

# Edge Computing in OAI 5G Core Network

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# About Me

- Intern in OSA since March 2022
- Student at TUW (Vienna) and Eurecom
- Computer Science and Software Engineering
  
- Master thesis title:
- Robotics and Edge Computing in 5G: A Prototype for the OAI 5G System

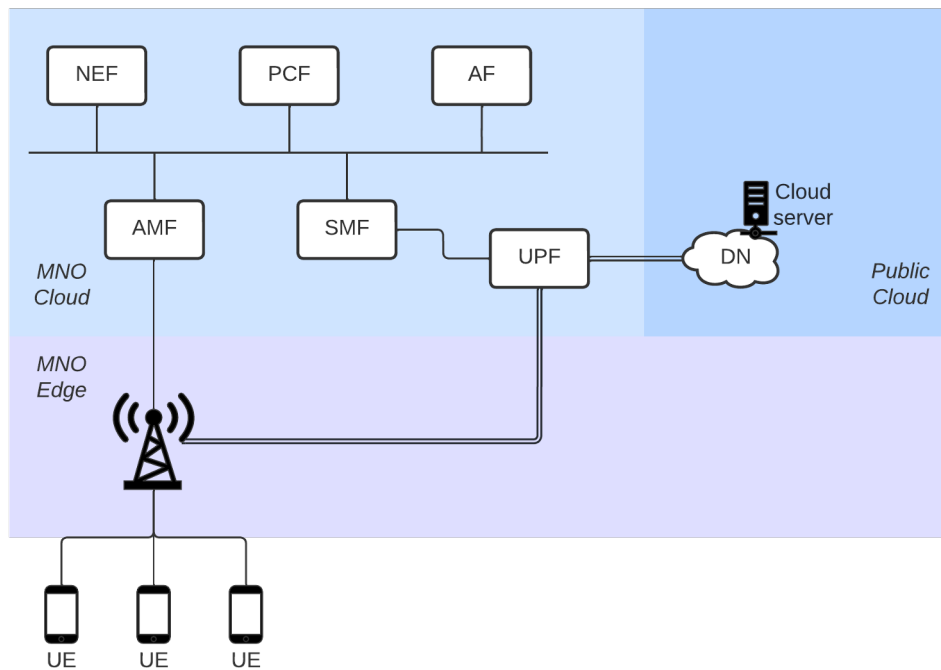
# About Edge Computing

- Move storage and computation closer to the user
  - Apply principles of cloud computing
  - Critical requirement for low latency applications (URLLC)
  - Enables many applications and services
- 
- In summary:
    - Advantage of cloud computing + Advantage of local computing
    - Move some control back into operator domain

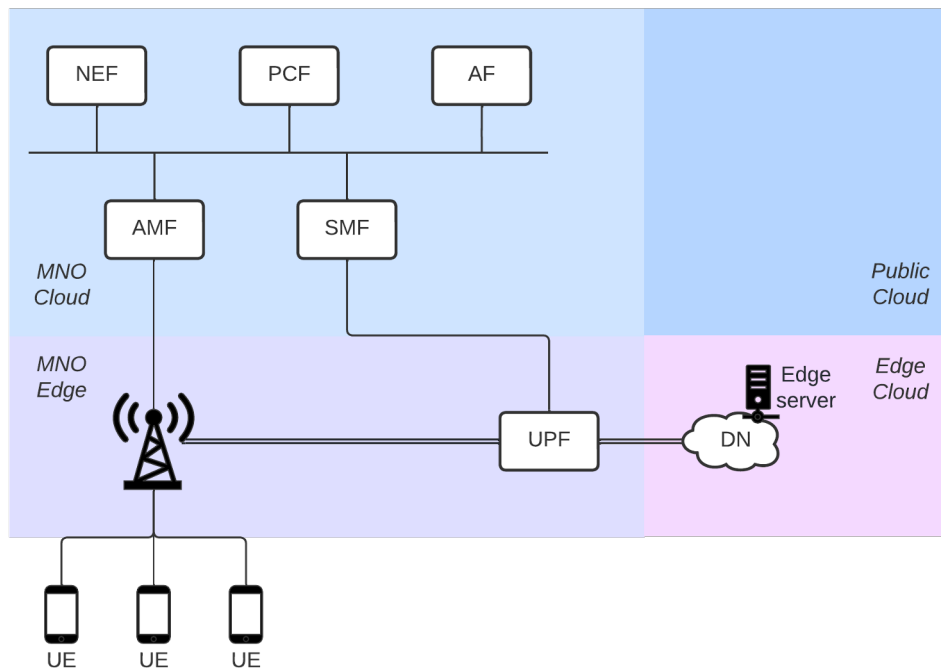
# Edge Computing Architectures

- ETSI MEC and 3GPP EDGEAPP (R17)
  - Handle orchestration, VM startup and shutdown
  - Utilizes Virtualization Infrastructure (e.g. NFVI)
  - Edge Application discovery
  - Edge Application mobility and relocation
  - Instruments 4G/5G system to handle traffic accordingly
- 
- Ultimate goal from CN perspective: “Bring traffic close to user”

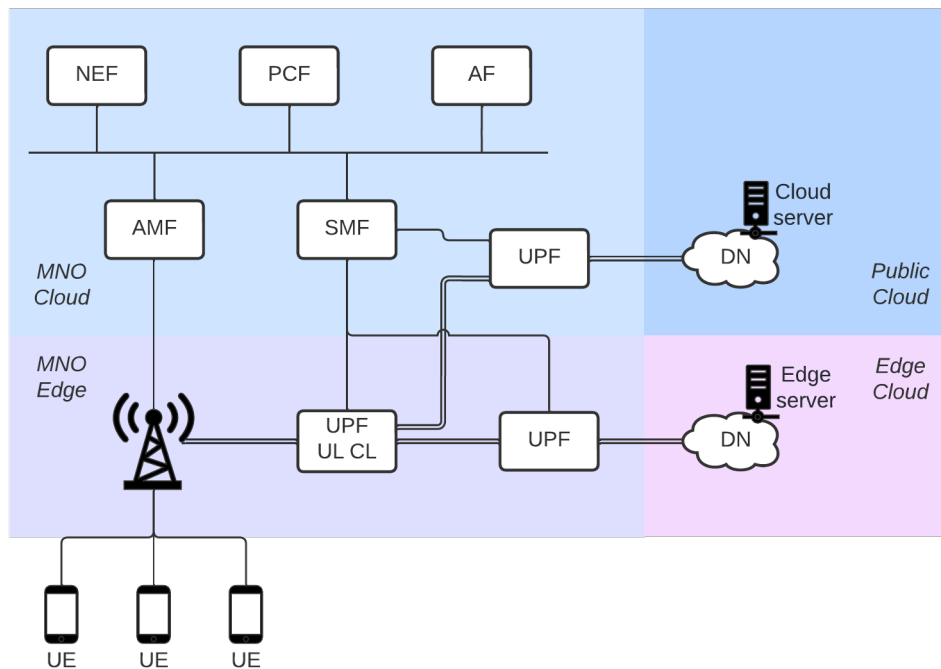
# Centralized UPF



# Edge-only UPF



# Central and Edge UPF



# Edge Computing from OAI CN Perspective

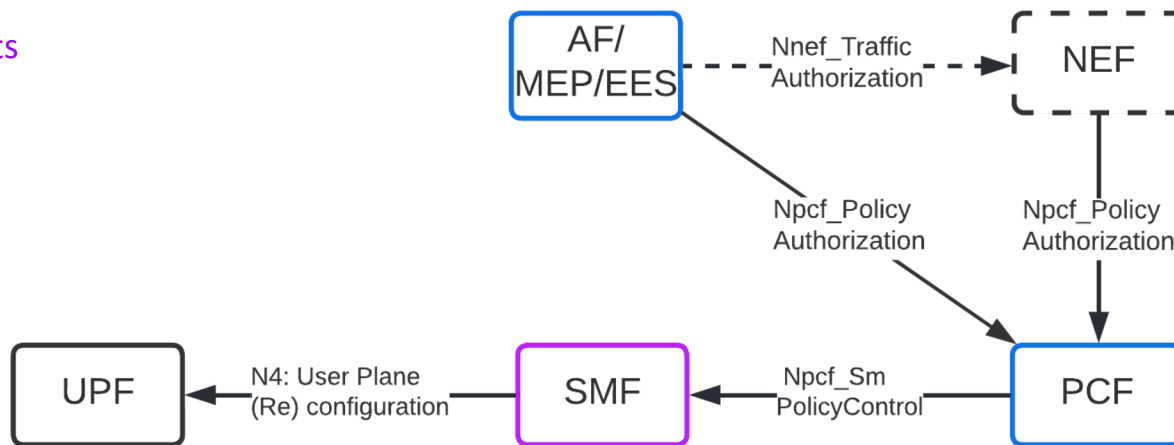
- Need to provide a way to dynamically configure UP scenarios
- Dynamic UPF selection
- Allow user / operator flexibility in configuration
- Procedures at MEC Layer / AF out of scope
- Need to interface with AF
- Standard-compliance

# CN Architecture - Interfaces

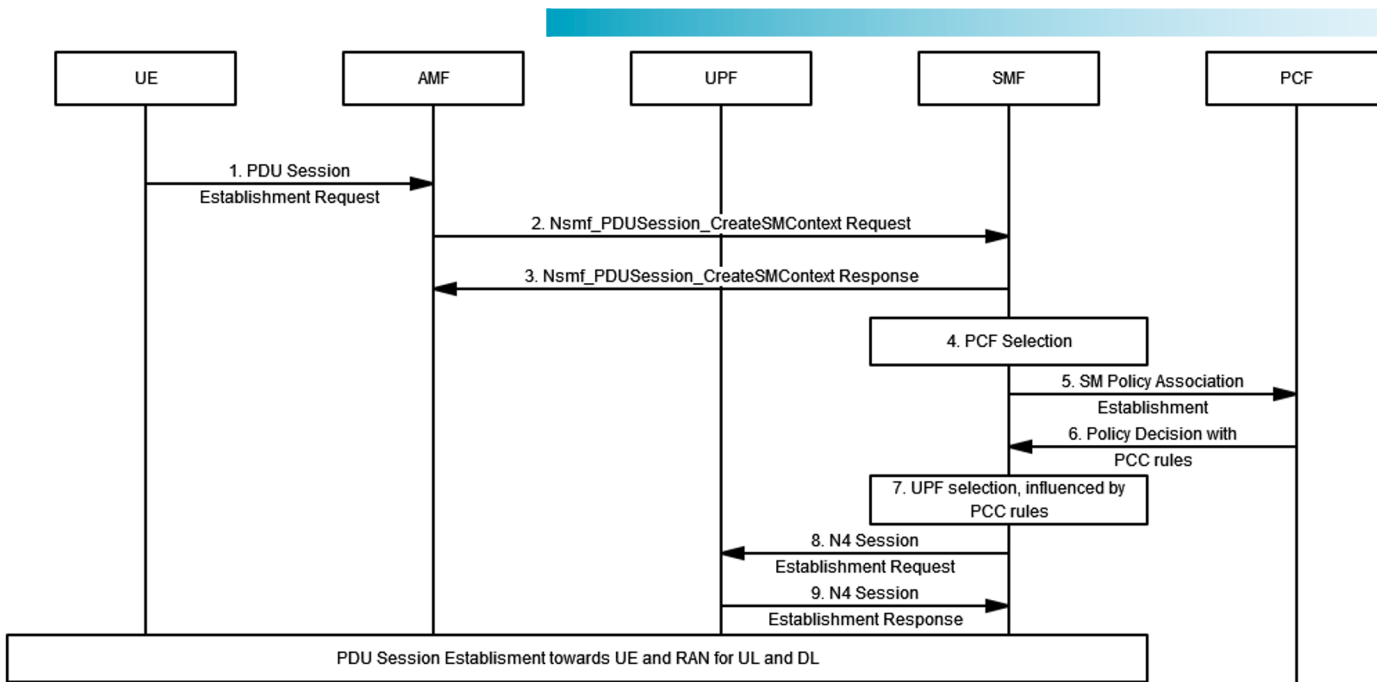
## Changes in OAI CN

New NF

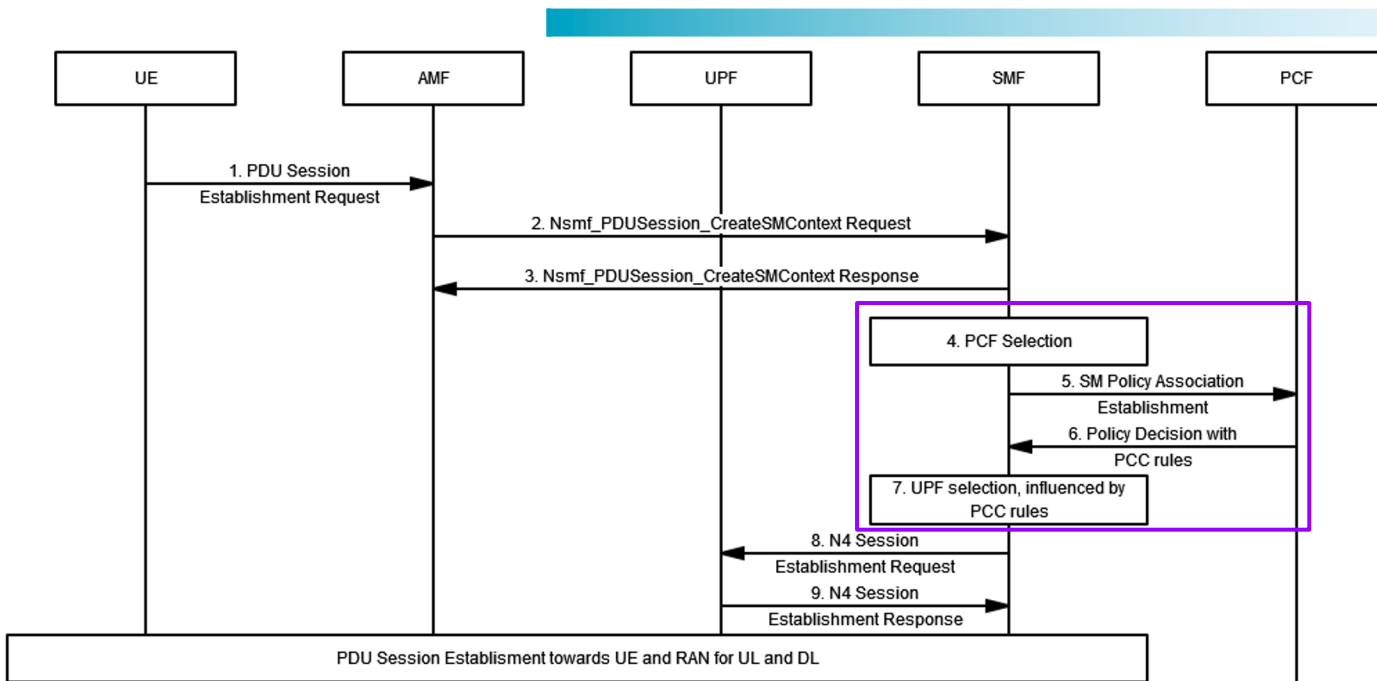
Enhancements



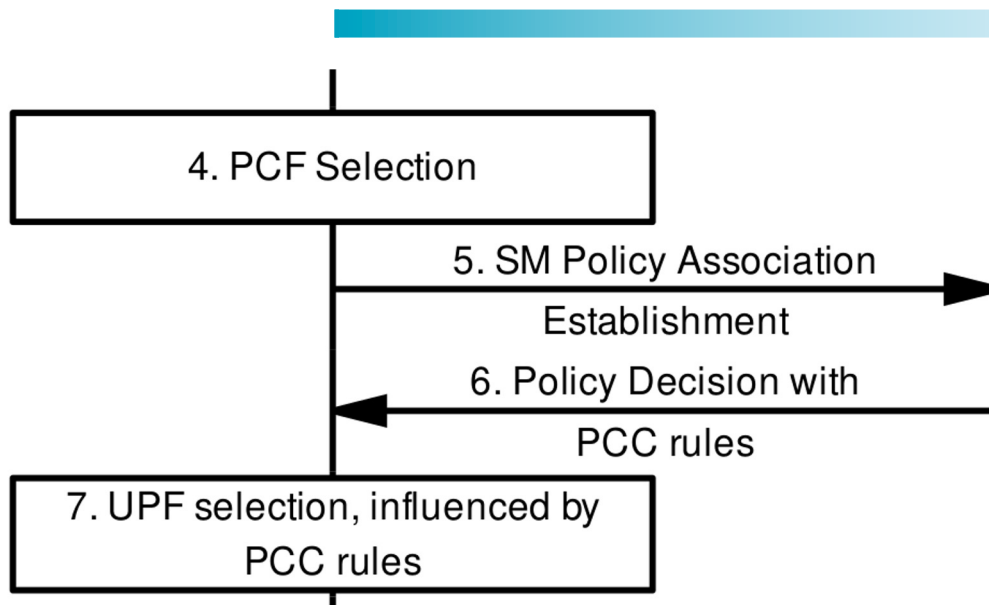
# Call Flow - Session Establishment



# Call Flow - Session Establishment



# Call Flow - Session Establishment



# Policy Control Function (PCF)

- Provides policies for SMF on how traffic shall be routed
- Also used for other functionality (e.g QoS)
  
- Policies are described in PCC rules
- SMF uses content of the rules for UPF selection and traffic steering
- Policy decision based on SUPI, DNN, Slice, Cell-ID, etc...

# PCC Rules

- Allows to define how to identify traffic (e.g. flow description)
- And what should be done with this flow
  
- Not used for defining UPF architecture, but very high level
- Needs pre-arrangement between SMF and PCF

# PCC Rules

- Allows to define how to identify traffic (e.g. flow description)
- And what should be done with this flow
  
- Not used for defining UPF architecture, but very high level
- Needs pre-arrangement between SMF and PCF
  
- Either global steering policy per PCC rule
- Or steering policy per DNAI -> many steering policies per PCC rule
- DNAI = Data Network Access Identifier

# SMF UPF Selection Options

- Based on PCC rules there are different possibilities
- Option 1: Pre-configure UPF architecture in SMF
- Option 2: Use dynamic UPF selection based on NRF UPF Info

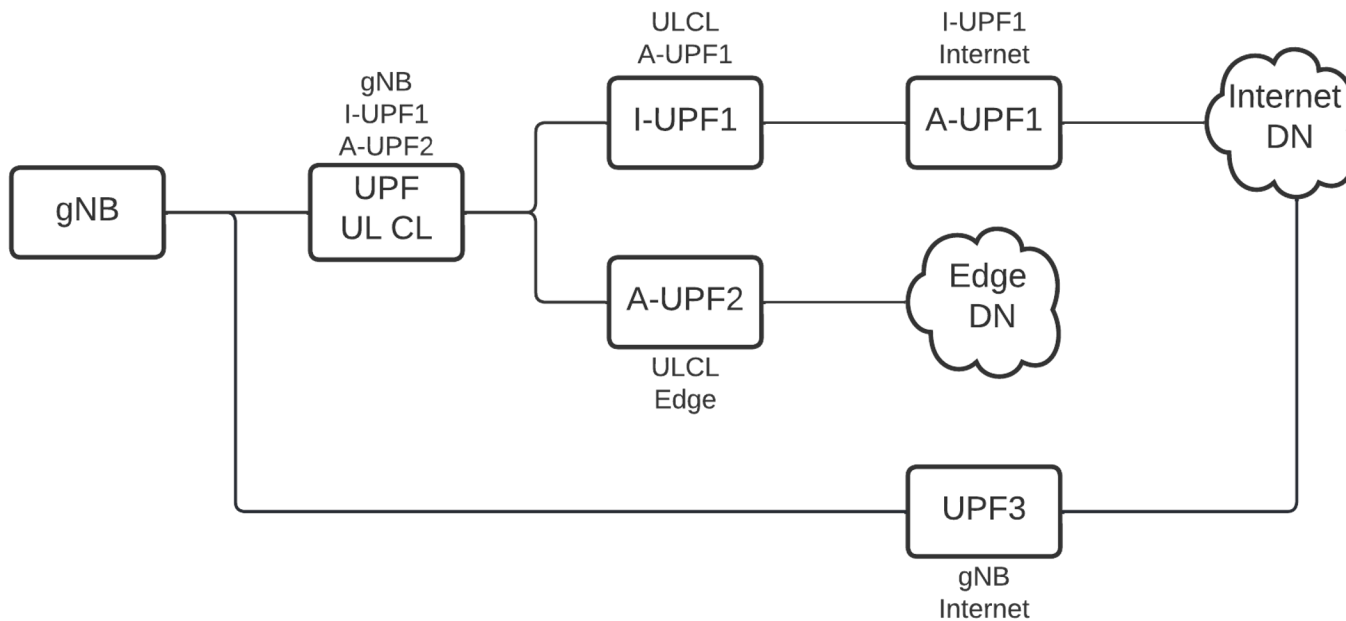
# Option 1 (static)

- PCC rules contain only one global steering policy or steering policy per DNAI
  - SMF has next-hop configuration with interface information locally configured
- 
- + Very simple solution
  - + Easy to configure, no dependencies
- 
- Configuration file may be very complicated for some scenarios
  - Not flexible (not really cloud native)

# Option 2 (our solution)

- Each UPF has a globally unique DNAI associated
  - PCF sends a list of all DNAIs that need to be in the flow
  - SMF uses UPF info from NRF to select UPFs that serve these DNAIs
- 
- + Very dynamic solution
  - + Cloud native, considers UPFs that spawned after SMF
- 
- Requires a NRF, more interactions
  - High programming effort

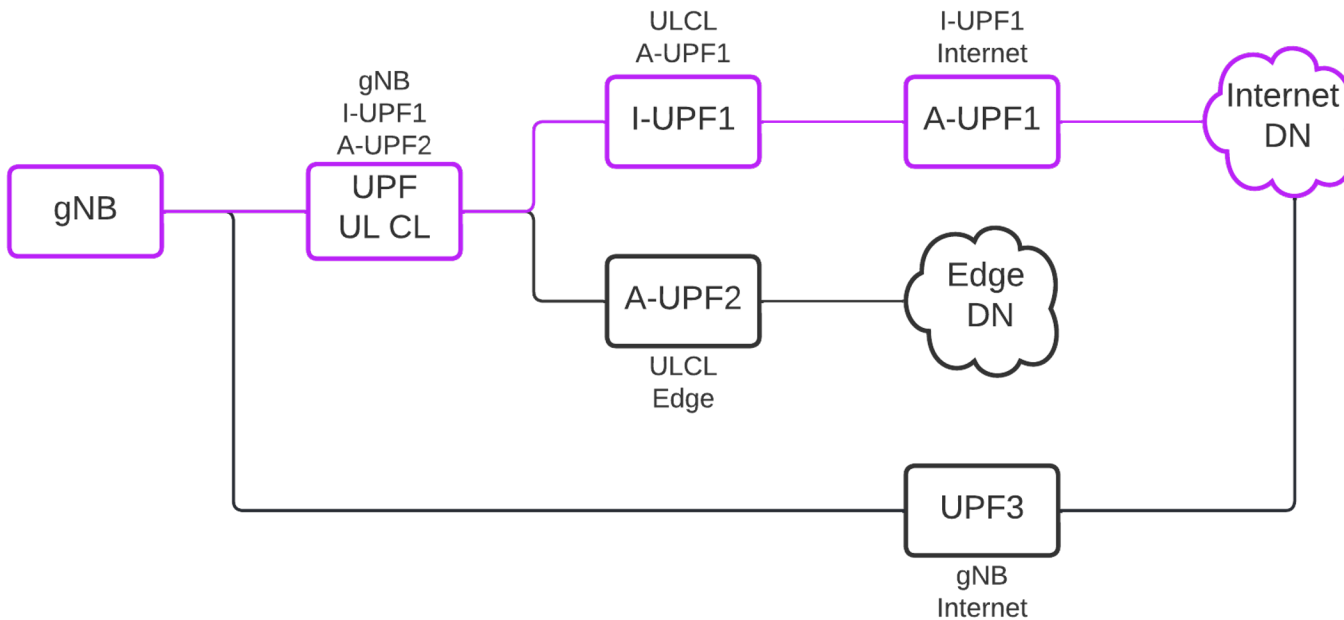
# Option 2 Example



# Option 2 Example

## PCC DNAI List

- gNB
- ULCL
- I-UPF1
- A-UPF1
- Internet



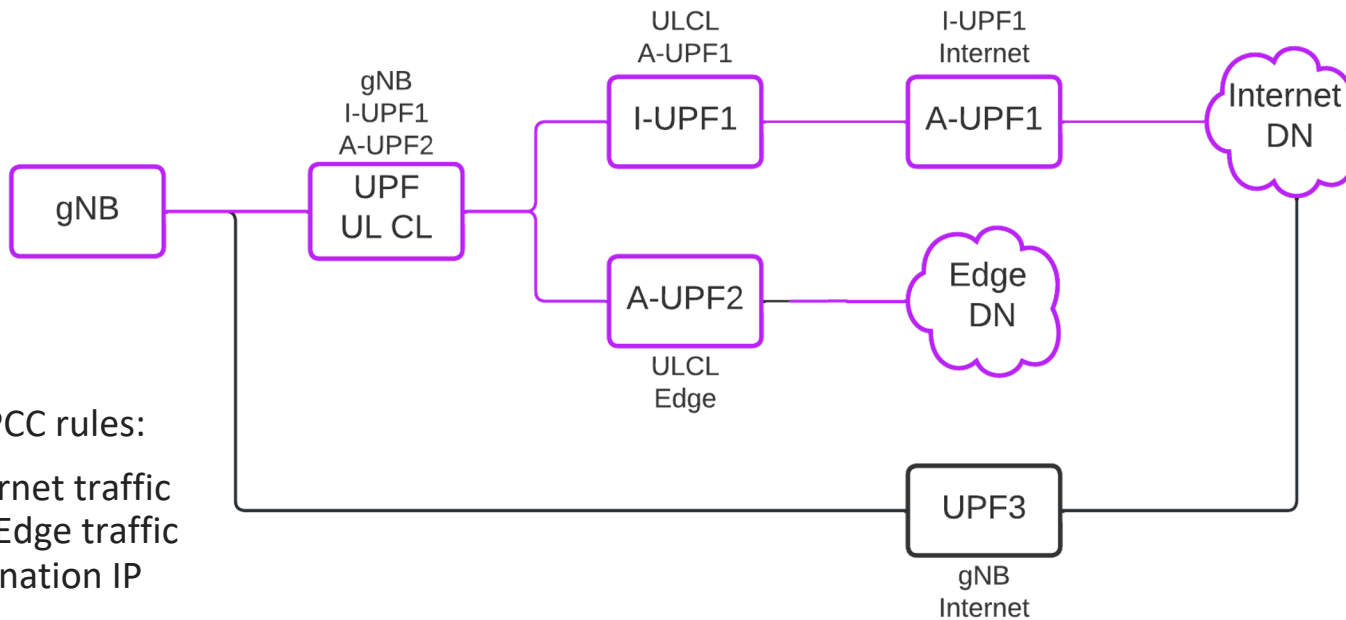
# Option 2 Example

## PCC DNAI List

- gNB
- ULCL
- I-UPF1
- A-UPF1
- Internet
- A-UPF2
- Edge

We need two PCC rules:

- Top: Internet traffic
- Bottom: Edge traffic  
e.g. destination IP



# Configuration at the UPF

- All next hop interfaces configured
- FQDN of next hop must match with the FQDN of that UPF
  
- All DNAs configured for the next hops
- Mapping between DNAI and Network Instance (R16.8 feature\*)
- Register its user profile to NRF

\* see 3GPP TS 29.510 Chapter 6.1.6.2.15

# Configuration at the AF/PCF

- Create a policy decision (e.g. for specific UE)
- Must contain DNAs for all UPFs which need to be contained
  
- Optional (not yet covered)
  - Define a mapping between DNAI configurations and cell-id / TAC
  - To have real edge computing: Always select closest UPF
  - Requires PCF to receive events on UE location
  - May also be done in AF

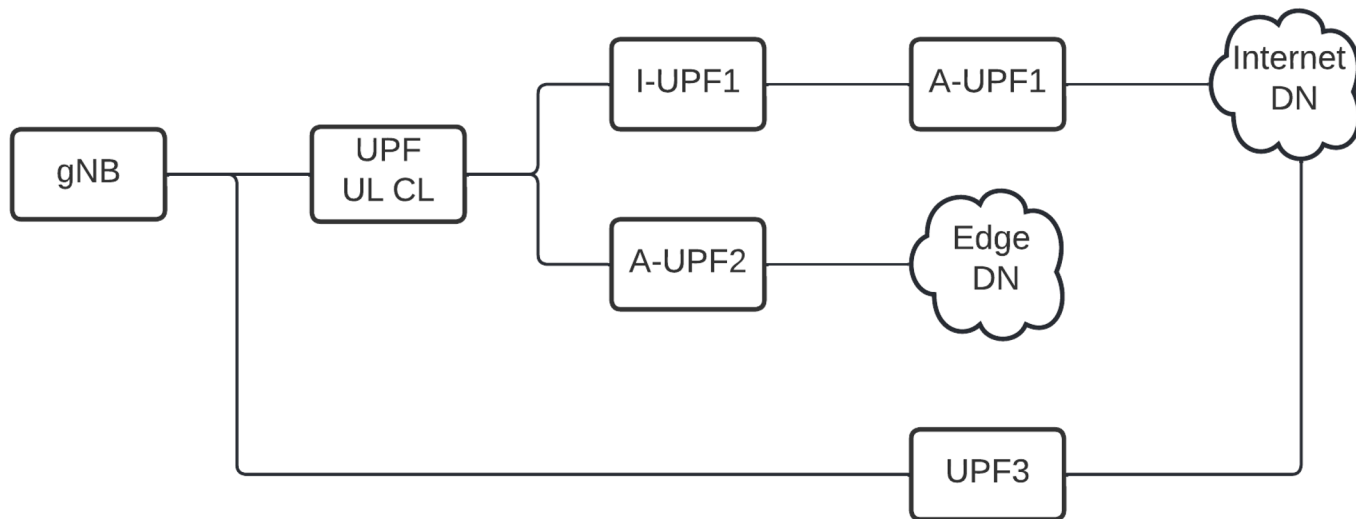
# Configuration at the SMF

- SMF subscribes for UPF information to NRF
- SMF creates policy association towards PCF
- Otherwise, no special configuration needed
  
- Configure what to do when UPF path could not be found:
  - Reject PDU session establishment
  - Or use any available UPF

# Implementation Details in SMF

- UPFs are represented as graph
- Graph edge when FQDN/IP addresses match
- Three phases
  - Phase 1: PFCP association -> Build global graph
  - Phase 2: PDU session -> Select sub-graph based on DNAs
  - Phase 3: Create PFCP Session for all UPFs in sub-graph

# Example Reminder



# Phase 1: UPF3

## UPF

FQDN: upf3.oai.org

Next Hops:

- gNB
- Internet DN

Empty graph, just insert



UPF3

# Phase 1: A-UPF1

## UPF

FQDN: aupf1.oai.org

Next Hops:

- I-UPF1
- Internet DN

A-UPF1

No connection, insert node

UPF3

# Phase 1: I-UPF1

## UPF

FQDN: iupf1.oai.org

Next Hops:

- **A-UPF1**
- ULCL

Edge between I-UPF1 and A-UPF1



# Phase 1: A-UPF2

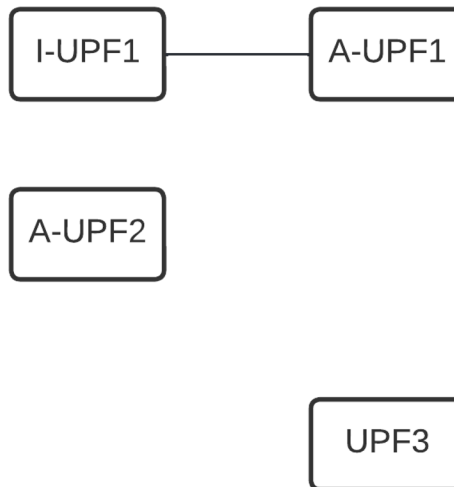
## UPF

FQDN: aupf2.oai.org

Next Hops:

- ULCL
- Edge DN

No connection, insert node



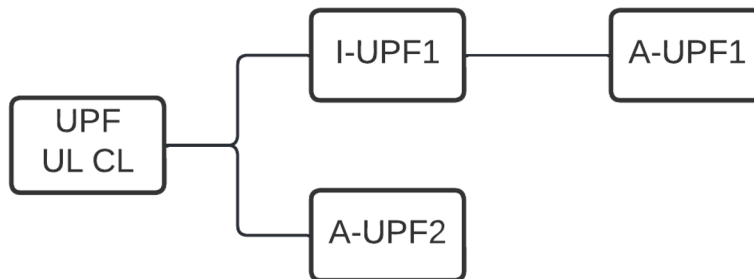
# Phase 1: UL CL UPF

## UPF

FQDN: ulcl.oai.org

Next Hops:

- gNB
- **I-UPF1**
- **A-UPF2**



Edge between ULCL and I-UPF1

Edge between ULCL and A-UPF2



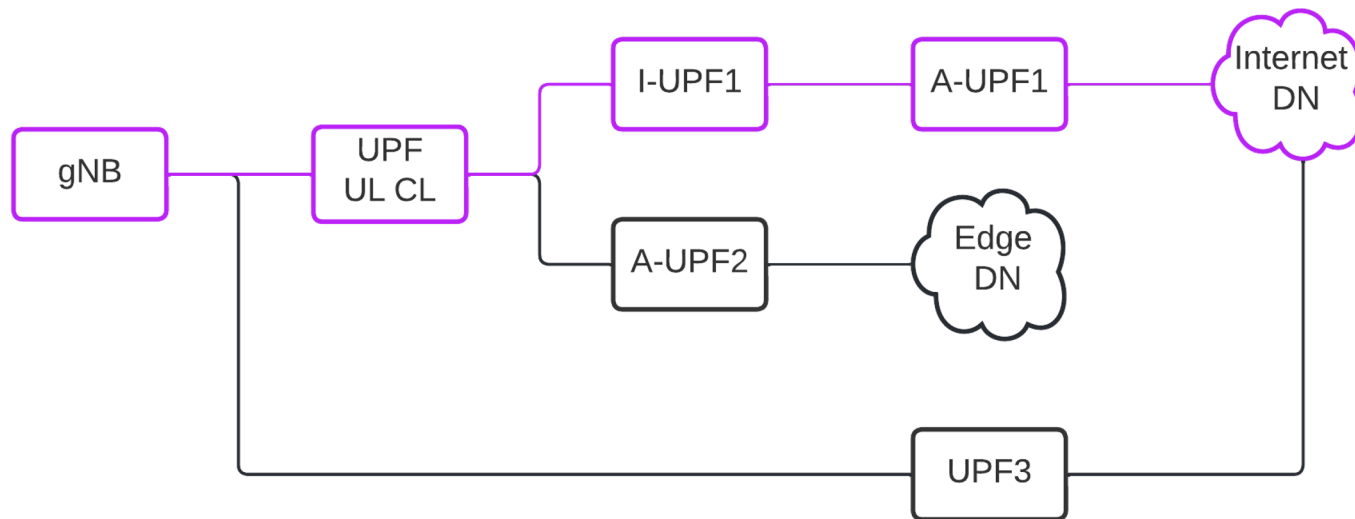
# Phase 2: PDU Session Establishment

- We already have a graph with all the available UPFs
  - Now, we need to find a path
  - Depth-First Search Algorithm
- 
- Runtime is in  $O(V + E)$  -> linear time complexity
  - $V$  = Number of UPFs
  - $E$  = Number of edges between UPFs
  - Fully connected graph:  $E = V-1 \Rightarrow O(2V)$  -> still linear

# Phase 2: Desired Path

## PCC DNAI List

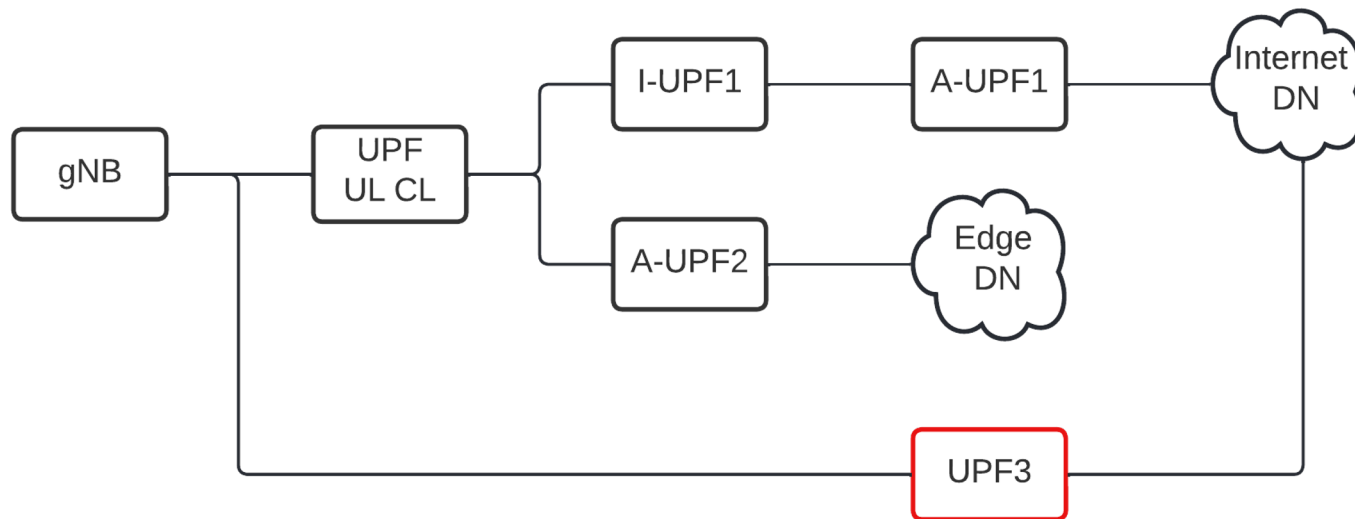
- gNB
- ULCL
- I-UPF1
- A-UPF1
- Internet



# Phase 2: UPF3

## PCC DNAI List

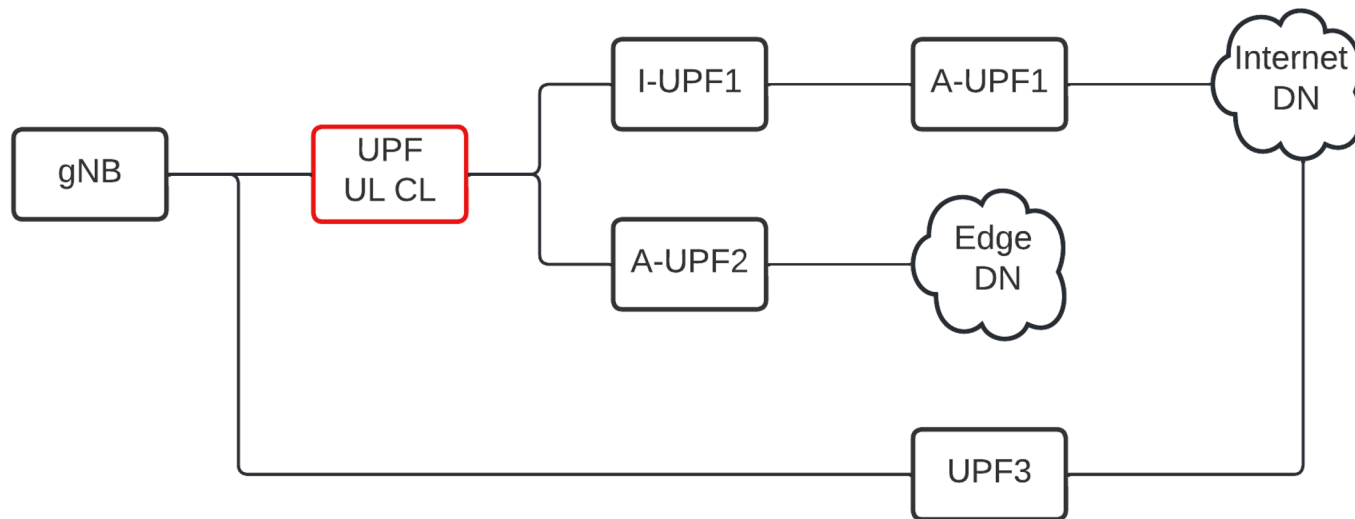
- gNB
- ULCL
- I-UPF1
- A-UPF1
- Internet



# Phase 2: UL CL

## PCC DNAI List

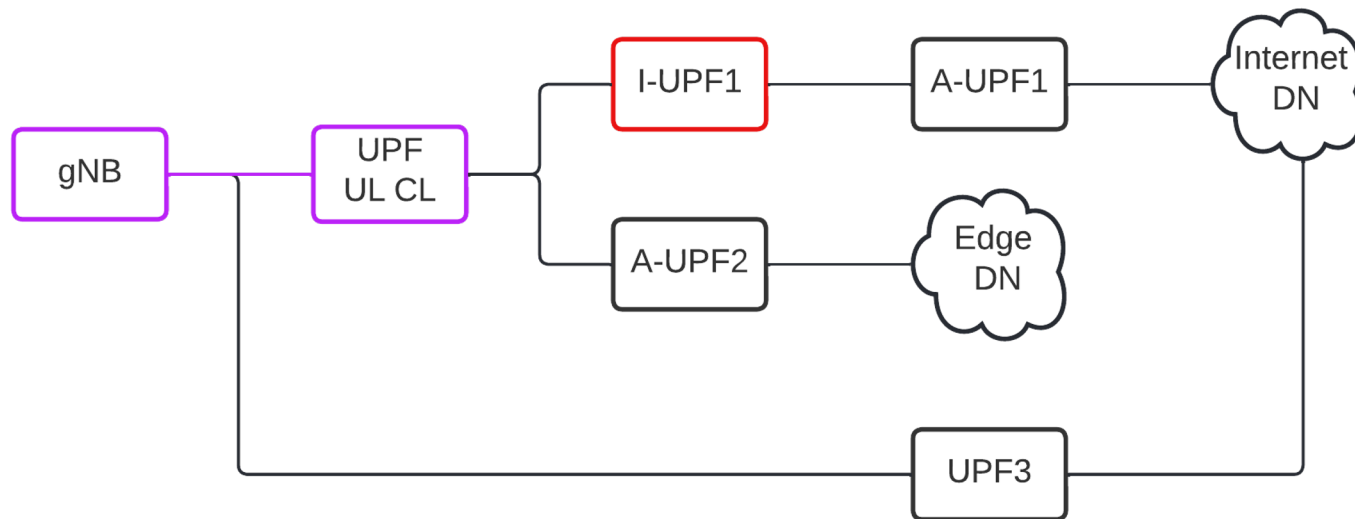
- gNB
- ULCL
- I-UPF1
- A-UPF1
- Internet



# Phase 2: I-UPF1

## PCC DNAI List

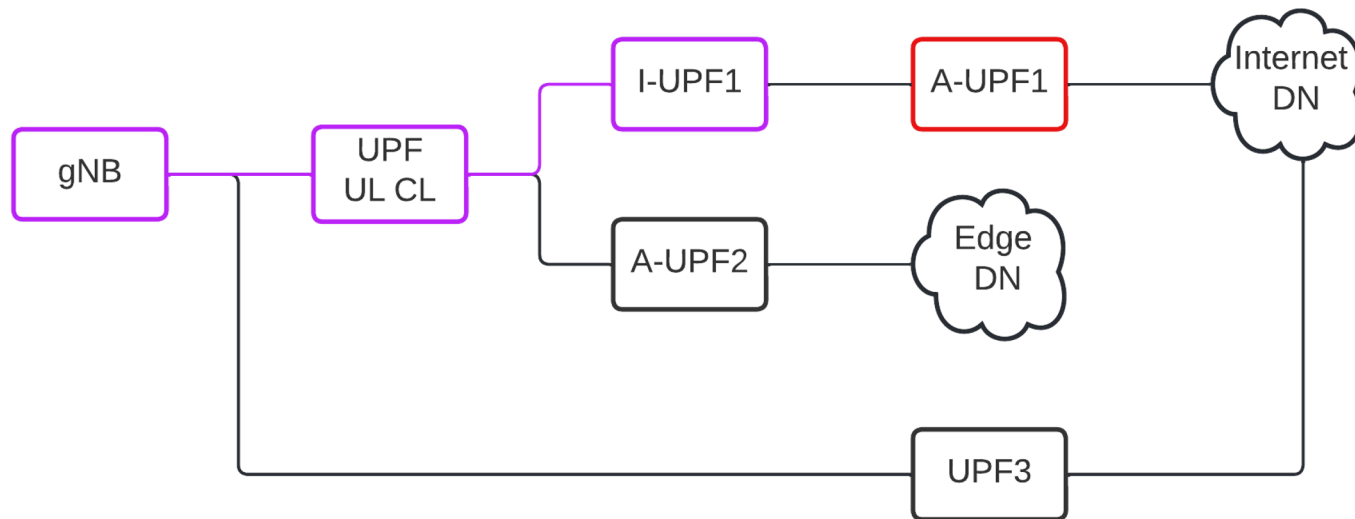
- gNB
- ULCL
- I-UPF1
- A-UPF1
- Internet



# Phase 2: A-UPF1

## PCC DNAI List

- gNB
- ULCL
- I-UPF1
- A-UPF1
- Internet



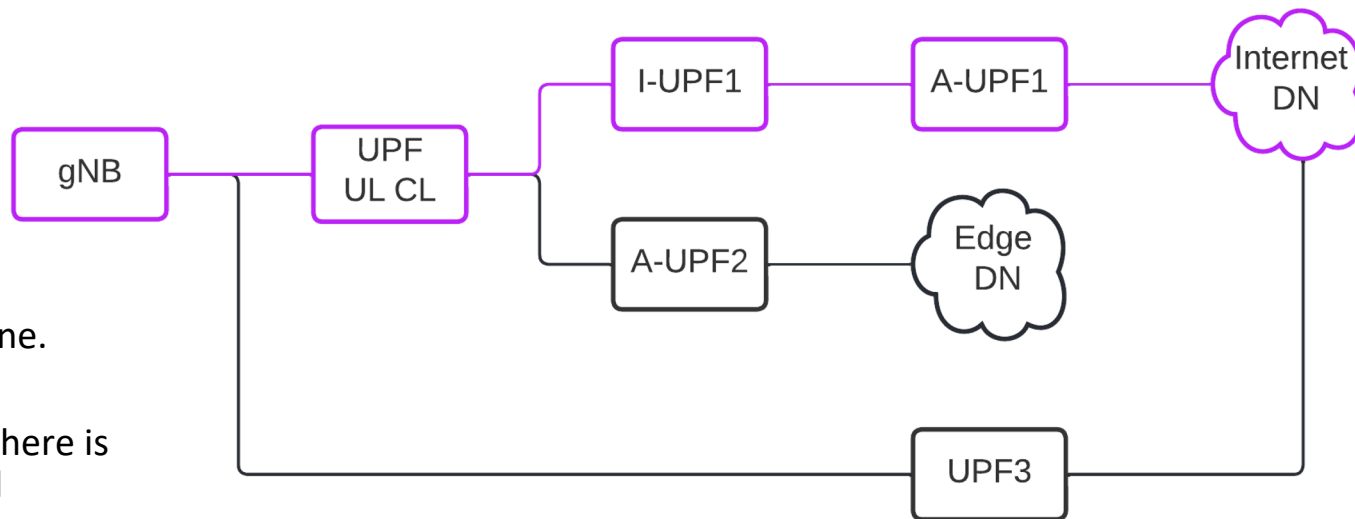
# Phase 2: Done

## PCC DNAI List

- gNB
- ULCL
- I-UPF1
- A-UPF1
- Internet

Sub-graph is done.

All DNAIs are contained and there is an exit (N6) and access (N3) node



# Phase 3: PFCP Session Establishment

- Now we have a graph of all UPFs that need to be part of the session
  - Again perform DFS algorithm on the sub-graph
  - Start at the exit nodes
  - Create PFCP Session between exit node and all direct neighbors
  - Wait until Session Establishment is accepted by neighbor UPFs
  - Continue until all nodes are covered
- 
- Once for uplink, once for downlink

# How to use the solution?

- Development to be finished soon (July/August)
- When the final version is available, we will publish a tutorial

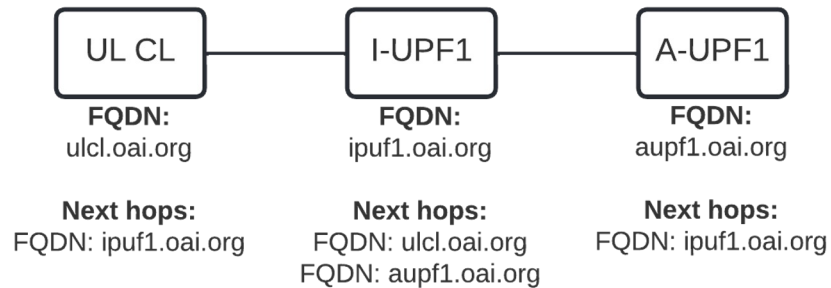
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# Questions?

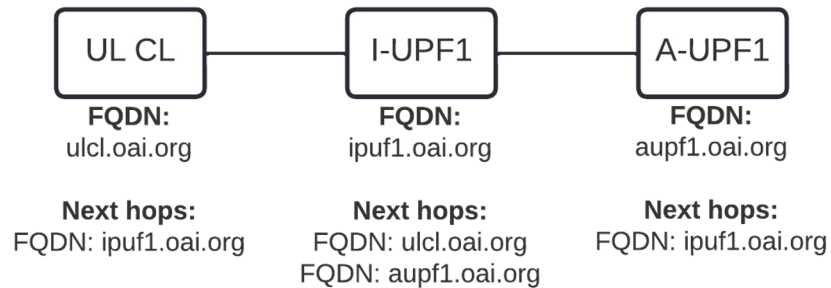
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# Backup

# Option 1 Example Configuration



# Option 1 Example Configuration



SMF configuration for rule “internet”

PCF tells SMF to activate this rule

# PCC Rules Example

```
"internet-rule": {  
  "flowInfos": [  
    {  
      "flowDescription": "permit out ip from  
any to assigned"  
    }  
  ],  
  "pccRuleId": "internet-rule",  
  "precedence": 10,  
  "refTcData": [  
    "internet-scenario1"  
  ]  
}
```

```
"edge-rule": {  
  "flowInfos": [  
    {  
      "flowDescription": "permit out ip from  
8.8.8.8 to assigned"  
    }  
  ],  
  "pccRuleId": "edge-rule",  
  "precedence": 9,  
  "refTcData": [  
    "edge-scenario1"  
  ]  
}
```

# Traffic Description Internet Scenario

```
"internet-scenario1": {  
  "routeToLocs": [  
    {  
      "dnai": "gnb",  
    },  
    {  
      "dnai": "ulcl1",  
    },  
    {  
      "dnai": "iupf1",  
    },  
    {  
      "dnai": "iupf2",  
    }  
  ],  
  {  
    "dnai": "aupf1",  
  },  
  {  
    "dnai": "internet",  
  }  
}
```

# Traffic Description Edge Scenario

```
"edge-scenario1": {  
  "routeToLocs": [  
    {  
      "dnai": "ulcl1",  
    },  
    {  
      "dnai": "aupf2",  
    },  
    {  
      "dnai": "edge1",  
    }  
  ],  
}
```

# UPF Info List (for UL CL and A-UPF2)

```
"dnnUpfInfoList": [  
  {  
    "dnn": "default",  
    "dnaiList": [  
      "gNB",  
      "iupf1",  
      "aupf2"  
    ],  
    "dnaiNwInstanceList": {  
      "gNB": "access_nwi"  
    },  
    "iupf1": "ulcl1_iupf1_nwi",  
    "aupf2": "ulcl1_aupf2_nwi",  
  }  
]
```

```
"dnnUpfInfoList": [  
  {  
    "dnn": "default",  
    "dnaiList": [  
      "edge-dnai",  
      "ulcl1"  
    ],  
    "dnaiNwInstanceList": {  
      "edge-dnai": "aupf2_edgedn_nwi",  
      "ulcl1": "ulcl1_aupf2_nwi"  
    }  
  }  
]
```