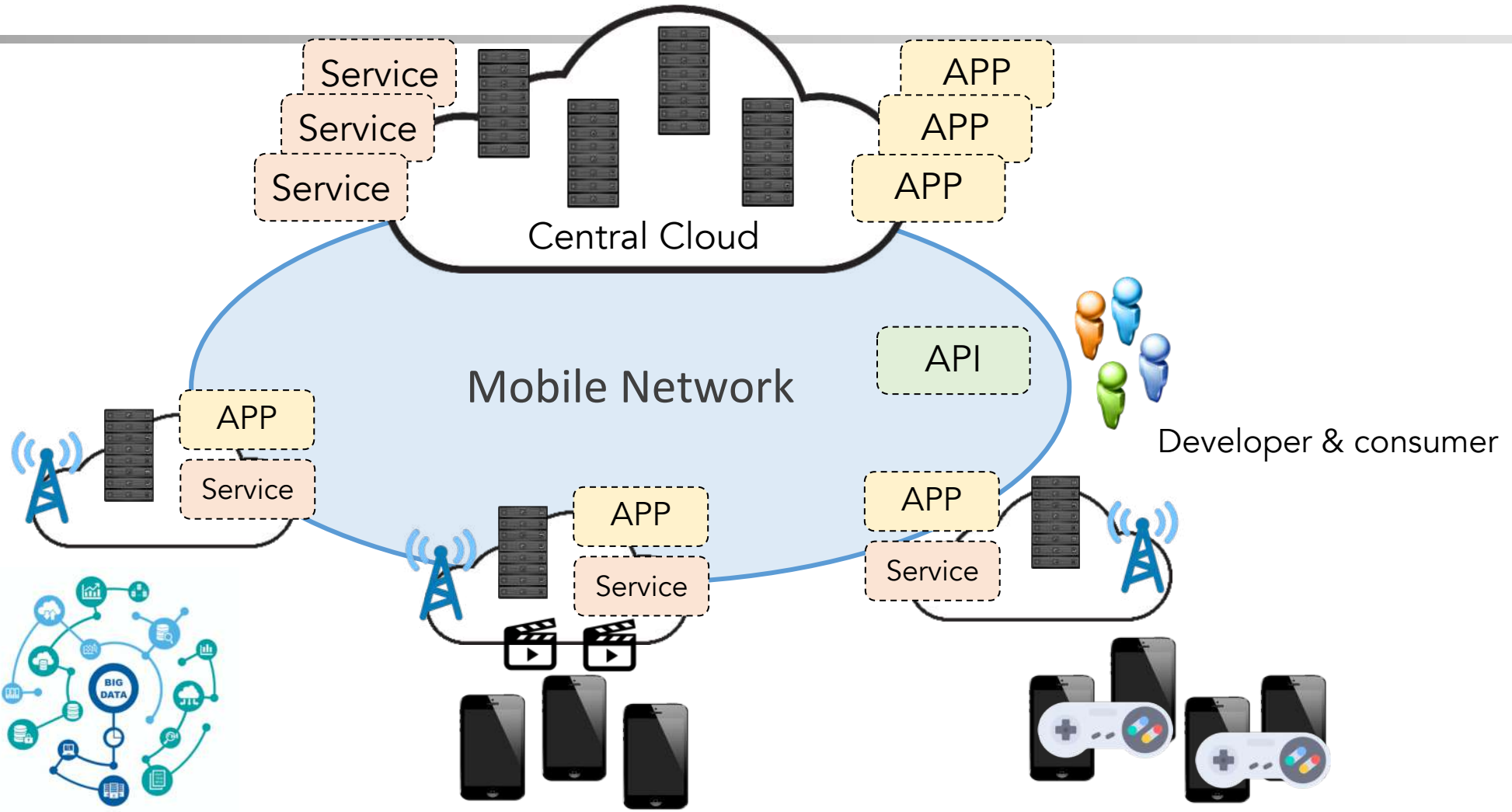
Outline

- 5G Mobile Platform with free5GC
- Reduce Loading in MEC with P4 Switch
- P4-enabled Network Slicing

5G Requirements

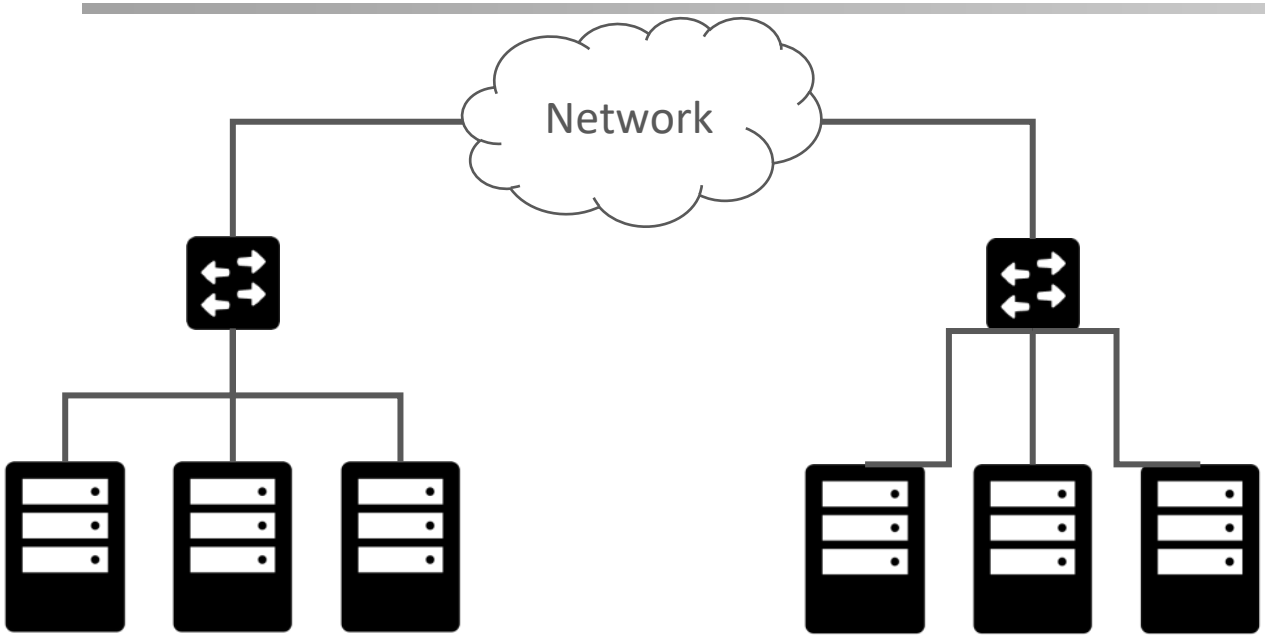


Big data and IoT

Edge caching

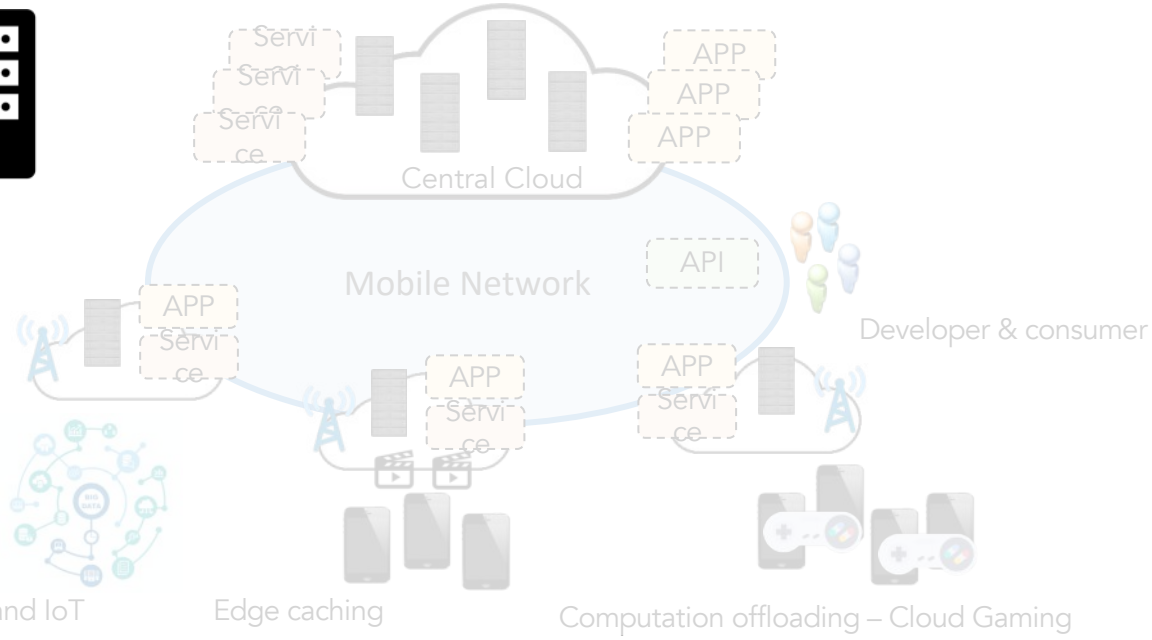
Computation offloading – Cloud Gaming

Multi-cluster Architecture

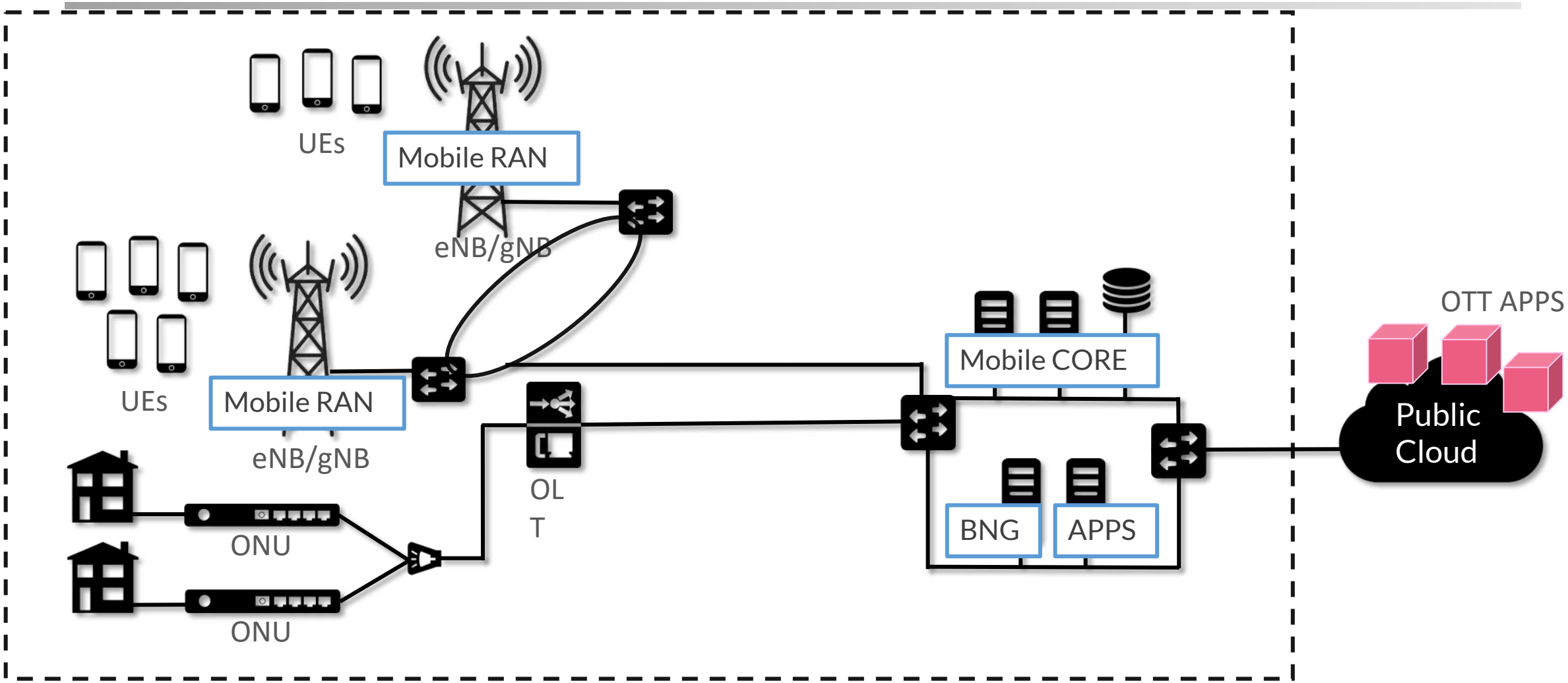


Edge Cloud
(Local Cluster)

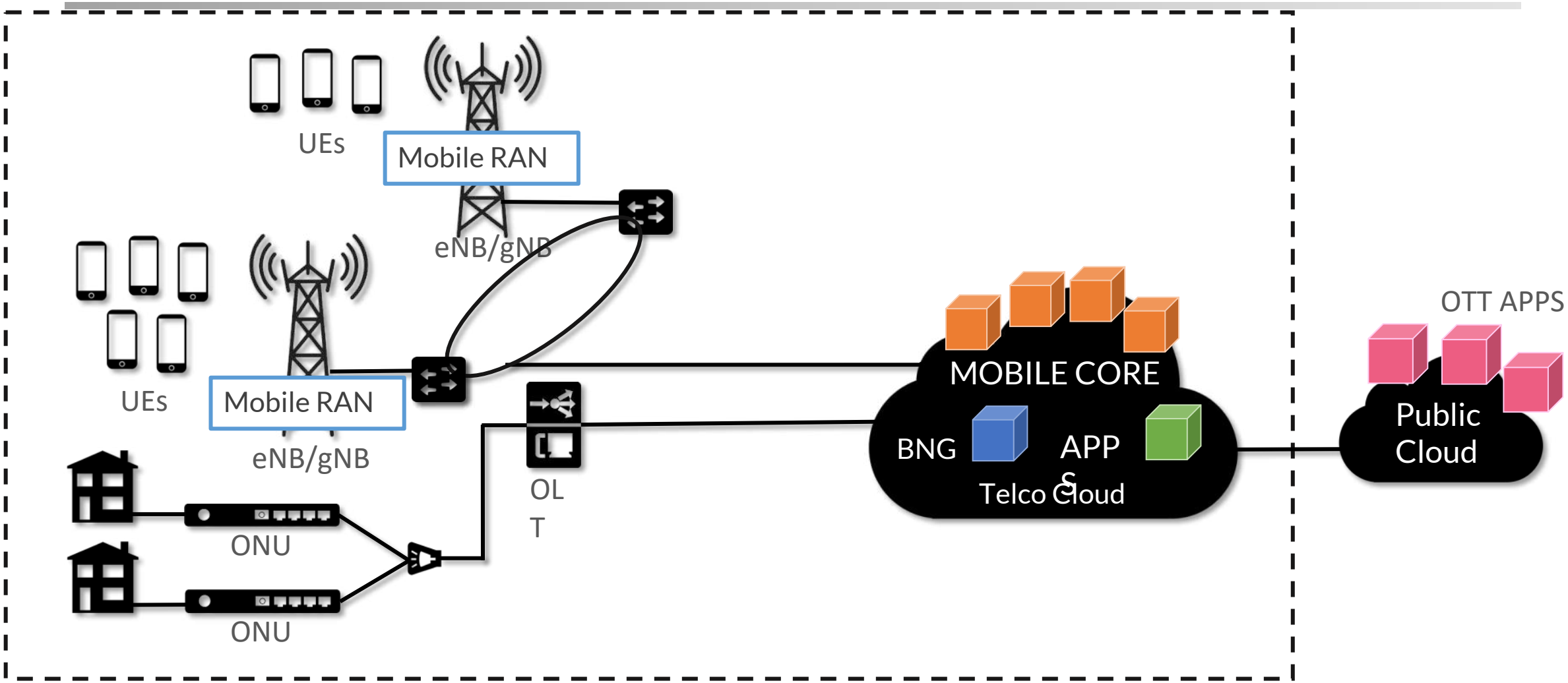
Central Cloud
(Remote Cluster)



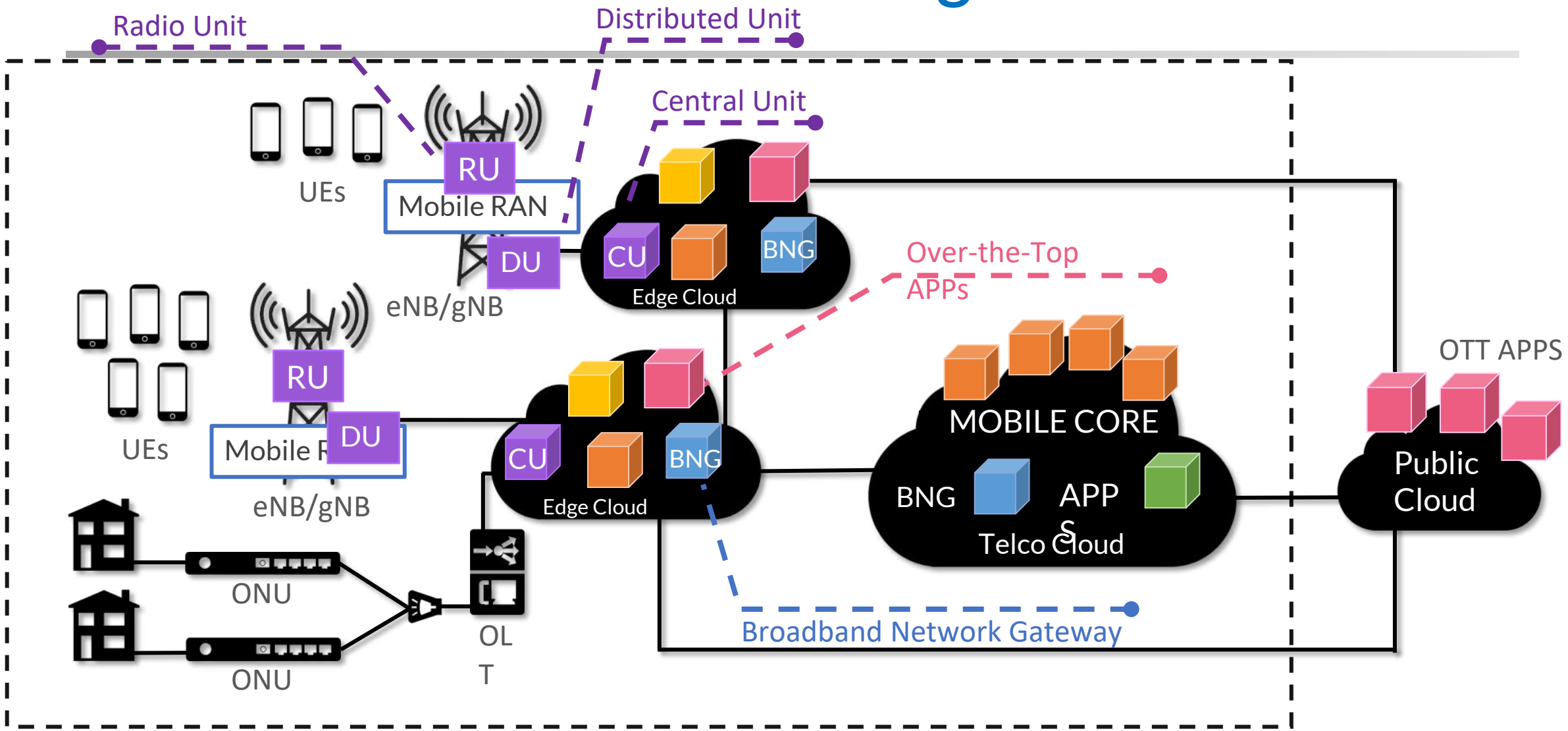
Legency Hardware Device

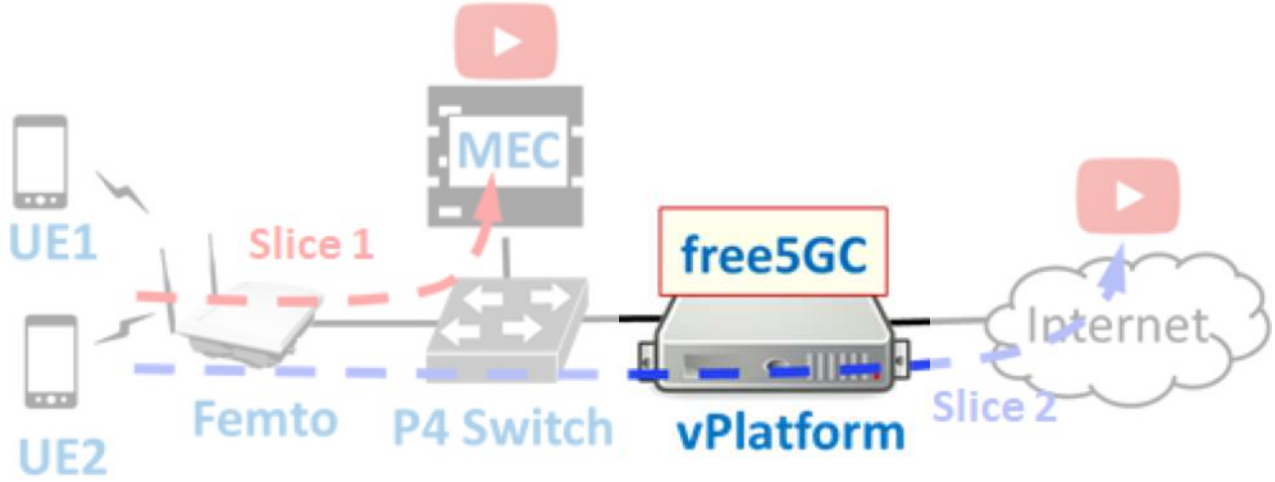


Virtualization



Evolution towards the Edge





5G Mobile Platform with free5GC

Motivation

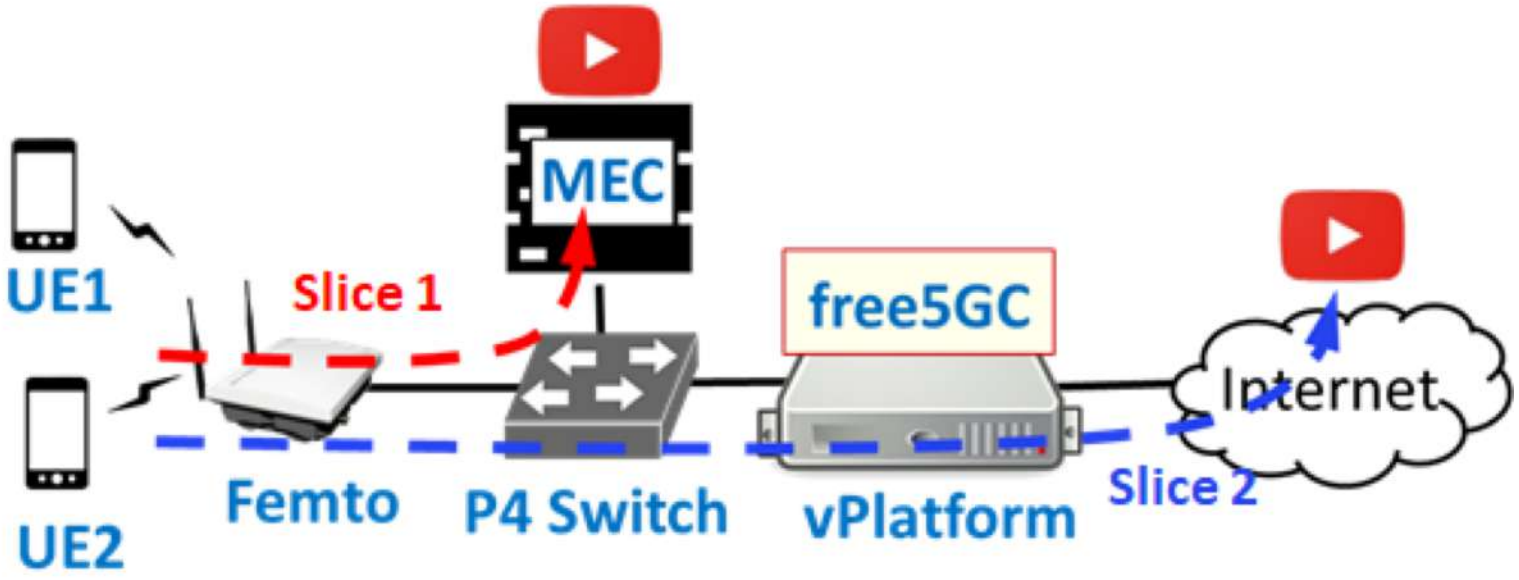
- 5G need **Virtualized Network Functions (VNFs)**
  - Flexible and efficient network
- **Cloud-Native VNFs (CNF)**
  - VNFs based on Cloud-Native containerization technology
  - Lower overhead and higher performance
- ETSI proposes **NFV Management and Orchestration (NFV-MANO)** architecture
- Many existing NFV-MANO projects
  - Complex service development
  - Insufficient support of CNF orchestration
  - High resource usage, e.g. CPU, memory, disk

➢ Need a 5G Lightweight NFV-MANO platform

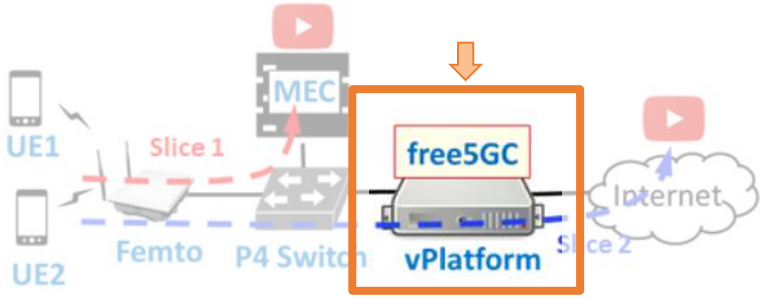
So we want to

Propose a 5G Lightweight NFV-MANO Mobile Platform

- Utilize SDN, NFV, Cloud to provide 5GC flexibility and scalability
- All open sources
  - Kubernetes, ONOS, free5GC
- NFV functionality
  - Scalable free5GC CNFs
- Cloud functionality
  - Agile orchestration
- SDN functionality
  - Flexible underlay network



ETSI NFV-MANO



- **NFVO: NFV Orchestrator**
  - Management of the instantiation of VNFMs
- **VNFM: VNF Manager**
  - Manage lifecycle of VNF instances
- **VIM: Virtualized Infrastructure Manager**
  - E.g. OpenStack, Kubernetes, ONOS
- **VNF: Virtualized Network Function**
  - **free5GC**
- **NFVI: NFV Infrastructure**
  - Provide the infrastructure resources
- EM: Element Management
- OSS/BSS: Operation/Business System Support

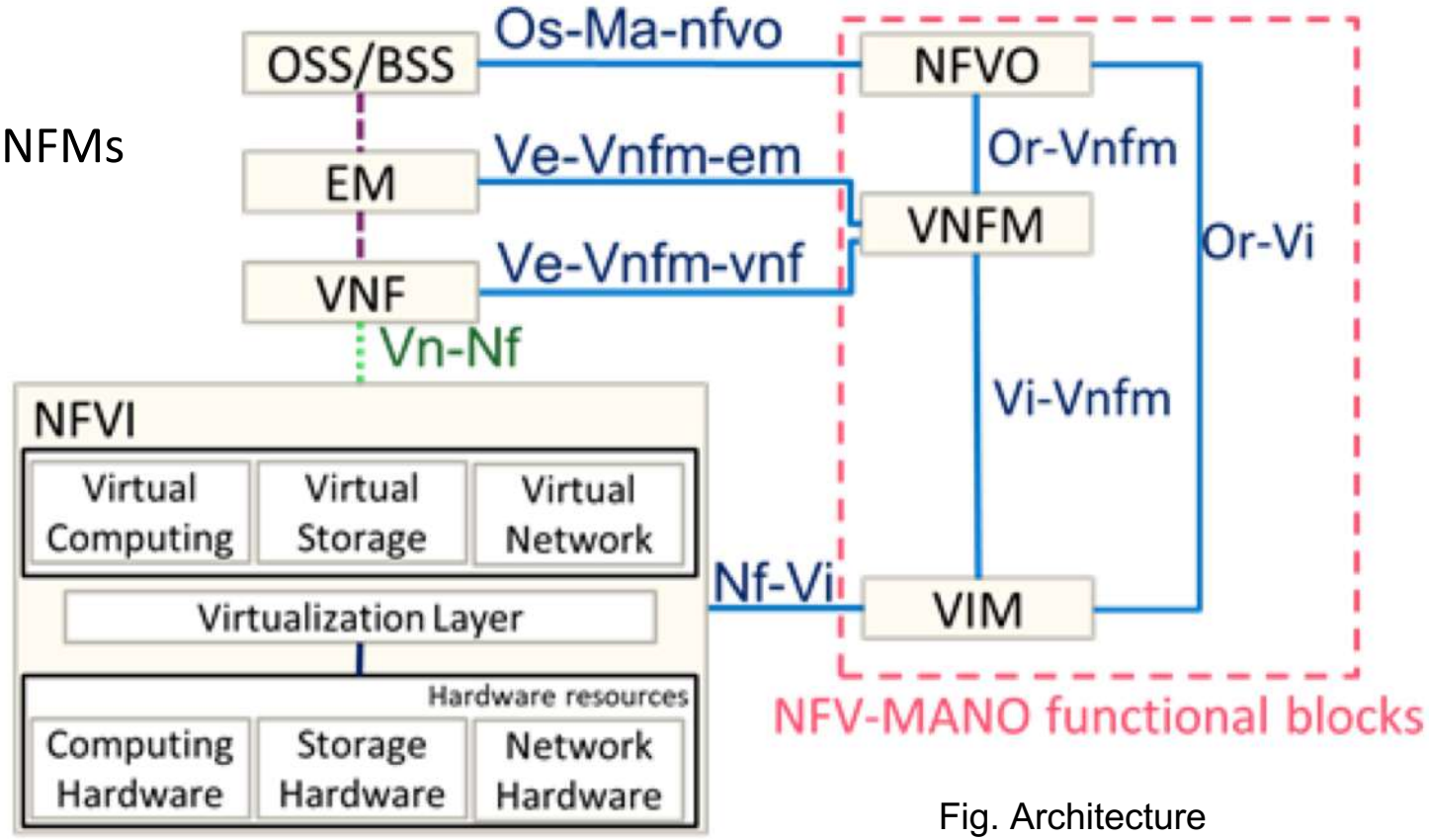
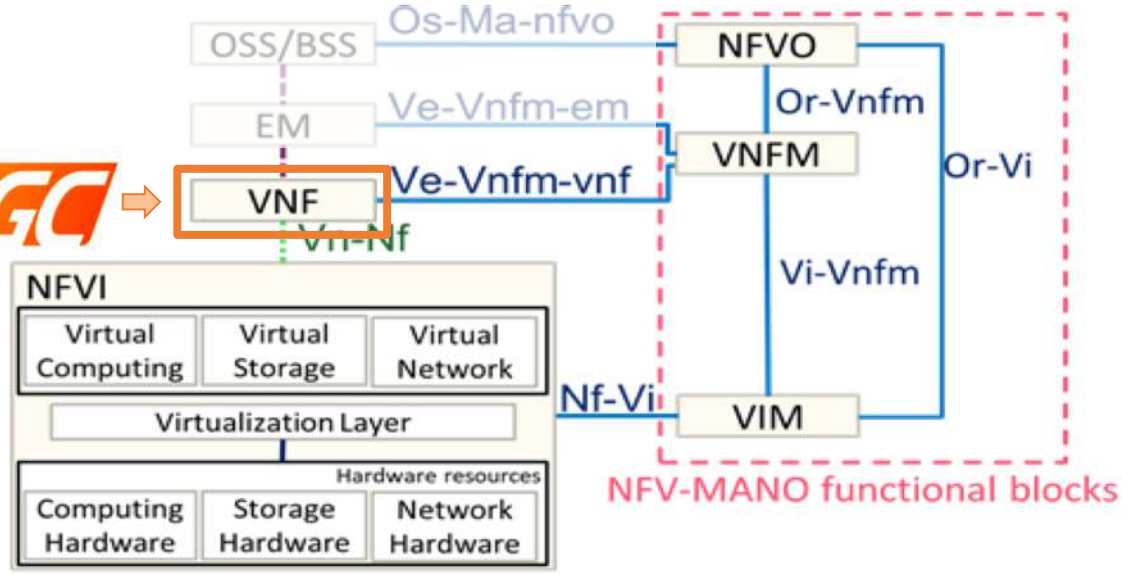


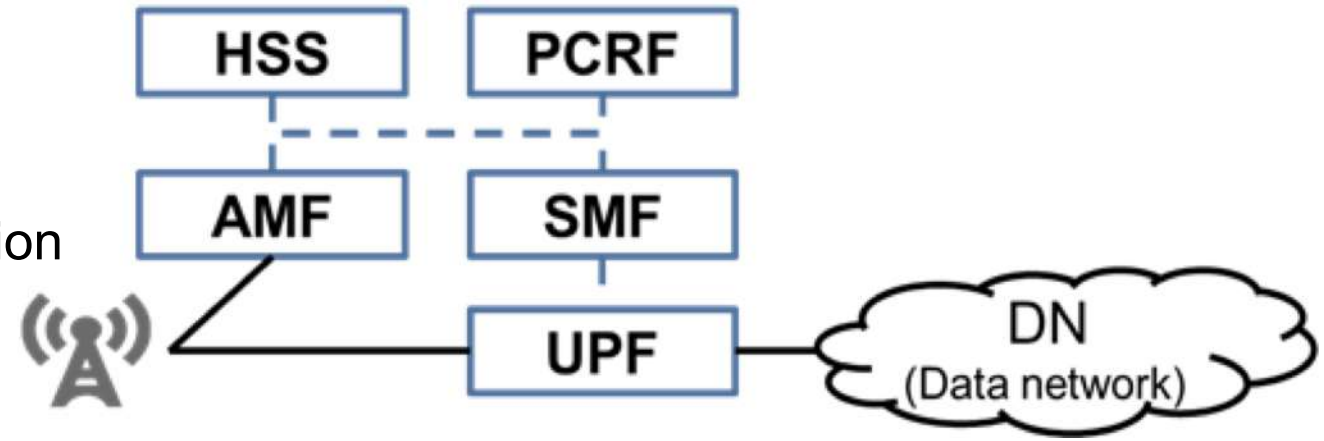
Fig. Architecture

free5GC



- The free5GC is an open-source project code for 5G generation mobile core network created by NCTU

- CNFs (Cloud-Native VNFs)
  - AMF: Access Management Function
  - SMF: Session Management Function
  - HSS: Home Subscriber Server
  - PCRF: Policy and Charging Rules Function
  - UPF: User Plane Function

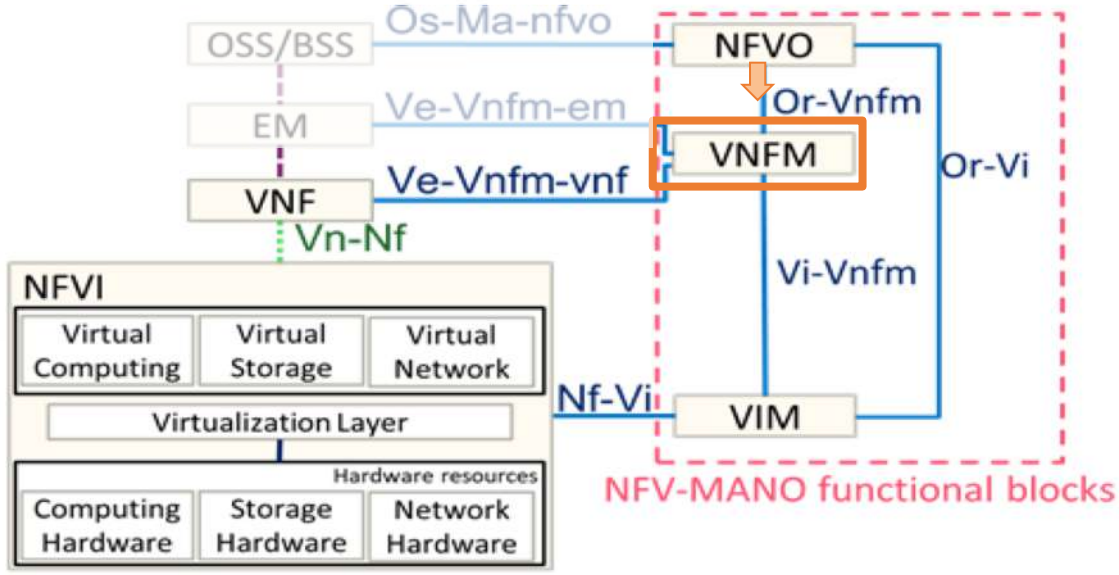


- All CNFs are containerization and running on K8s cluster

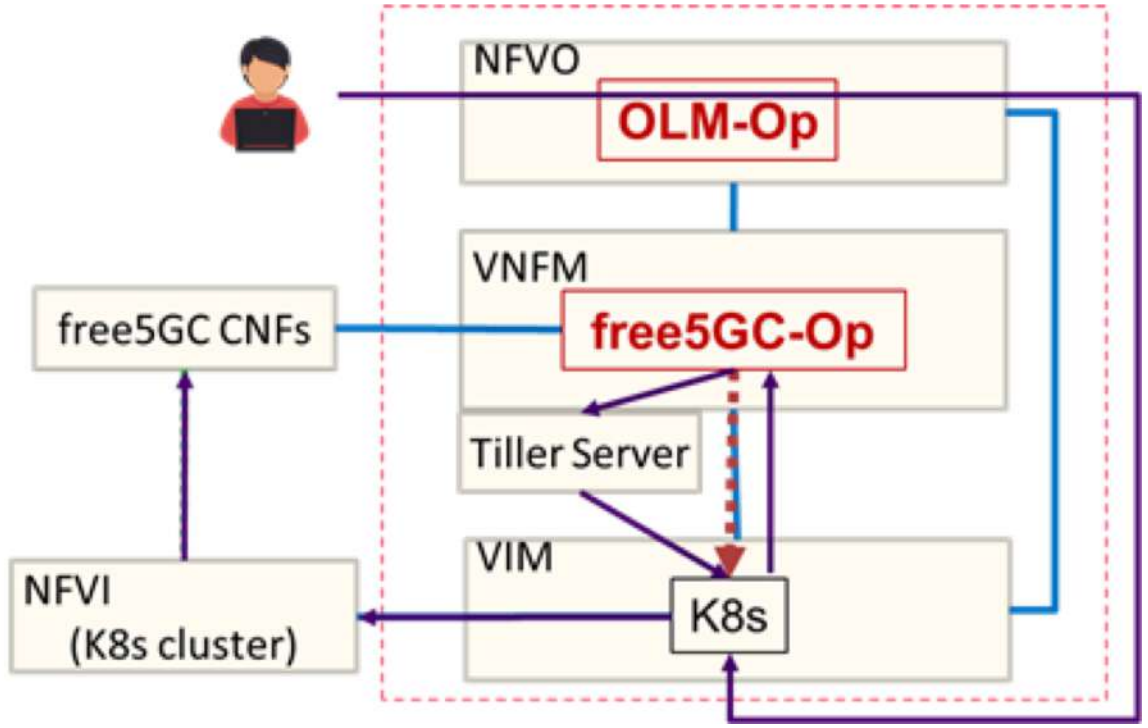
free5GC-Op

Cloud-Native VNF

- Each NF of free5GC is a CNF
- May install/update a group of designated free5GC CNFs
  - Using **Helm**

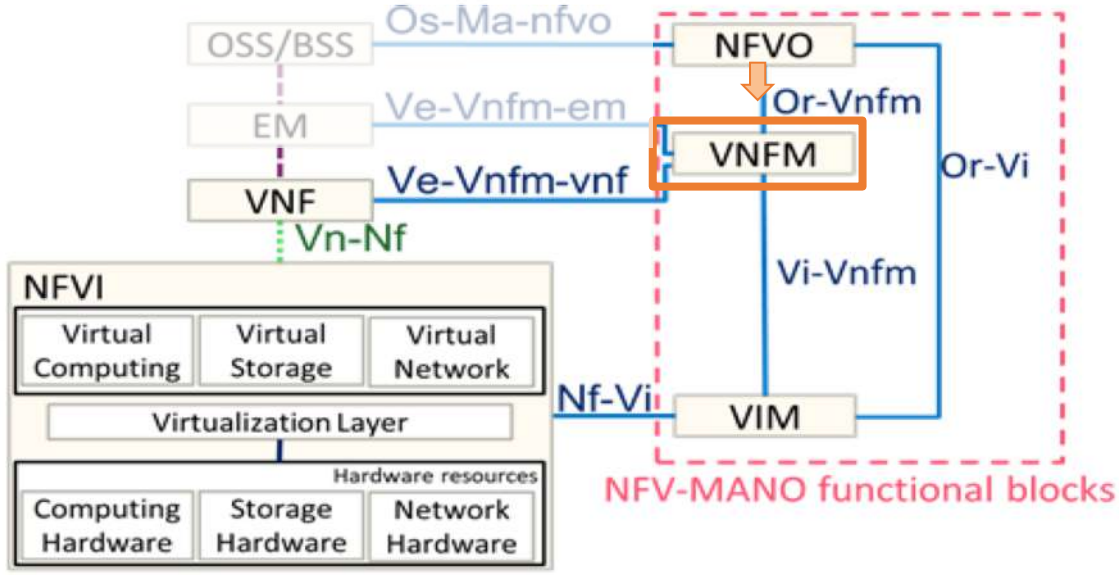


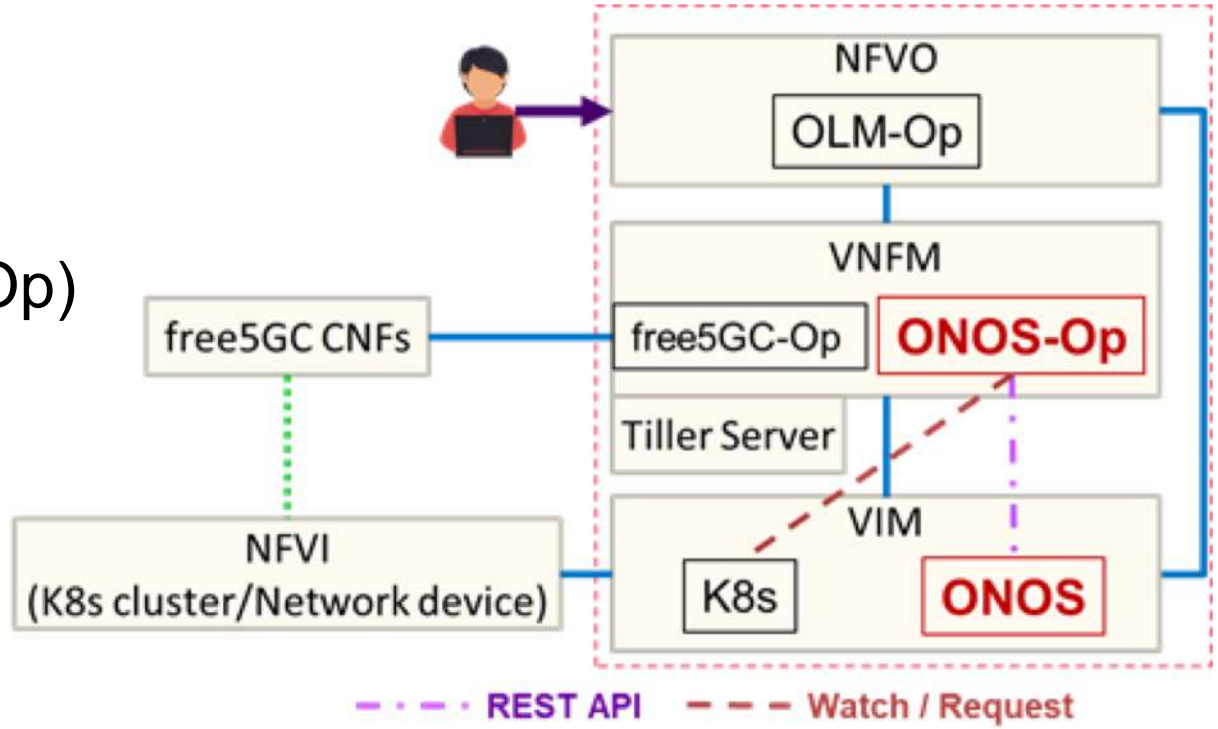
- Create Custom Resource Definition (**CRD**) for free5GC CNFs
- Introduce a free5GC Operator (**free5GC-Op**) as VNFM for free5GC CNFs CR



ONOS-Op

- Use **ONOS** to manage underlying SDN network
- Interact with ONOS
  - Modify **OLM-Op**
  - Introduce **ONOS-Op**
- Introduce a ONOS Operator (ONOS-Op) as VNFM
  - Implement a ONOS-Op as VNFM for **ONOS REST API**
  - Create CRD for ONOS REST API
    - Treat ONOS REST API as CR





Operator Lifecycle Manager (OLM)

- Create Custom Resource Definition for **Custom Operators (C-Ops)**
  - Treat Custom Operator (C-Op) as CR in K8s

- Employ two operators to manage C-Op CR:

1. **OLM Operator (OLM-Op)**:
   - Watch C-Op CR update request
   - Perform C-Op installation/modification

2. Catalog Operator (optional)
   - Cache of C-Op custom resource

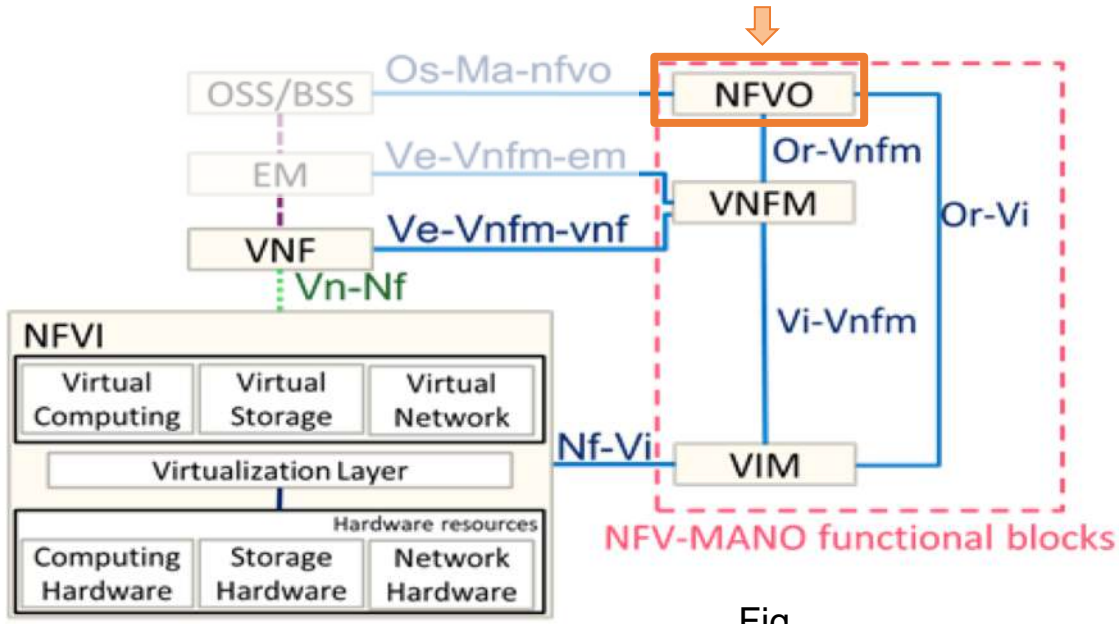
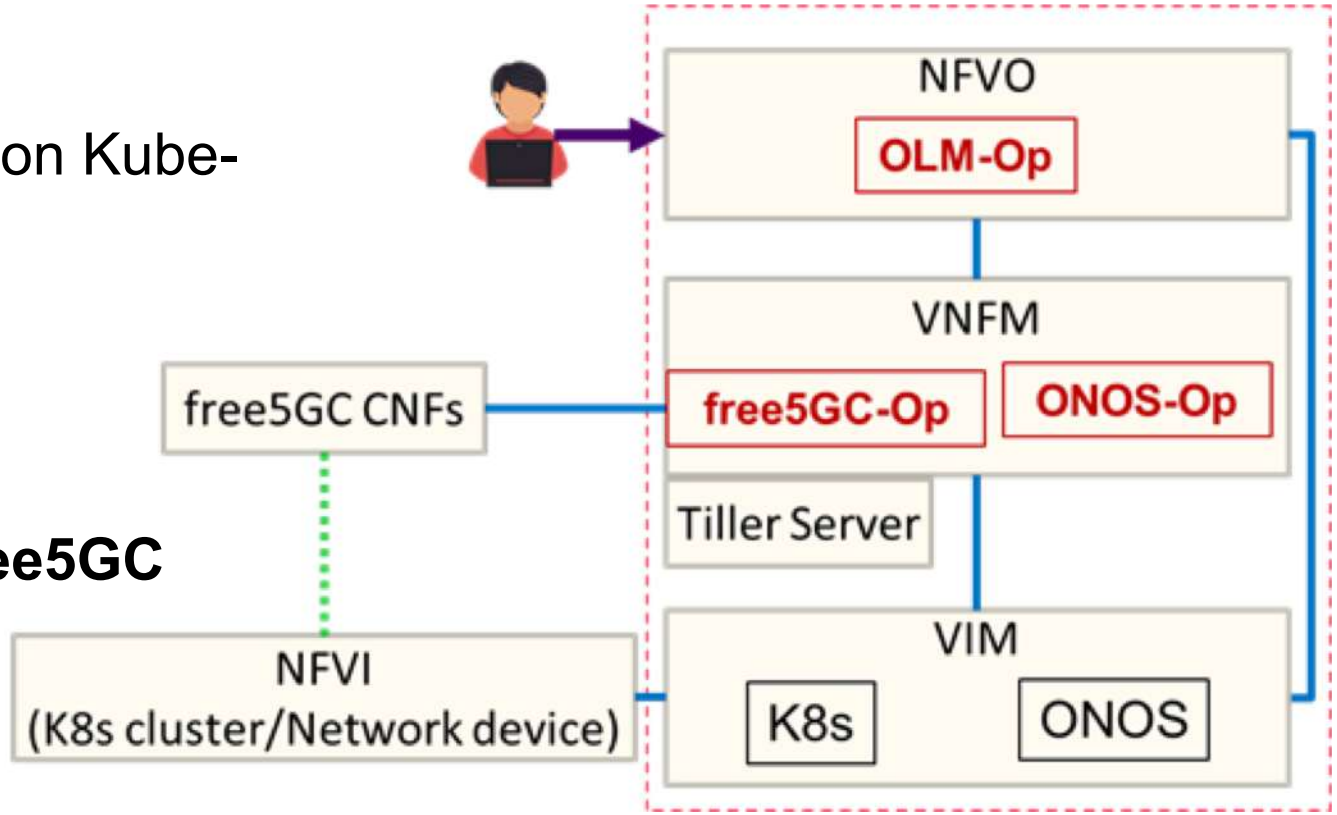


Fig. Architecture

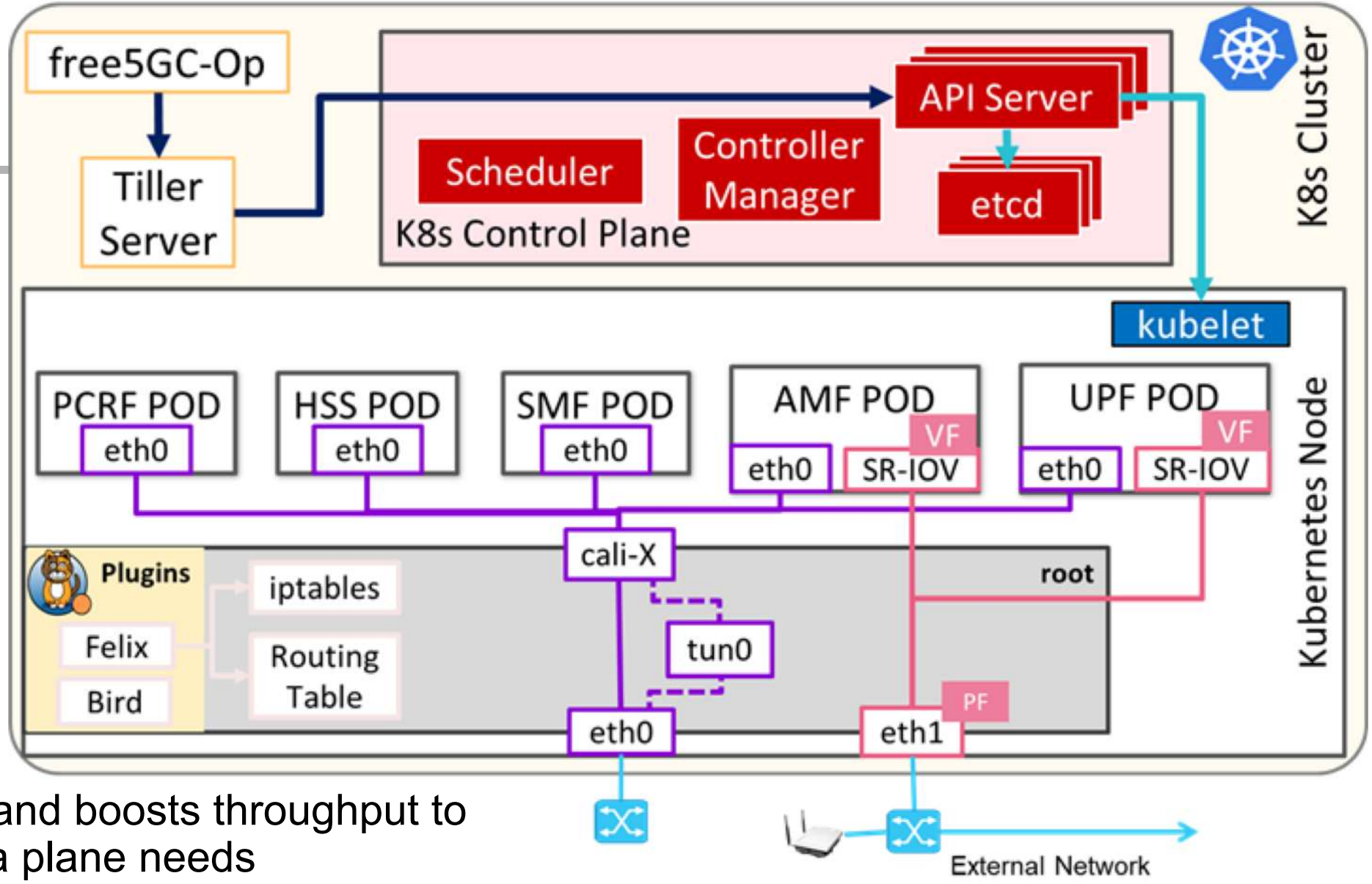
Architecture of 5G Mobile Platform

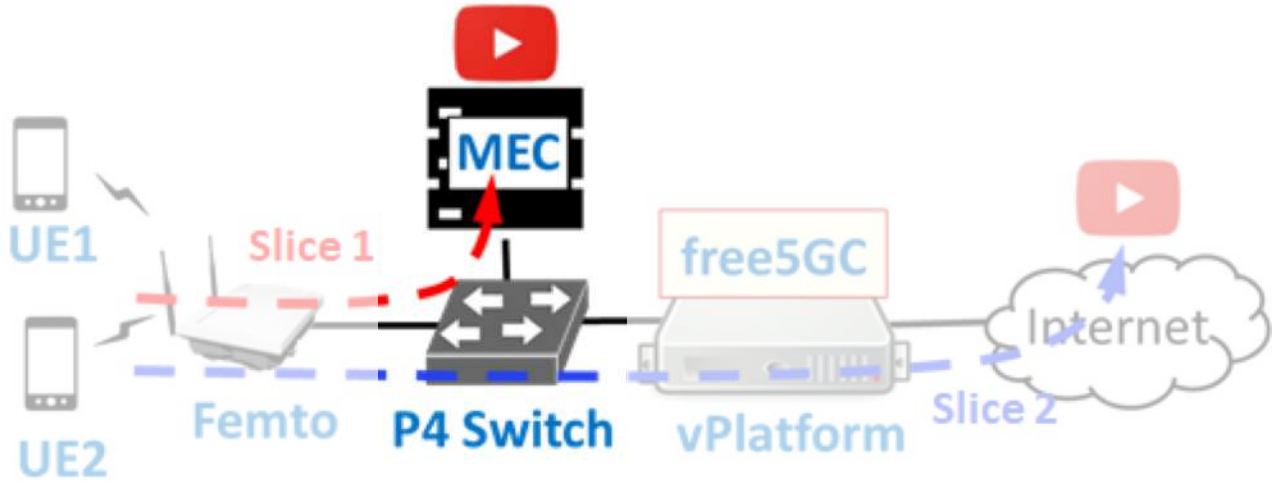
- **NFVO: OLM-Op**
  - Watch **CR** update requests of **C-Op** on Kube-apiserver
  - Install / update C-Op
- **VNFMs:** C-Ops
  - free5GC Operator (**free5GC-Op**)
    - Watch **CR** update requests of **free5GC** on Kube-apiserver
    - Install / update free5GC CNFs
  - ONOS Operator (**ONOS-Op**)
    - Watch **CR** update requests of **ONOS REST API** on Kube-apiserver
    - Call **ONOS northbound REST API**



Data Network

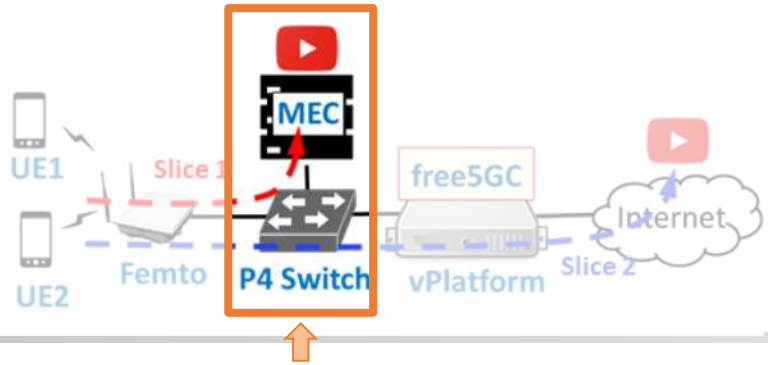
- Multus
  - multi-interface
    - eth0: Internal
    - eth1: external
- Calico
  - Deliver native Linux networking dataplane
- SR-IOV
  - Lowers latency and boosts throughput to satisfy CNF data plane needs





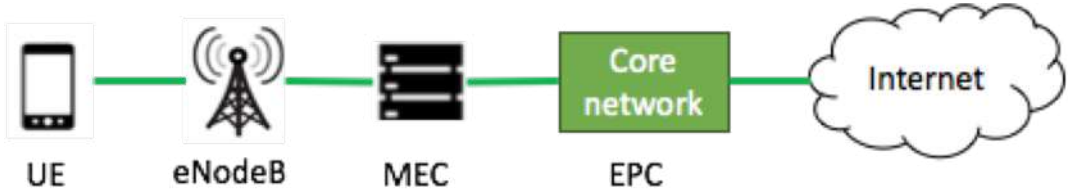
Reduce Loading in MEC with P4 Switch

P4-based MEC network

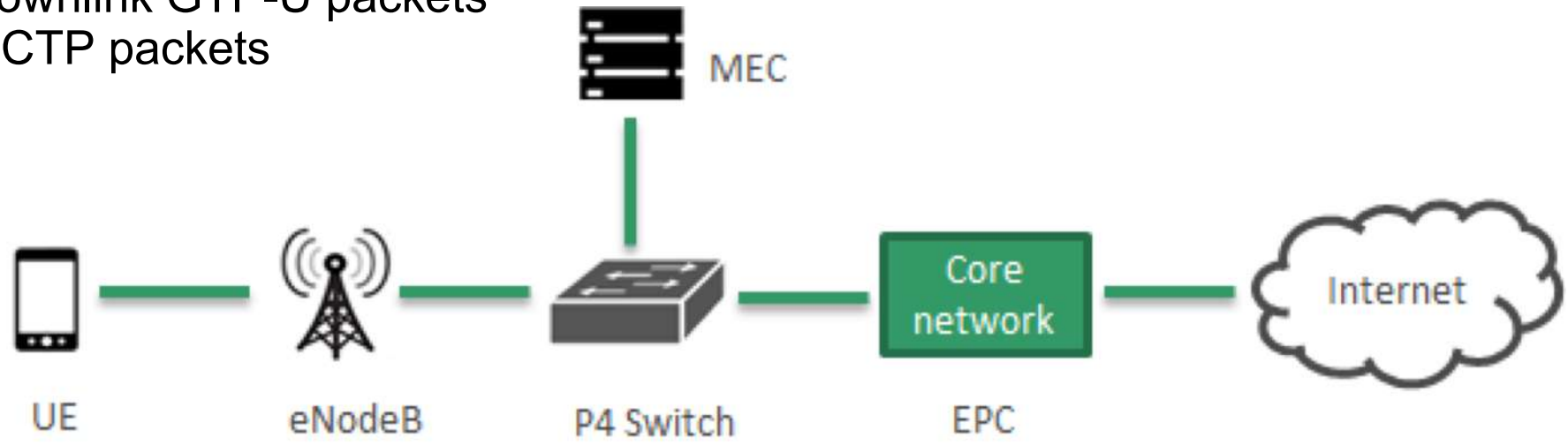


Network feature

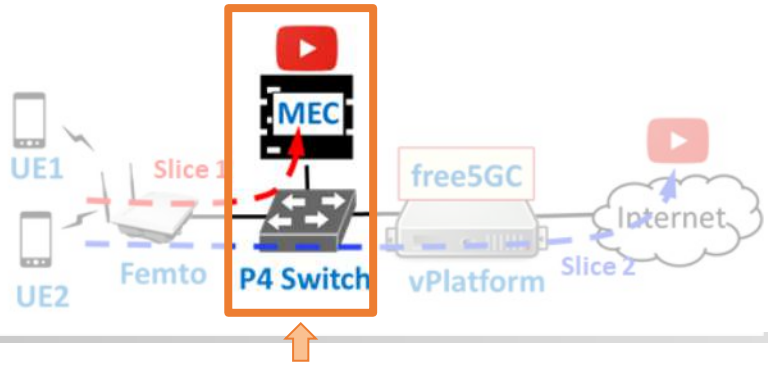
- Provide better packet I/O with P4 switch



- Reduce MEC loading from packet encapsulation and decapsulation
  - Two approaches
    - Packet-in downlink GTP-U packets
    - Packet-in SCTP packets
- Redirect DNS



Outline



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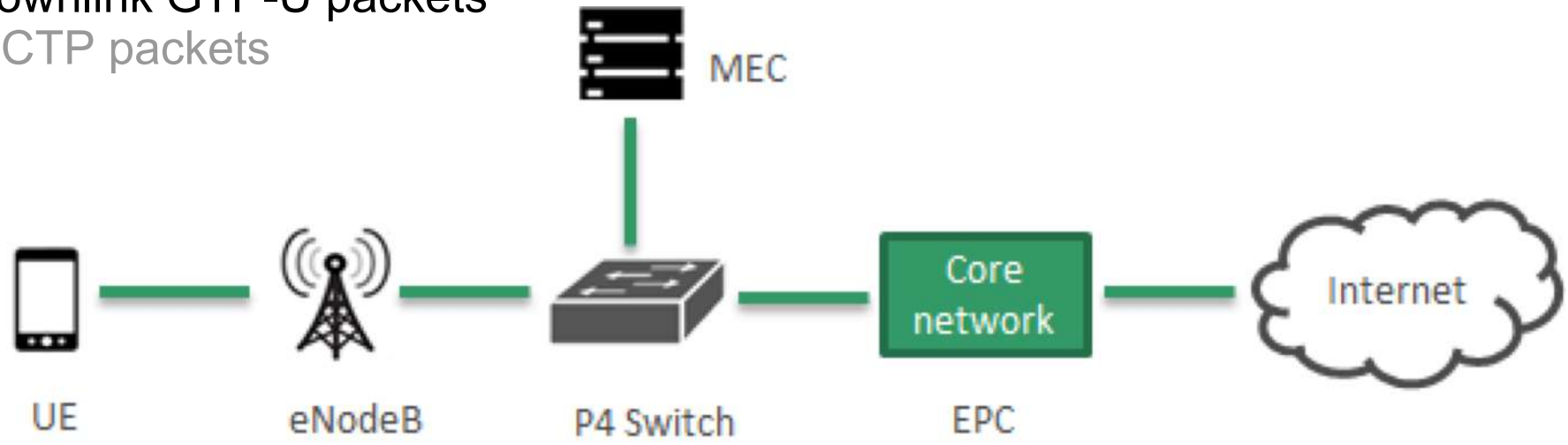


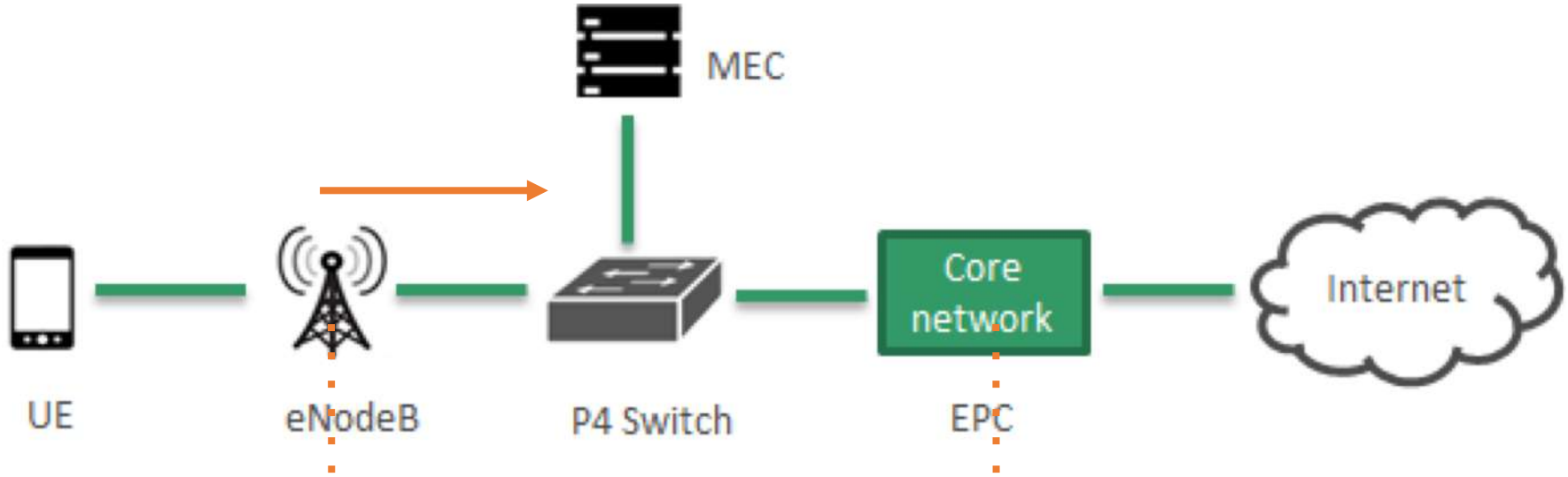
Stateful GTP packet tracking (1/3)

- Decapsulate GTP-U header before sending it MEC
- Encapsulate packet with GTP-U header before sending it to UE
  - Tracking mapping between **UE IP** and downlink **TEID**

Tunnel endpoint identifier

Payload
TCP/UDP
IP
Ethernet

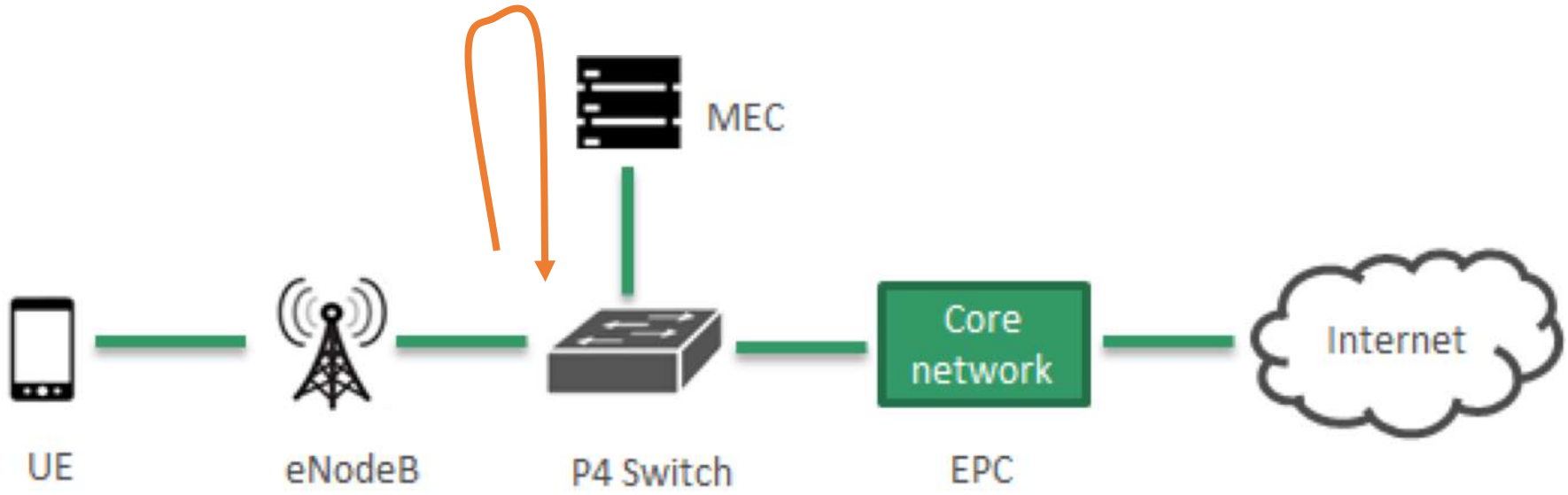
GTP-U(**TEID=XXX**)
UDP
IP
Ethernet



Stateful GTP packet tracking (2/3)

- Decapsulate GTP-U header before sending it MEC
- Encapsulate packet with GTP-U header before sending it to UE
  - Tracking mapping between **UE IP** and downlink **TEID**

Payload
TCP/UDP
IP
Ethernet



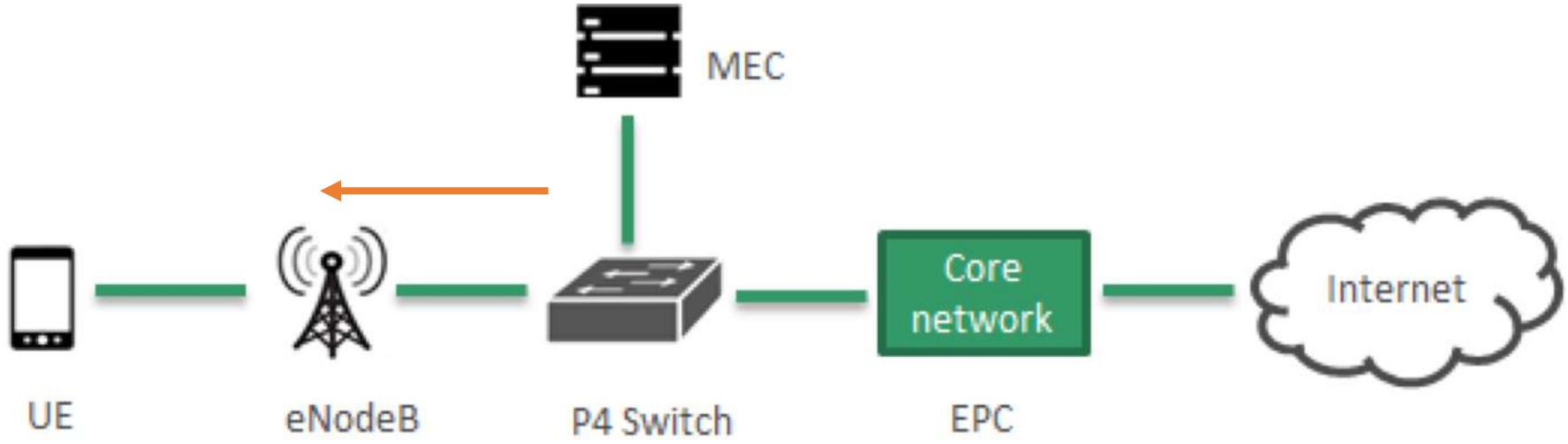
Stateful GTP packet tracking (3/3)

- Decapsulate GTP-U header before sending it MEC
- Encapsulate packet with GTP-U header before sending it to UE
  - Tracking mapping between **UE IP** and downlink **TEID**

Tunnel endpoint identifier

Payload
TCP/UDP
IP
Ethernet

GTP-U(**TEID=YYY**)
UDP
IP
Ethernet



Packet-in downlink GTP-U packets (1/3)

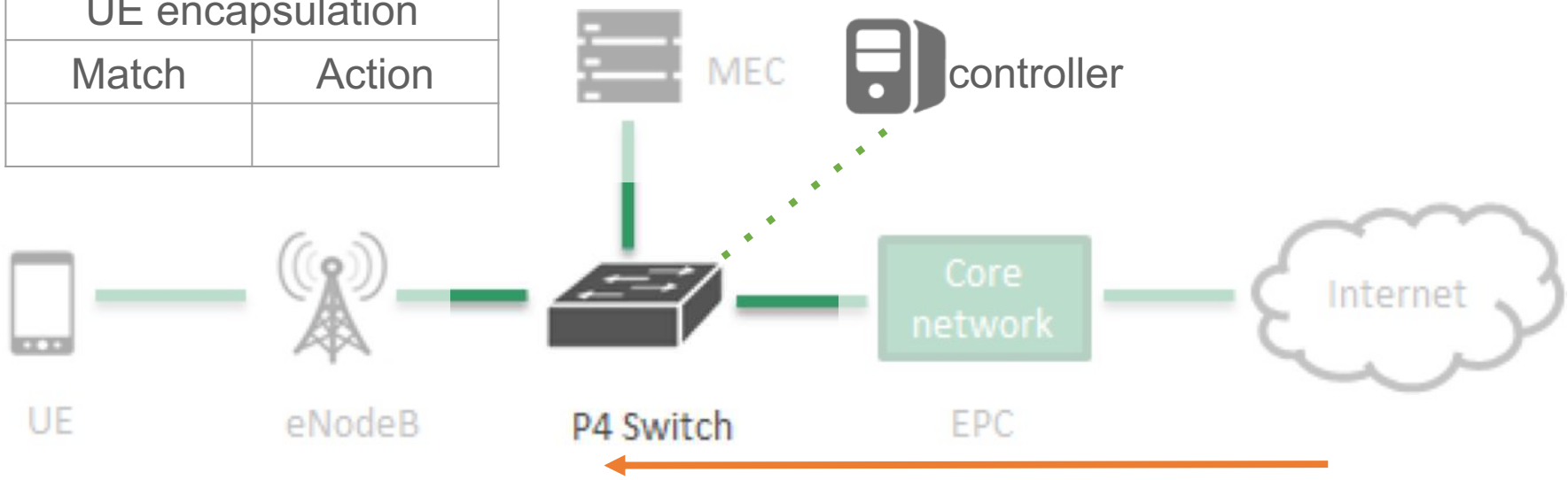
Switch

UE session state	
Match	Action

UE encapsulation	
Match	Action

Controller

UE Addr.	DL TEID



Packet-in downlink GTP-U packets (2/3)

Payload
TCP/UDP
IP
Ethernet
GTP-U(**TEID=XXX**)
UDP
IP
Ethernet

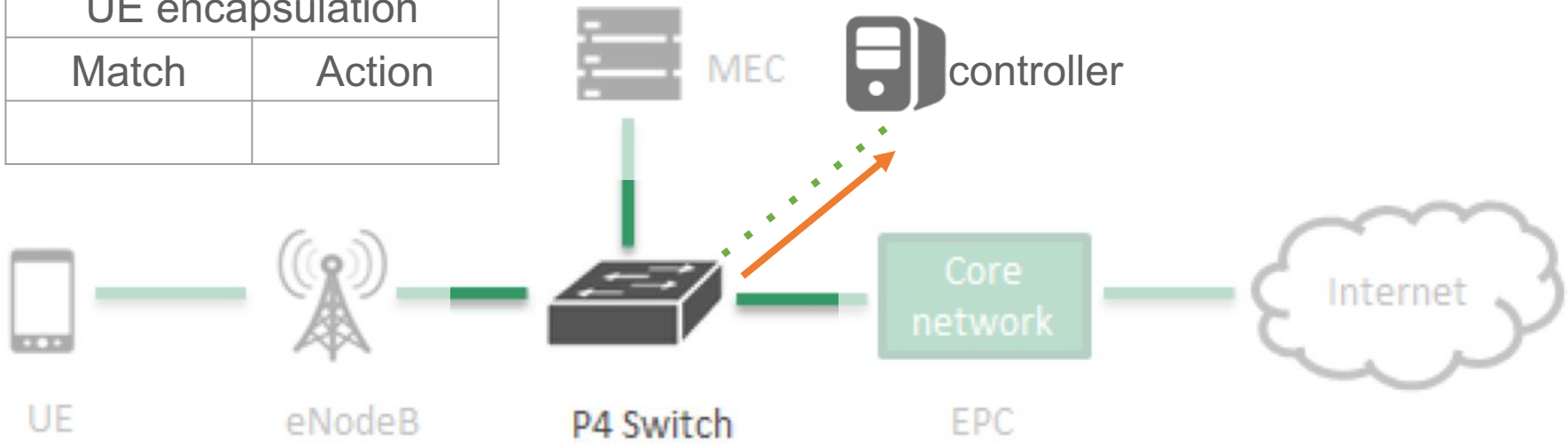
Switch

UE session state	
Match	Action

UE encapsulation	
Match	Action

Controller

UE Addr.	DL TEID
192.168.3.2	777



Packet-in downlink GTP-U packets (3/3)

Payload
TCP/UDP
IP
Ethernet

GTP-U(**TEID=XXX**)
UDP
IP
Ethernet

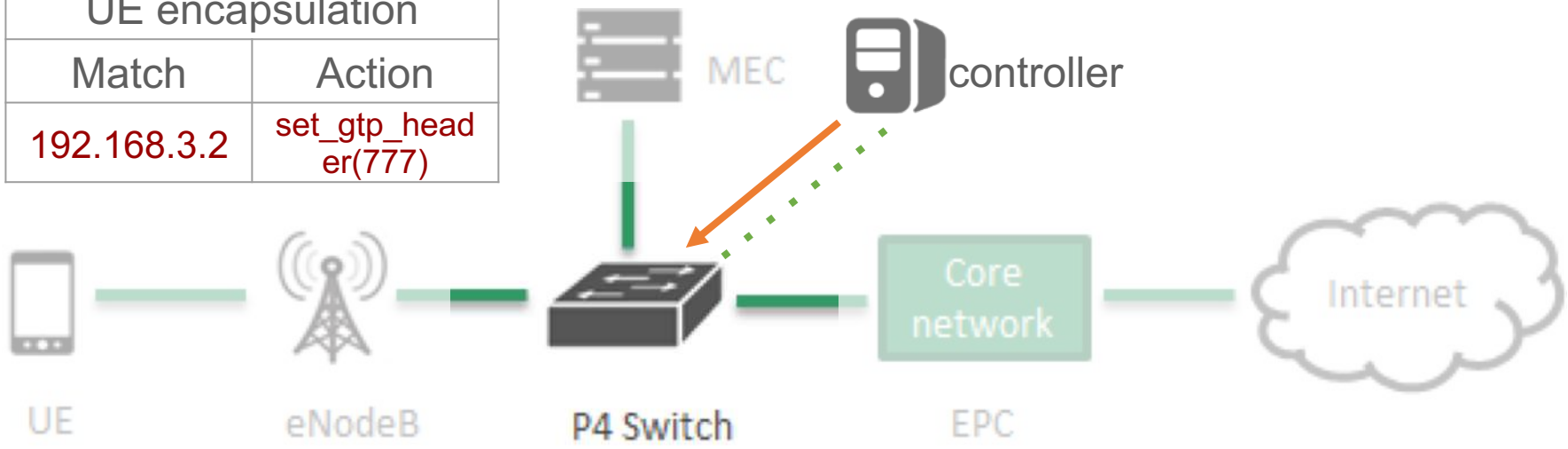
Switch

UE session state	
Match	Action
192.168.3.2	NoAction

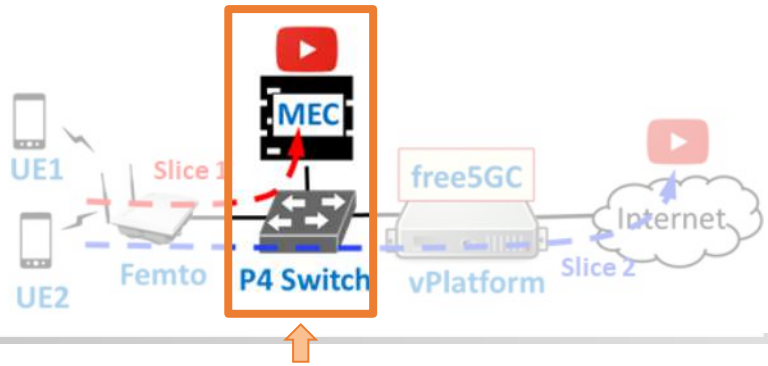
UE encapsulation	
Match	Action
192.168.3.2	set_gtp_header(777)

Controller

UE Addr.	DL TEID
192.168.3.2	777

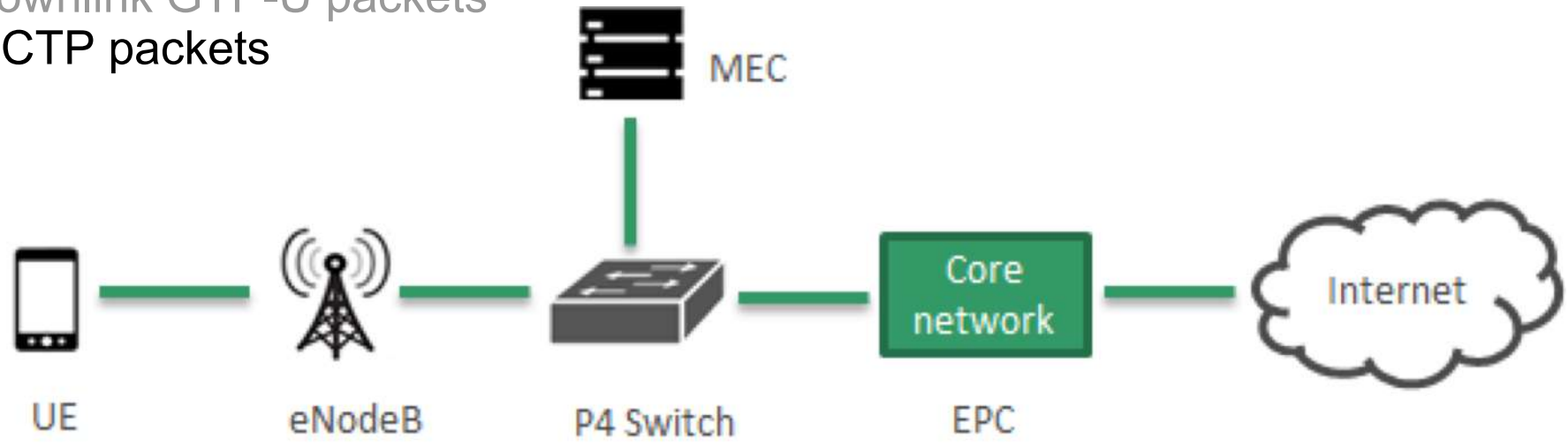


Outline



Network feature

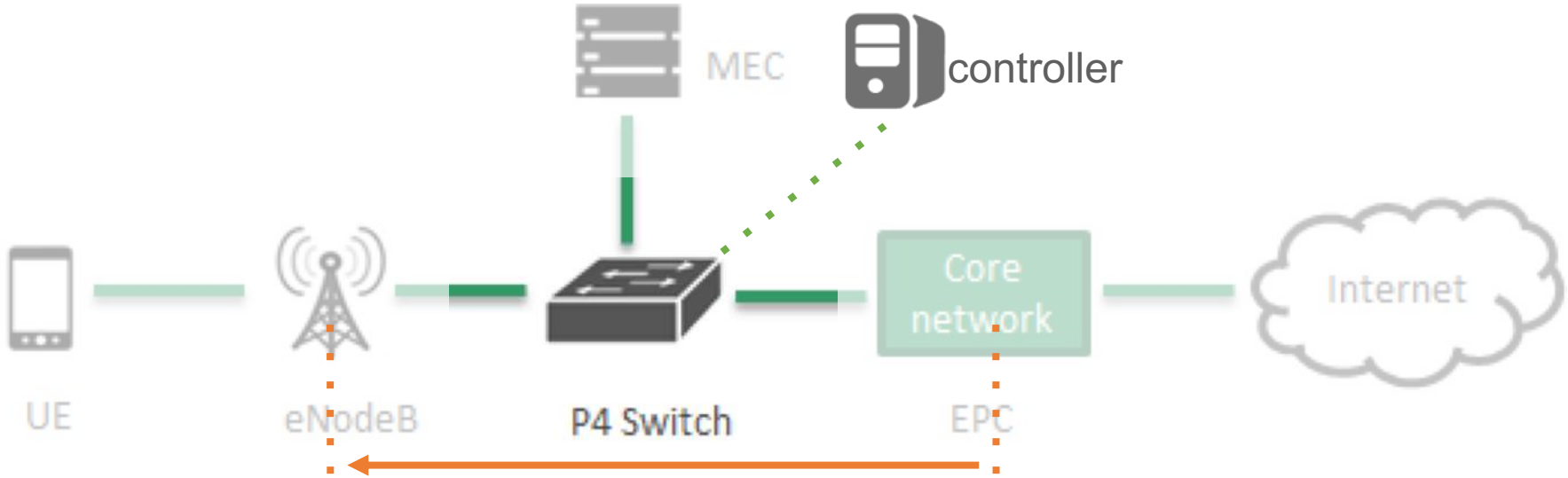
- Provide better packet I/O with P4 switch
- Reduce MEC loading from packet encapsulation and decapsulation
  - Two approaches
    - Packet-in downlink GTP-U packets
    - Packet-in SCTP packets
- Redirect DNS



Packet-in SCTP packets

Switch

Controller

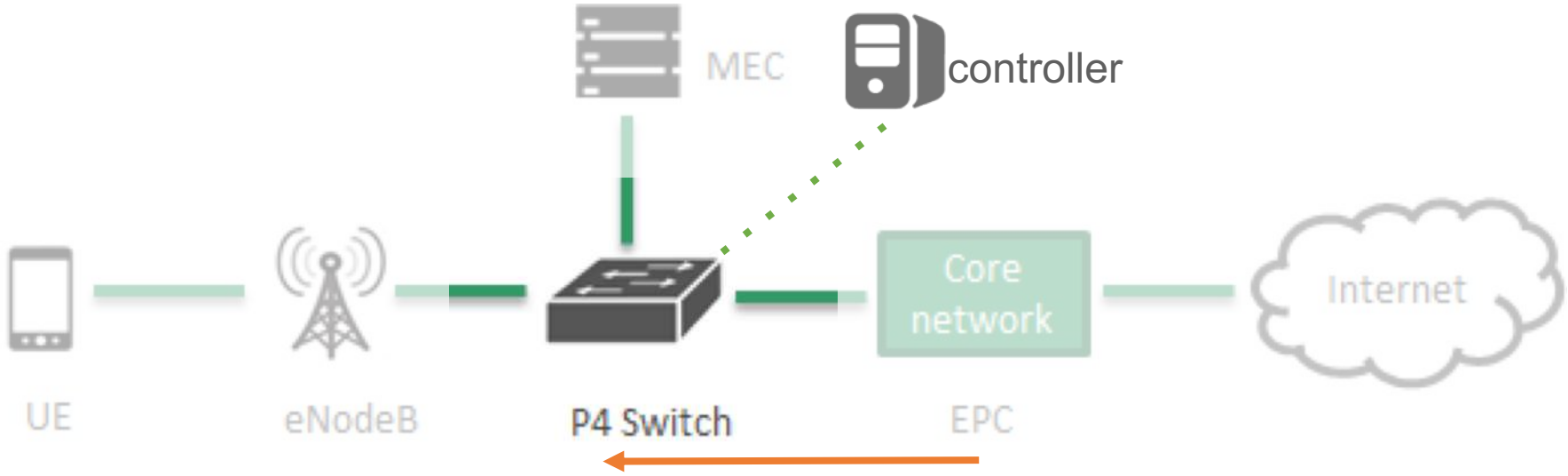


Packet-in SCTP packets (1/2)

Switch

Initial Context Setup Request
S1-AP
SCTP
IP
Ethernet

Controller



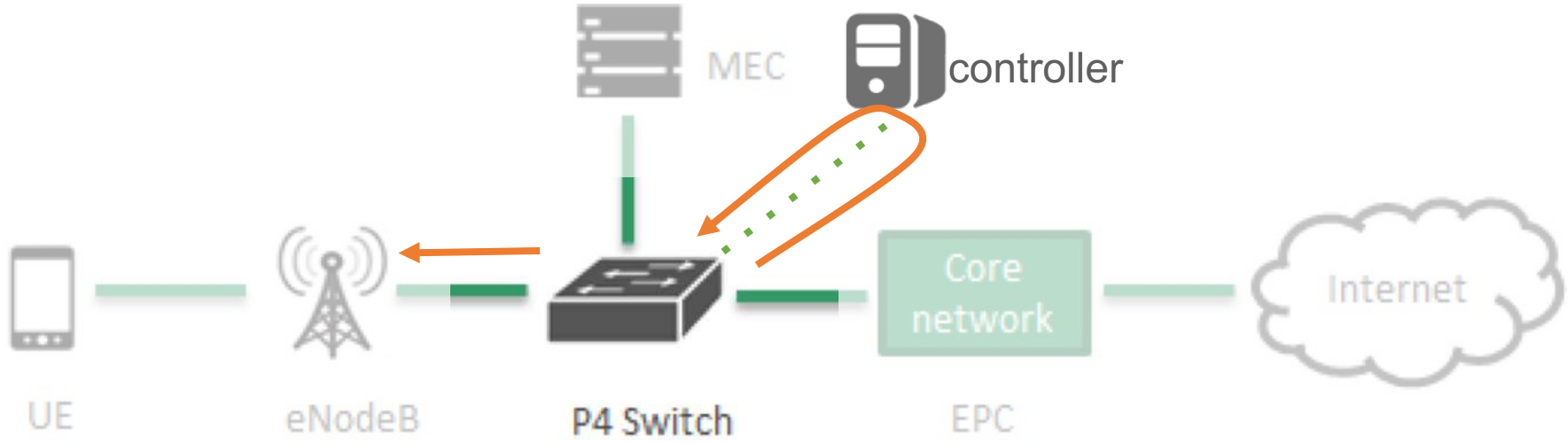
Packet-in SCTP packets (2/2)

Switch

Initial Context Setup Request
S1-AP
SCTP
IP
Ethernet

Controller

MME-UE-ID	SGW Addr.	ENB Addr.	DNS Addr.	UE Addr.	DL TEID	UL TEID
112233	10.0.9.2		8.8.8.8	192.168.3.2		1

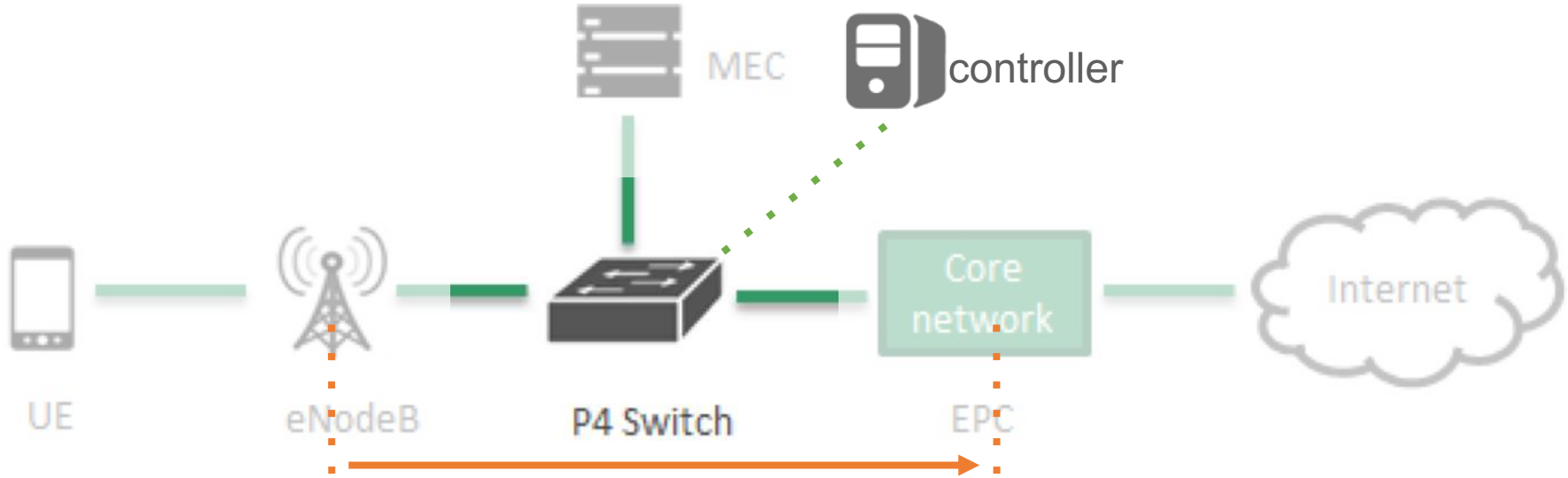


Packet-in SCTP packets

Switch

Controller

MME-UE-ID	SGW Addr.	ENB Addr.	DNS Addr.	UE Addr.	DL TEID	UL TEID
112233	10.0.9.2		8.8.8.8	192.168.3.2		1



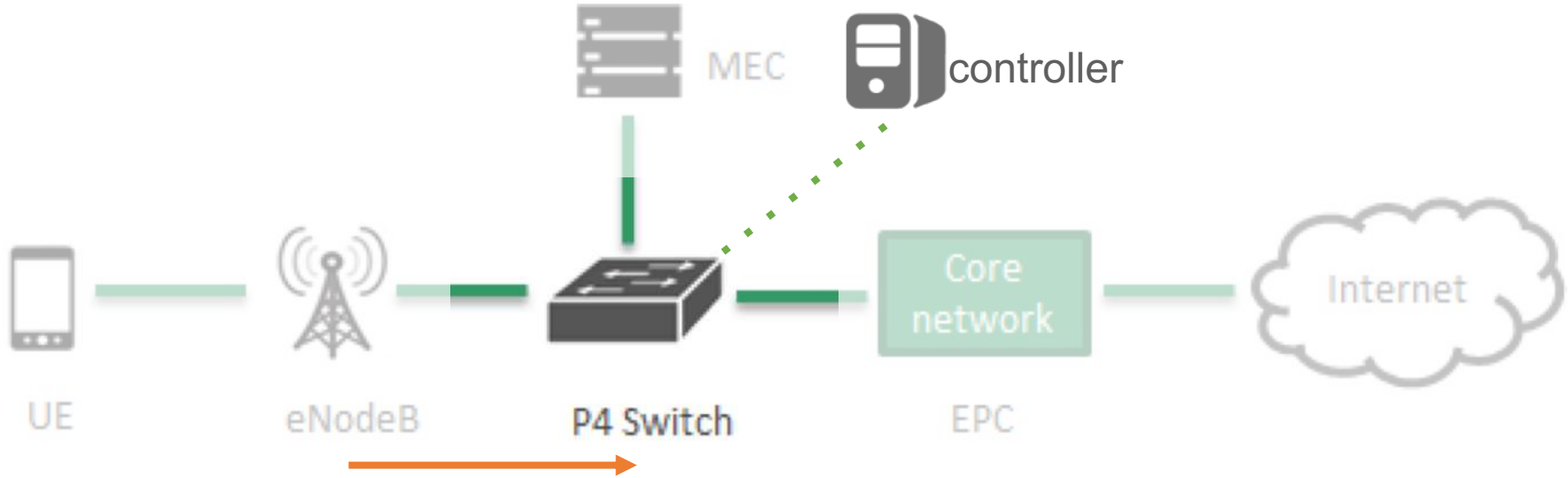
Packet-in SCTP packets (1/2)

Switch

Initial Context Setup Response
S1-AP
SCTP
IP
Ethernet

Controller

MME-UE-ID	SGW Addr.	ENB Addr.	DNS Addr.	UE Addr.	DL TEID	UL TEID
112233	10.0.9.2		8.8.8.8	192.168.3.2		1



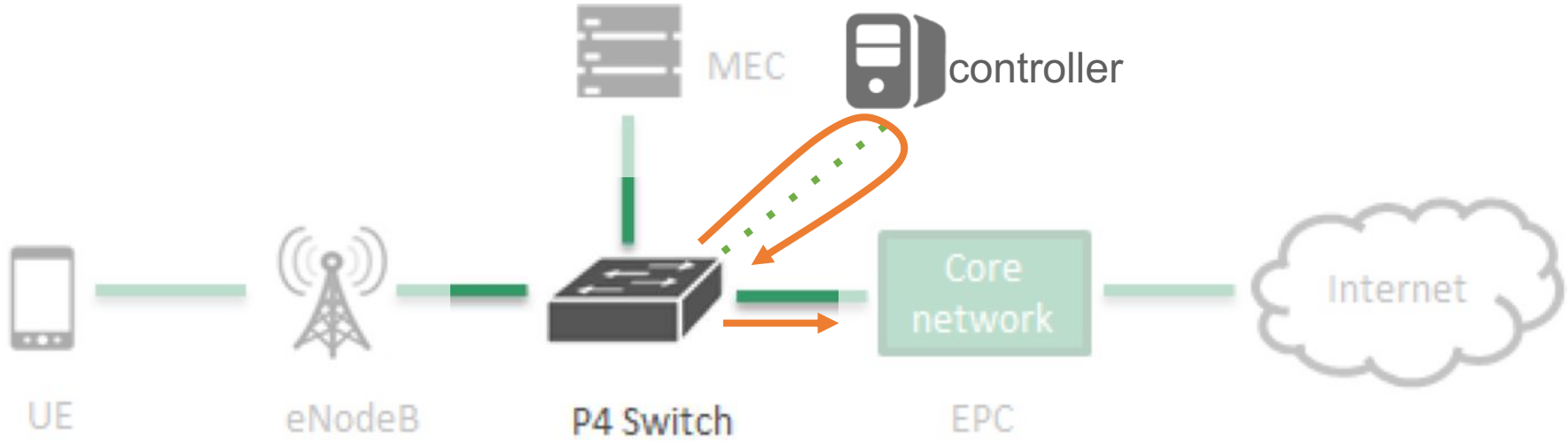
Packet-in SCTP packets (2/2)

Switch

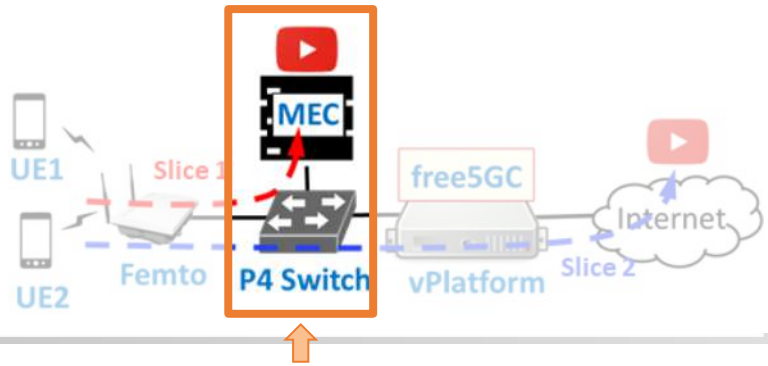
Initial Context Setup Response
S1-AP
SCTP
IP
Ethernet

Controller

MME-UE-ID	SGW Addr.	ENB Addr.	DNS Addr.	UE Addr.	DL TEID	UL TEID
112233	10.0.9.2	10.0.9.100	8.8.8.8	192.168.3.2	777	1



Outline



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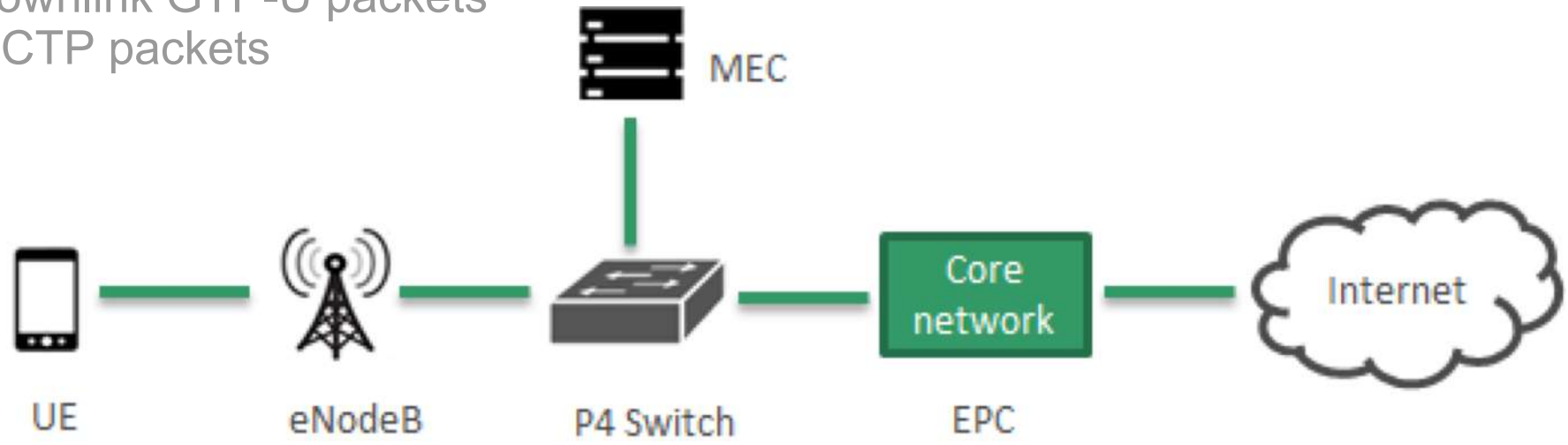
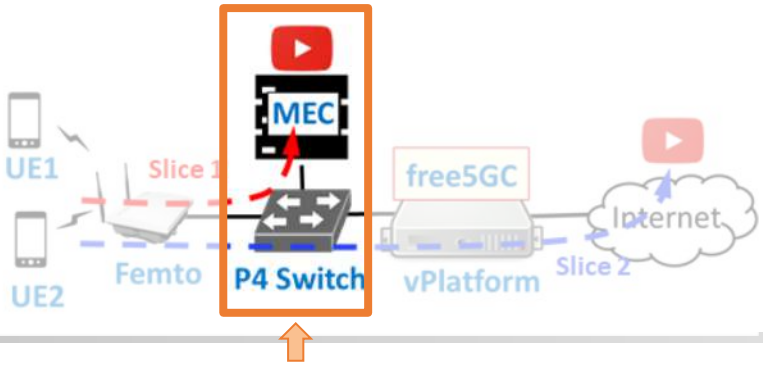
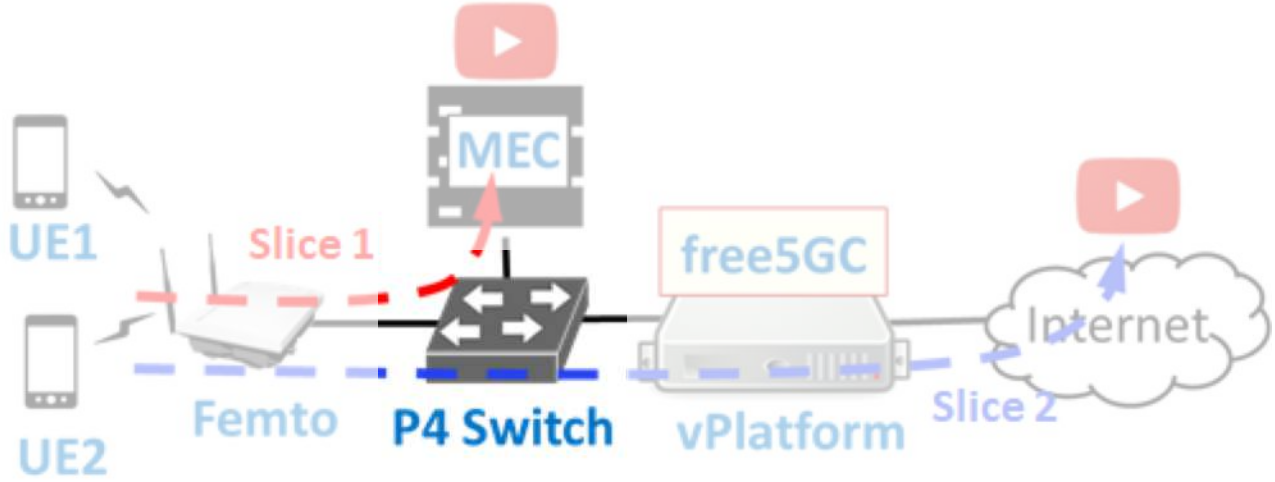


DNS traffic redirection



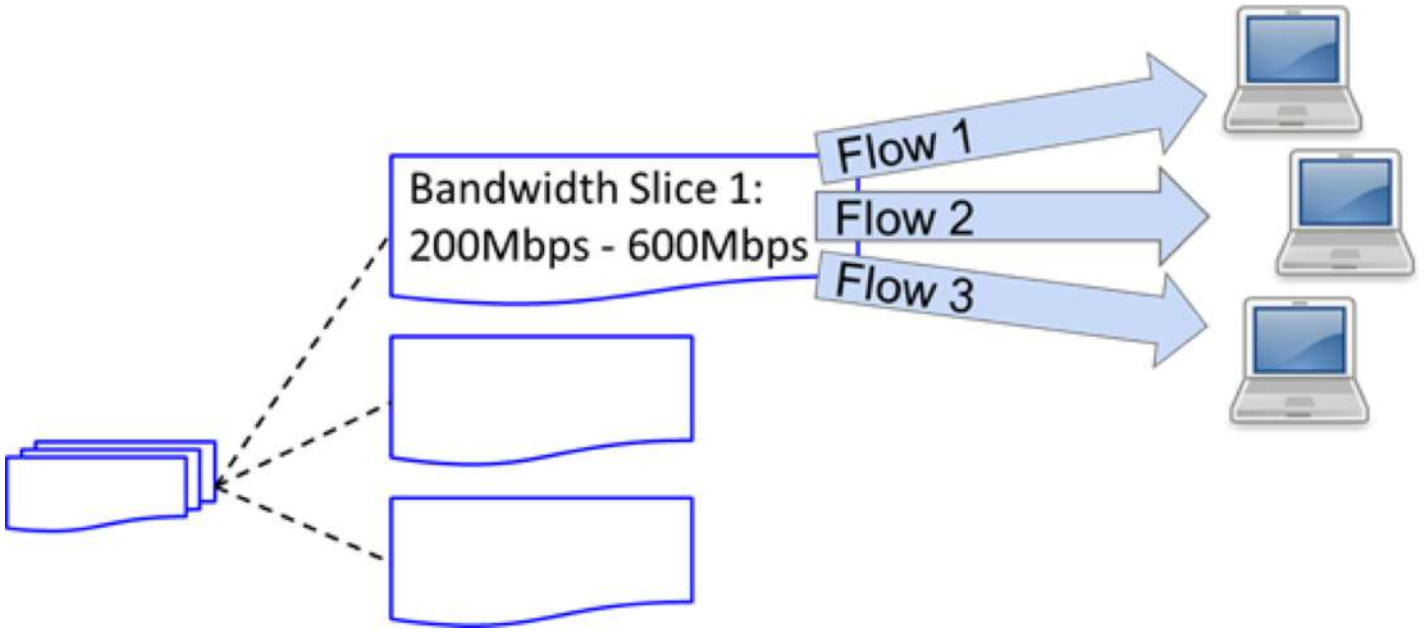
- UE sends DNS requests to ask for a specific service on the Internet
- Switch (P4) redirect the DNS query to MEC
  - Target service can be provided by MEC
    - Response the request by MEC address
  - Target service cannot be provided by MEC
    - Response the request by real service address
- UE send normal traffic to service



P4-enabled Network Slicing

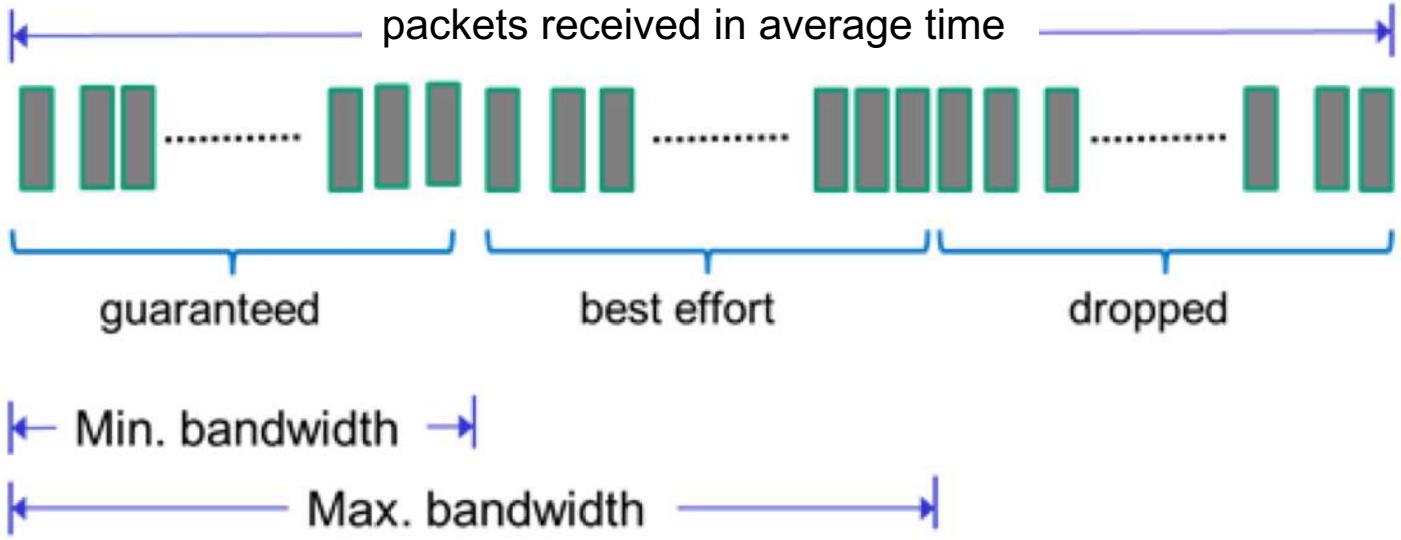
Design of Bandwidth Slice Management

- Bandwidth slice
  - Contain disjoint traffic flows identified from user-defined field
  - Reach isolation of bandwidth resources by priority forwarding
- Aggregated traffic flow in a slice will share the bandwidth resource



Policy of Bandwidth Management

- Sliced Traffic (aggregated traffic flows)
  - Guarantee minimum bandwidth
  - Best effort delivery without any guarantee
  - Limit maximum bandwidth

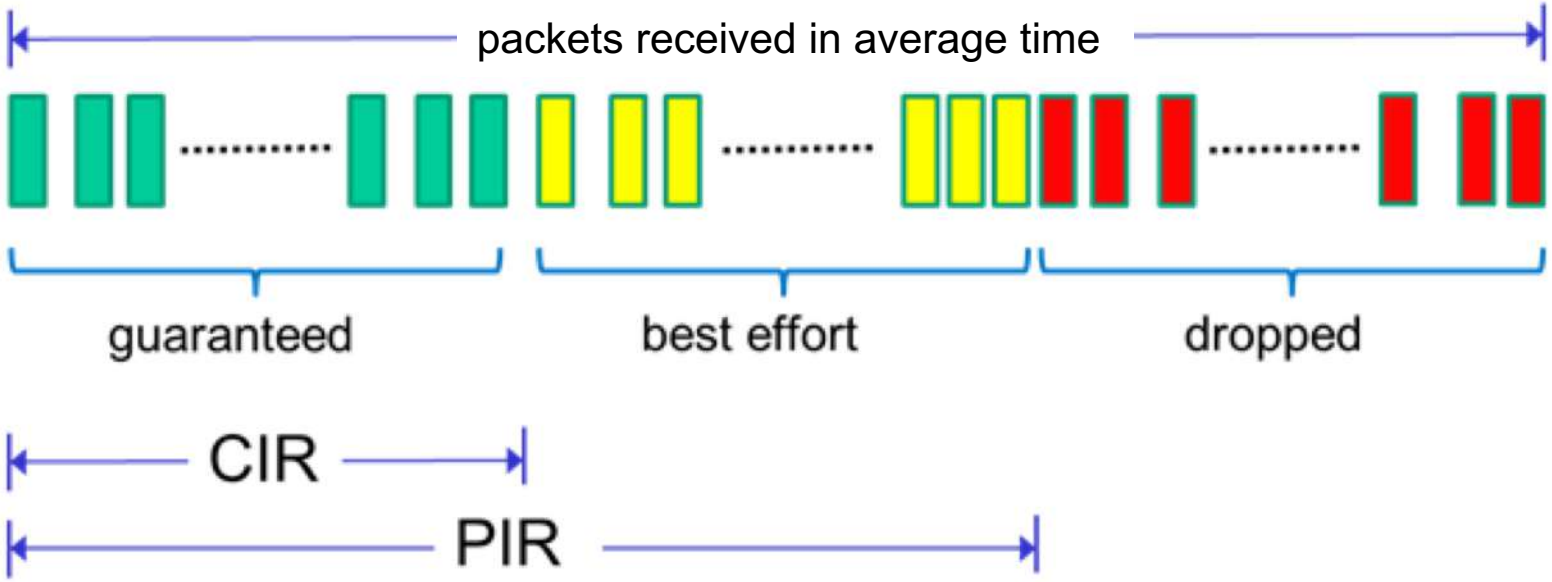


- Unspecified Traffic
  - Best effort delivery without any guarantee

Packet Classification

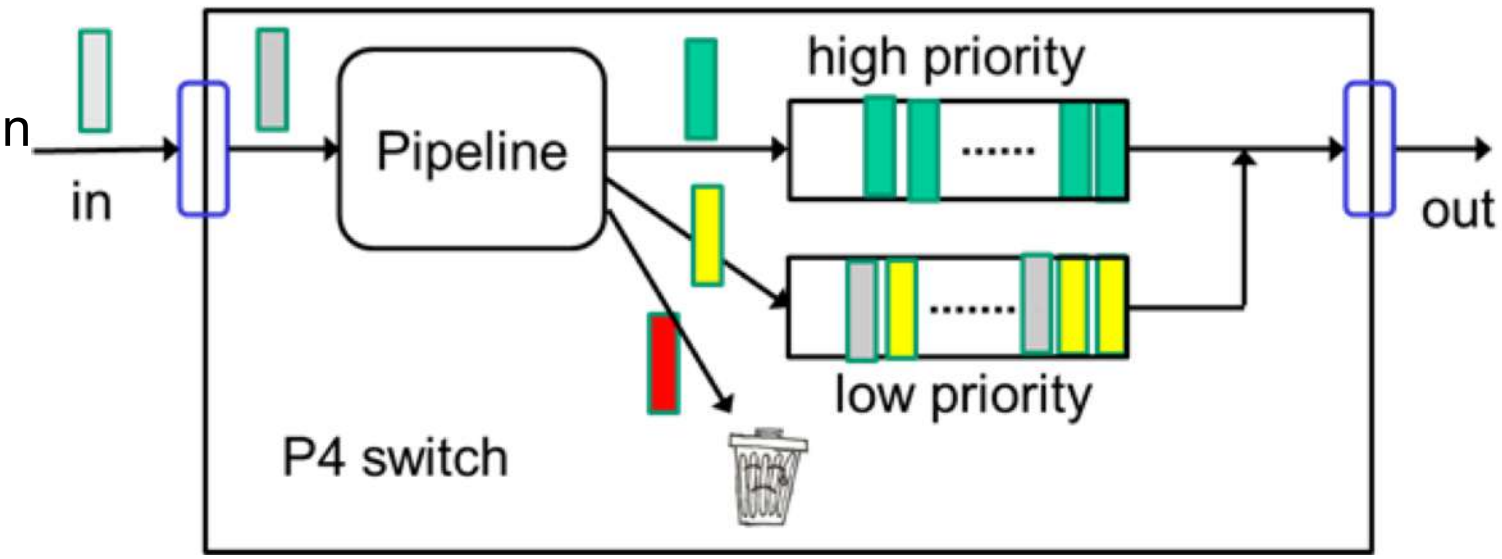
- P4 Meter with Two Rate Three Color Marker classification
  - minimum bandwidth: Committed Information Rate (CIR)
  - maximum bandwidth: Peak Information Rate (PIR)

- Color result
  - Green: Guarantee traffic
  - Yellow: Best Effort traffic
  - Red: Abandon traffic



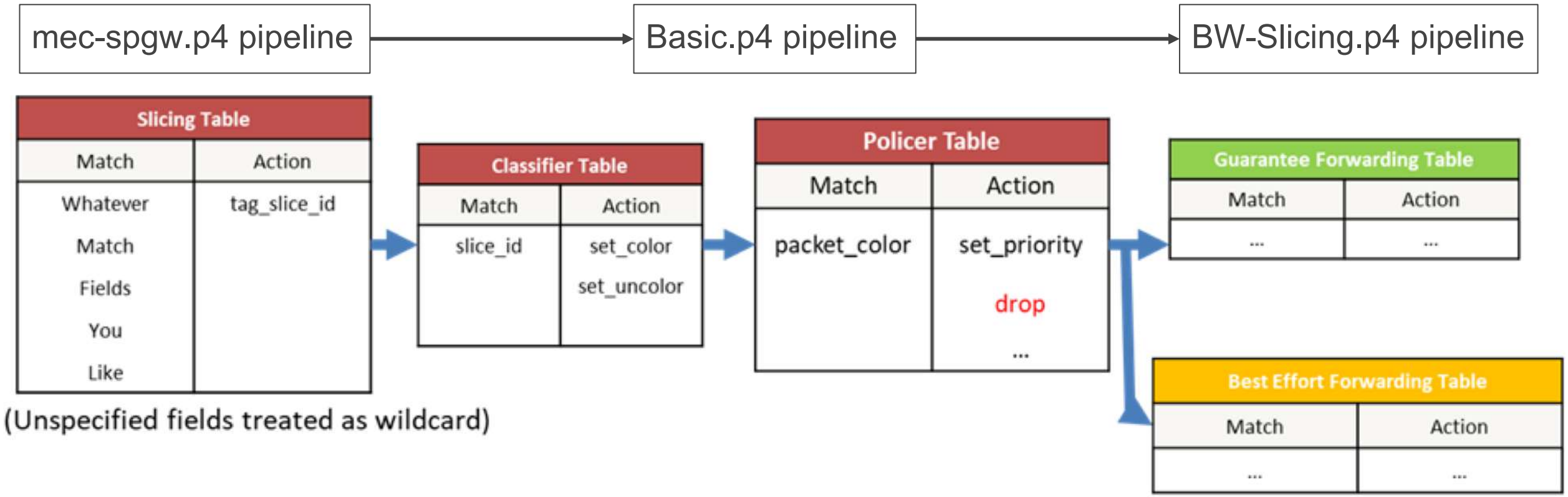
Priority Forwarding

- Guarantee traffic
  - Requested bandwidth cannot exceed link available bandwidth
- Best Effort traffic
  - Contain unspecified packets
  - Deliver by residual bandwidth
    - Maximize bandwidth utilization
- Abandon traffic



Implementation of BW-Slicing.p4

- Extension from ONOS Basic pipeline
  - Provides fundamental data-plane functionalities of the switch

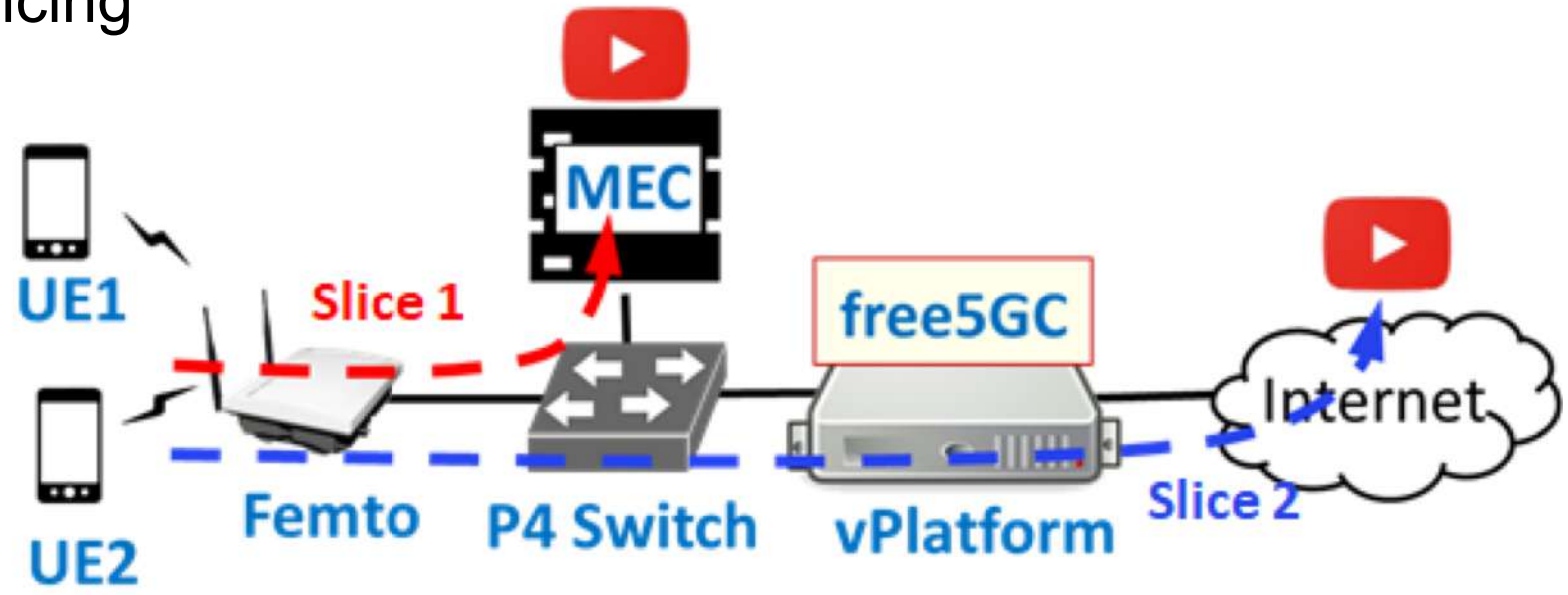


Conclusion

Conclusion

5G Mobile Platform with P4-enabled Network Slicing and MEC

- Compliant with ETSI MANO
- NCTU free5GC
- Loading Reduction in MEC with P4 Switch
- P4-enabled network slicing



Thank you.

Q & A

Packet-in downlink GTP-U packets

Payload
TCP/UDP
IP
Ethernet

GTP-U(**TEID=XXX**)
UDP
IP
Ethernet

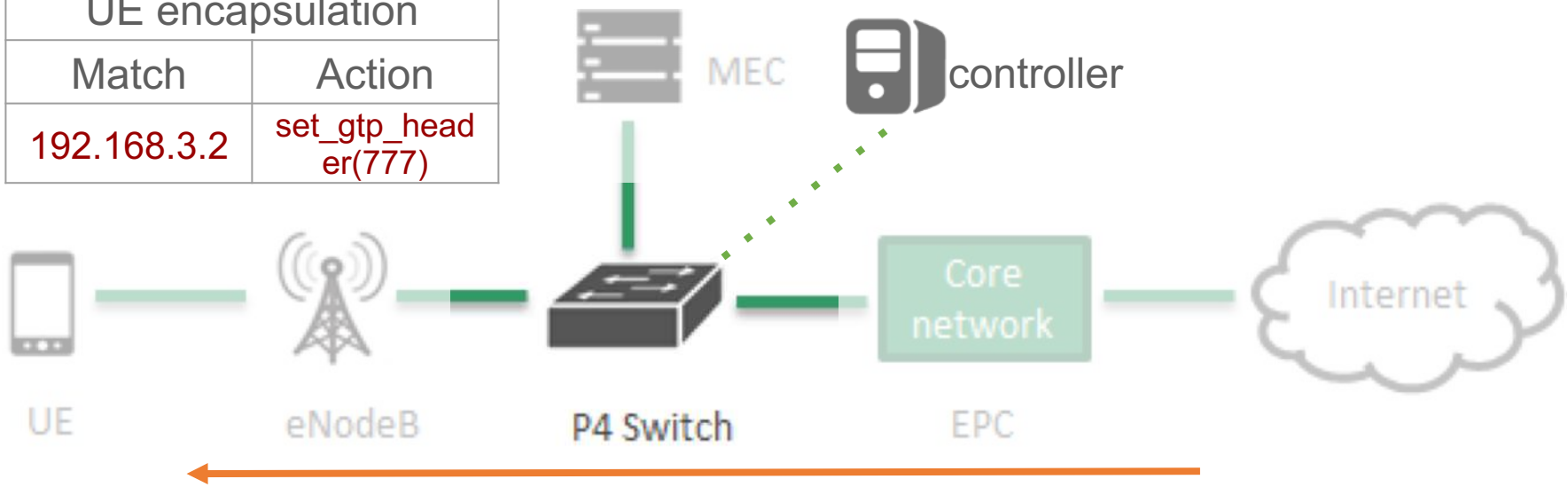
Switch

UE session state	
Match	Action
192.168.3.2	NoAction

UE encapsulation	
Match	Action
192.168.3.2	set_gtp_header(777)

Controller

UE Addr.	DL TEID
192.168.3.2	777



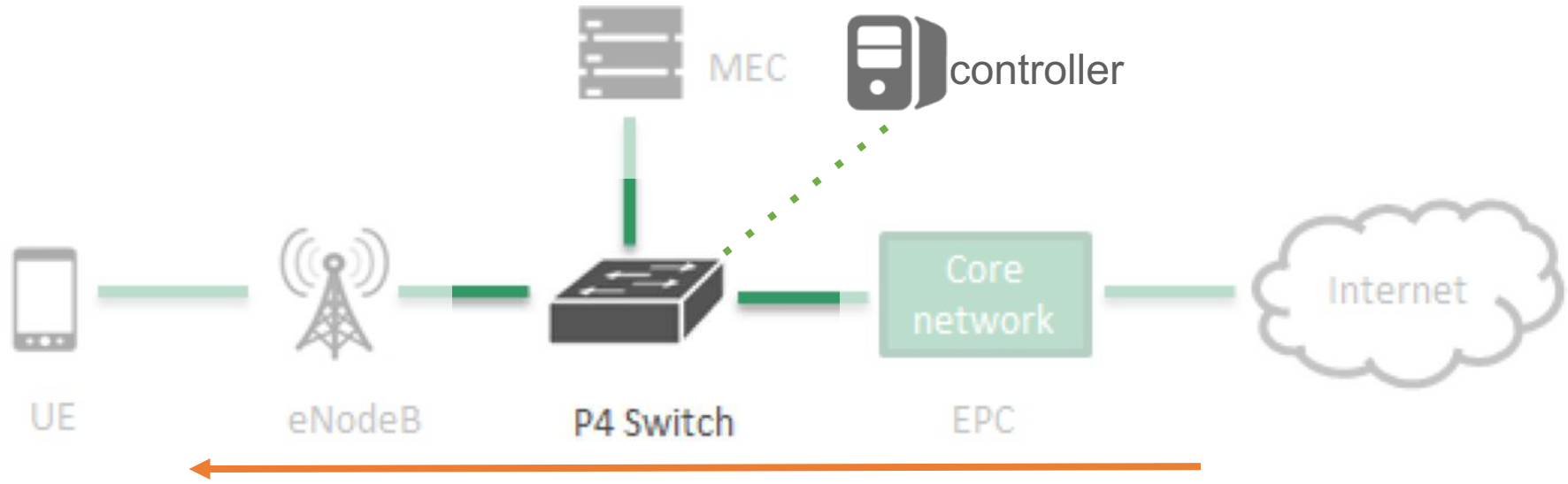
Packet-in SCTP packets

Switch

Initial Context Setup Response
S1-AP
SCTP
IP
Ethernet

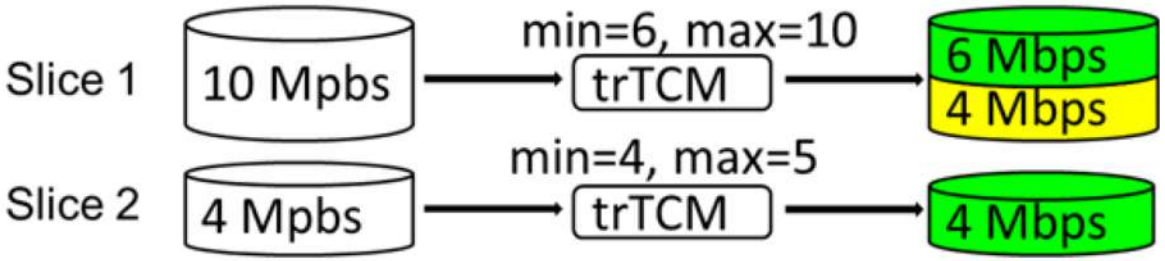
Controller

MME-UE-ID	SGW Addr.	ENB Addr.	DNS Addr.	UE Addr.	DL TEID	UL TEID
112233	10.0.9.2	10.0.9.100	8.8.8.8	192.168.3.2	777	1

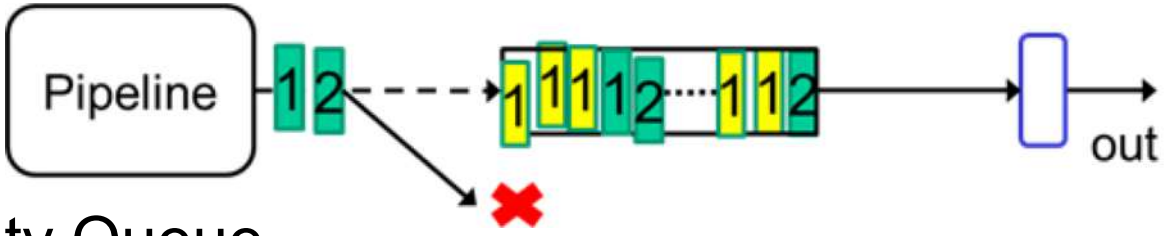


Priority Forwarding - Two-Level Priority Queue

- For example:



- Single Queue: Best effort packet interference



- Two-Level Priority Queue