Open Mobile Edge Computing in 4G LTE

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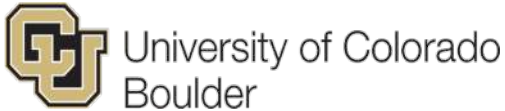

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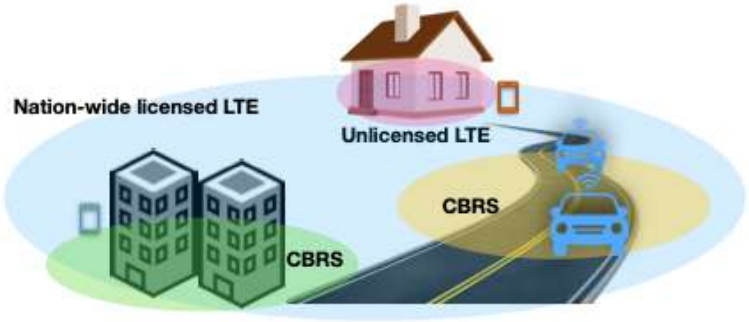
Outline

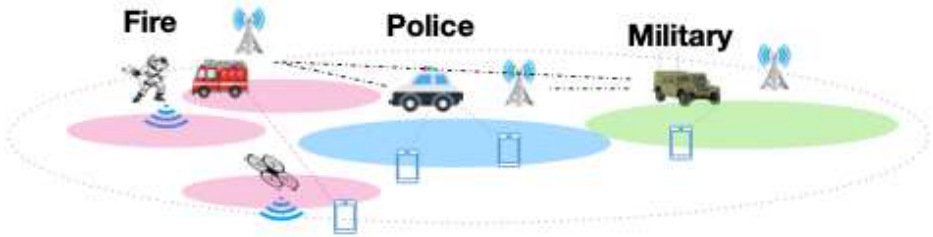
- Motivation
- Technical description
- Example scenario

Resilient Network Motivation

- LTE Network Design assumed a few, large network operators
- Enterprise and Gov't now deploying their own LTE networks



Community Cellular Networks (CCNs)



Public Safety

Using those multiple networks is key to resilient networks

Resilient Network Challenges

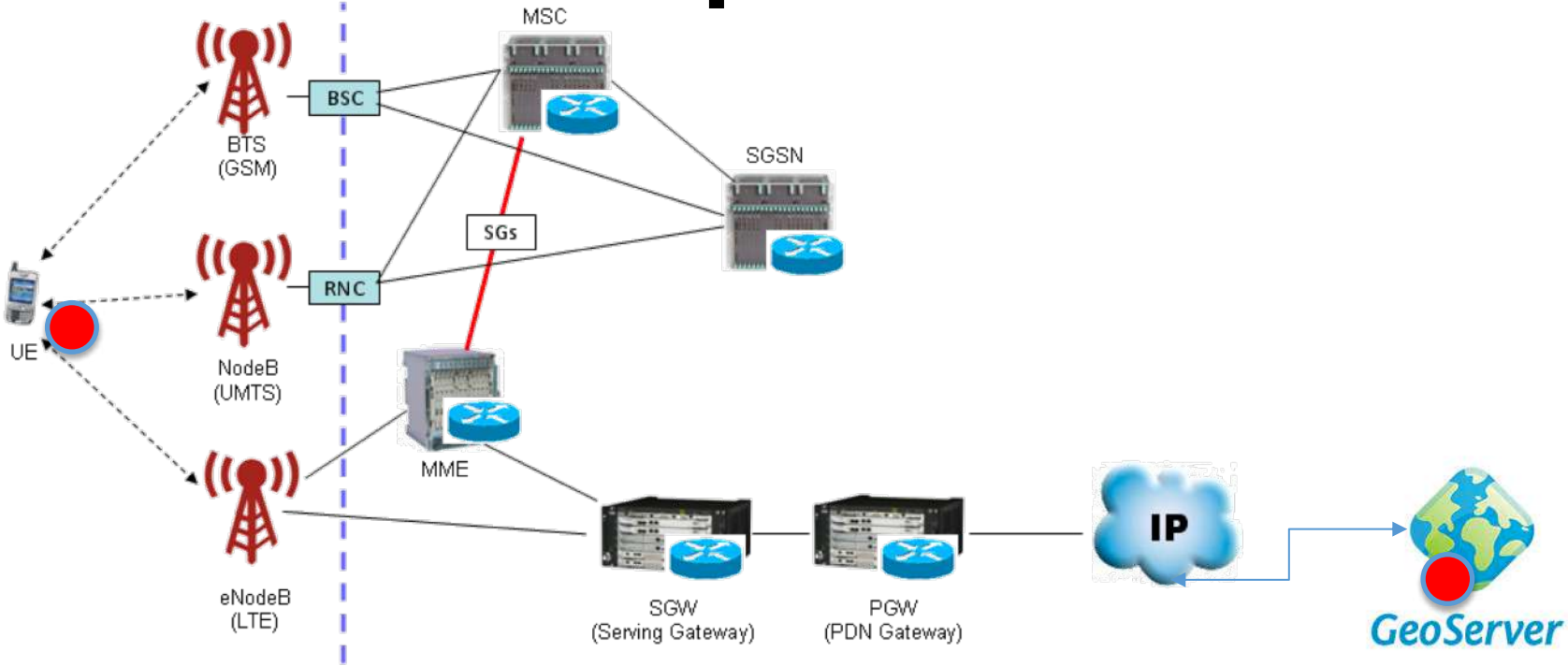
Connecting Multiple Networks

- LTE networks managed by Evolved Packet Core (EPC)
- Monolithic system that controls access, priority, connection to Internet, *etc.*
- Elastic EPC project makes EPC more resilient

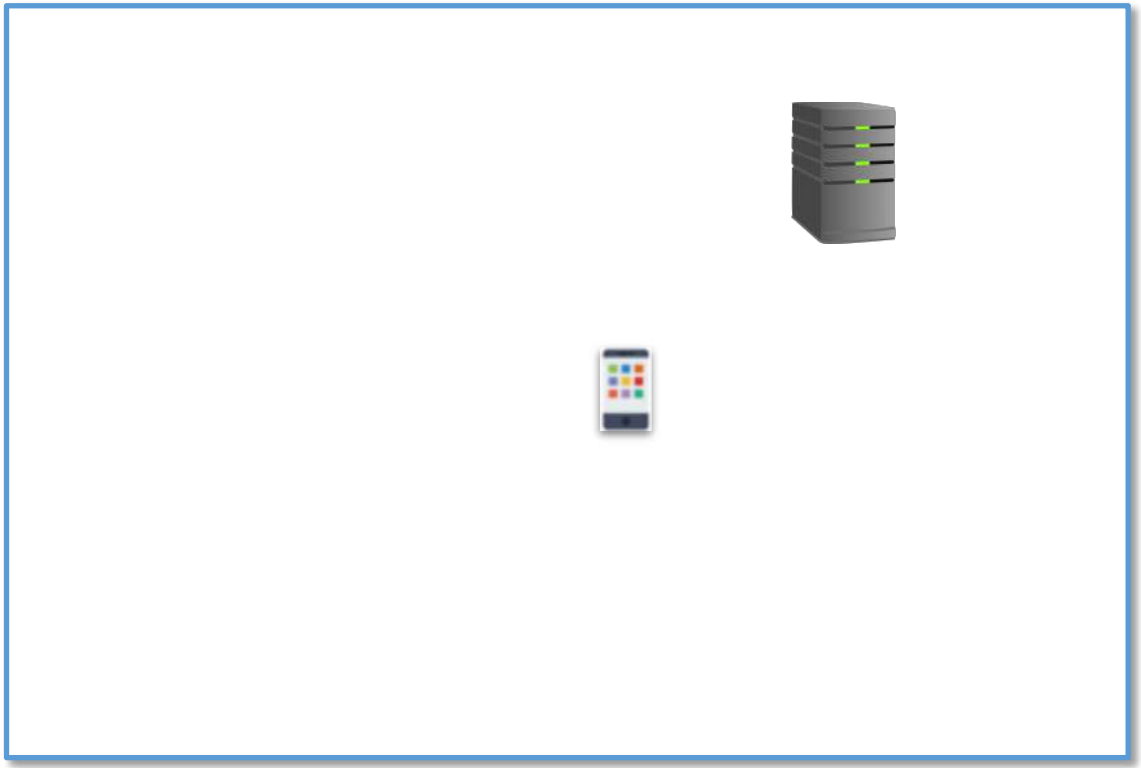
This Talk: Using Local Services

- We use networks to communicate and use services.
- Need those services even if the network is disrupted
- Mobile Edge Cloud

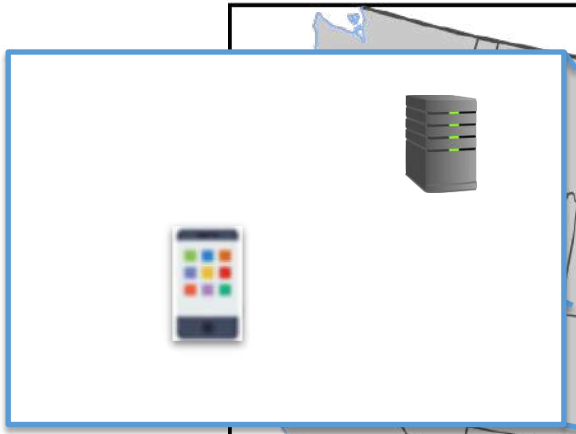
Just Enough LTE Network To Understand The problem



Services can be close....



Packet Gateways Can Be Far Away



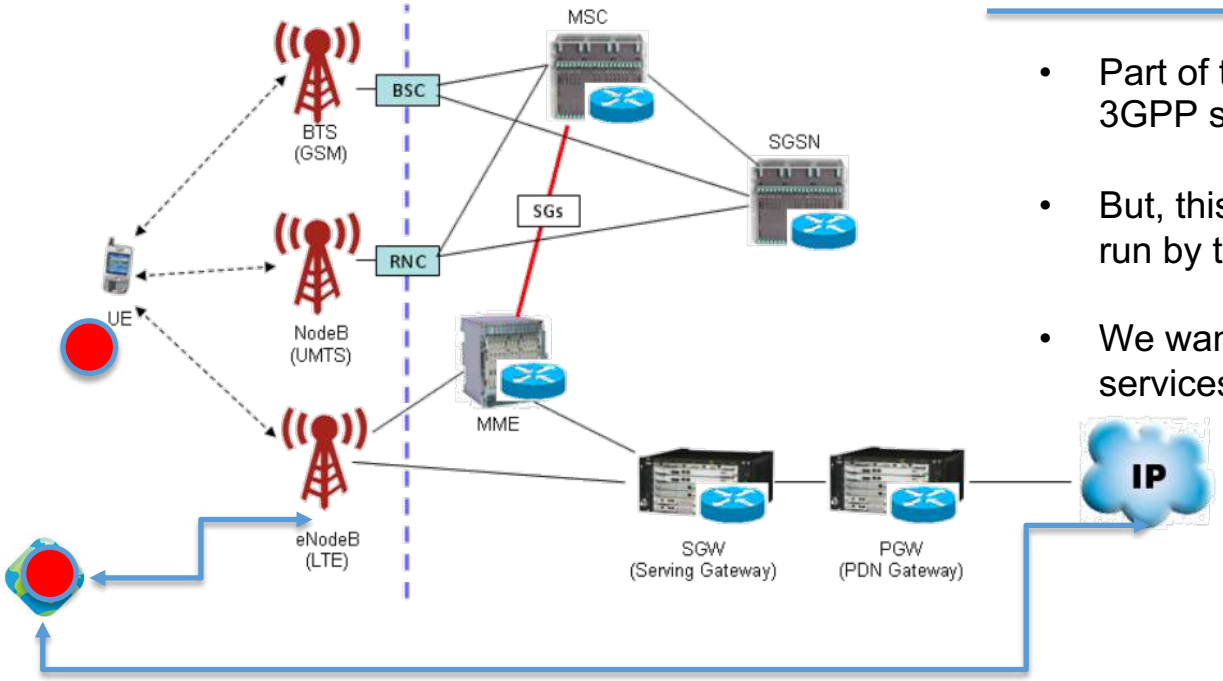

```
dirk-macpro18:grunwald $ traceroute 71.237.71.132
traceroute to 71.237.71.132 (71.237.71.132), 64 hops max, 52 byte packets
 1  192.168.43.1 (192.168.43.1)  3.935 ms  2.878 ms  2.924 ms
 2  * * *
 3  10.0.115.1 (10.0.115.1)  79.507 ms  71.266 ms  80.240 ms
 4  10.198.26.65 (10.198.26.65)  92.778 ms  100.327 ms  83.227 ms
 5  10.165.200.189 (10.165.200.189)  79.403 ms  80.837 ms  104.035 ms
 6  10.164.177.13 (10.164.177.13)  91.443 ms  84.619 ms  86.459 ms
 7  ae2.er1.ord2.us.zip.zayo.com (208.185.145.41)  79.590 ms  88.646 ms  83.124 ms
 8  * ae8.cs3.ord2.us.zip.zayo.com (64.125.31.172)  99.519 ms  97.660 ms
 9  ae11.er2.ord7.us.zip.zayo.com (64.125.26.251)  77.419 ms  107.859 ms  89.335 ms
10  be-204-pe01.350ecermak.il.ibone.comcast.net (66.208.229.253)  84.045 ms  76.237 ms  79.920 ms
11  be-10563-cr02.350ecermak.il.ibone.comcast.net (68.86.82.157)  95.540 ms  97.216 ms  102.302 ms
12  be-10521-cr02.1601milehigh.co.ibone.comcast.net (68.86.85.170)  125.634 ms  104.969 ms  109.804 ms
13  ae-79-ar01.denver.co.denver.comcast.net (68.86.92.122)  105.204 ms  113.412 ms  106.667 ms
14  ae-1-rur01.boulder.co.denver.comcast.net (162.151.50.250)  107.058 ms  116.337 ms  120.106 ms
15  lag-1-acr02.boulder.co.denver.comcast.net (68.86.129.230)  124.366 ms  119.514 ms  119.256 ms
16  * * *
17  *^C
```

What is the impact?

- Packet Gateways (PGW) can be 1000s of miles away.
- Faster communication may be necessary.
- Especially for localized information.
- What if Chicago is down?

Image Source: https://www.travelers.com/resources/auto/safe-driving/winter-driving-safety-tips

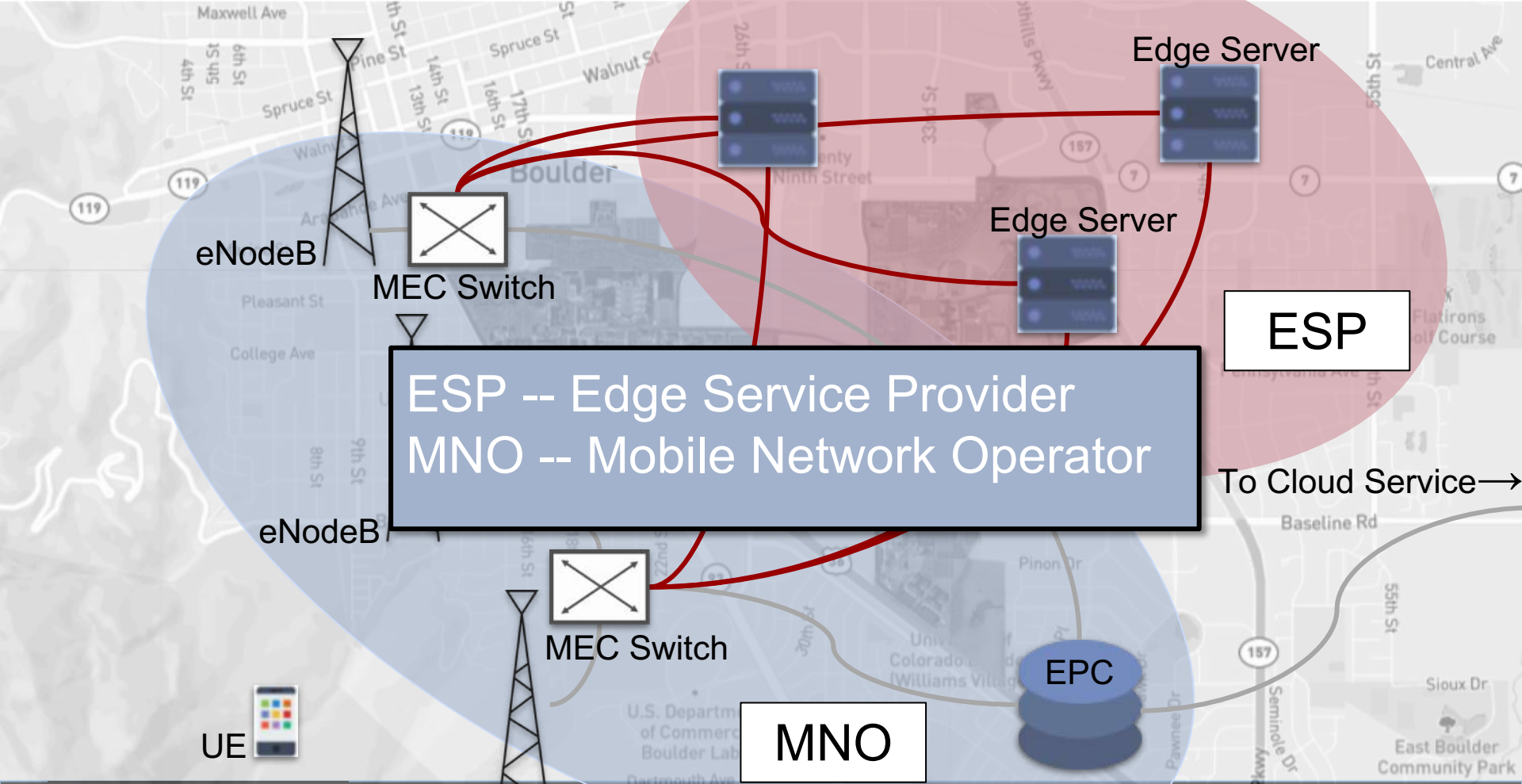
One Solution: Mobile Edge Cloud



What's New?

- Part of this (MEC) is defined by 3GPP standards
- But, this assumes the service is run by the network operator
- We want to use our local services…on multiple networks


eNodeB
eNodeB
UE
EPC
To Cloud Service⟶


Edge Server
Edge Server
eNodeB
MEC Switch
ESP
ESP -- Edge Service Provider
MNO -- Mobile Network Operator
To Cloud Service⟶
eNodeB
MEC Switch
EPC
UE
MNO

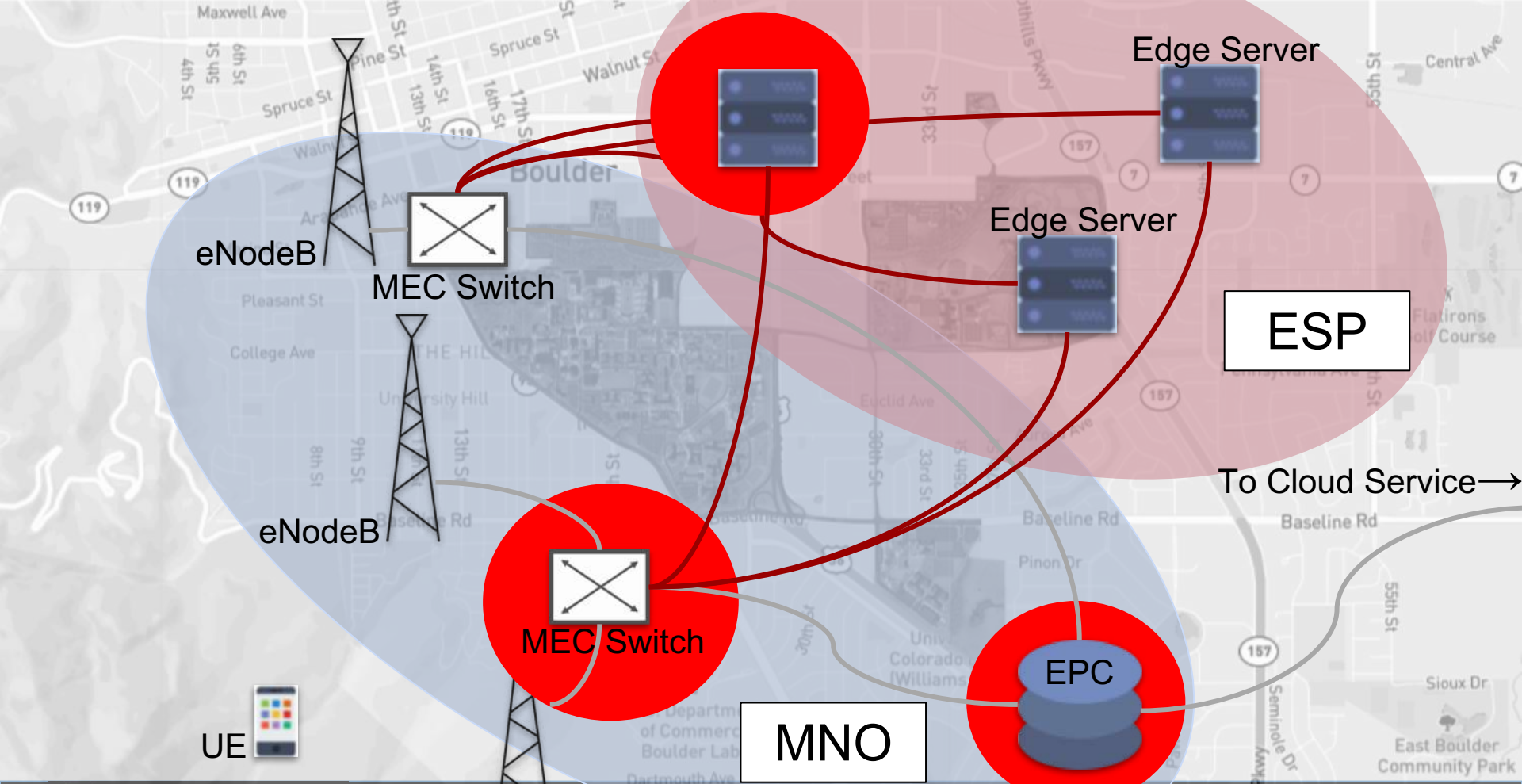
Multi-Mobile Edge Cloud Challenges

Mobile Network Operator (MNO)

- MNO does not want to expose network structure
- But, we need to handle roaming UE's
- And, connect to "best" edge service

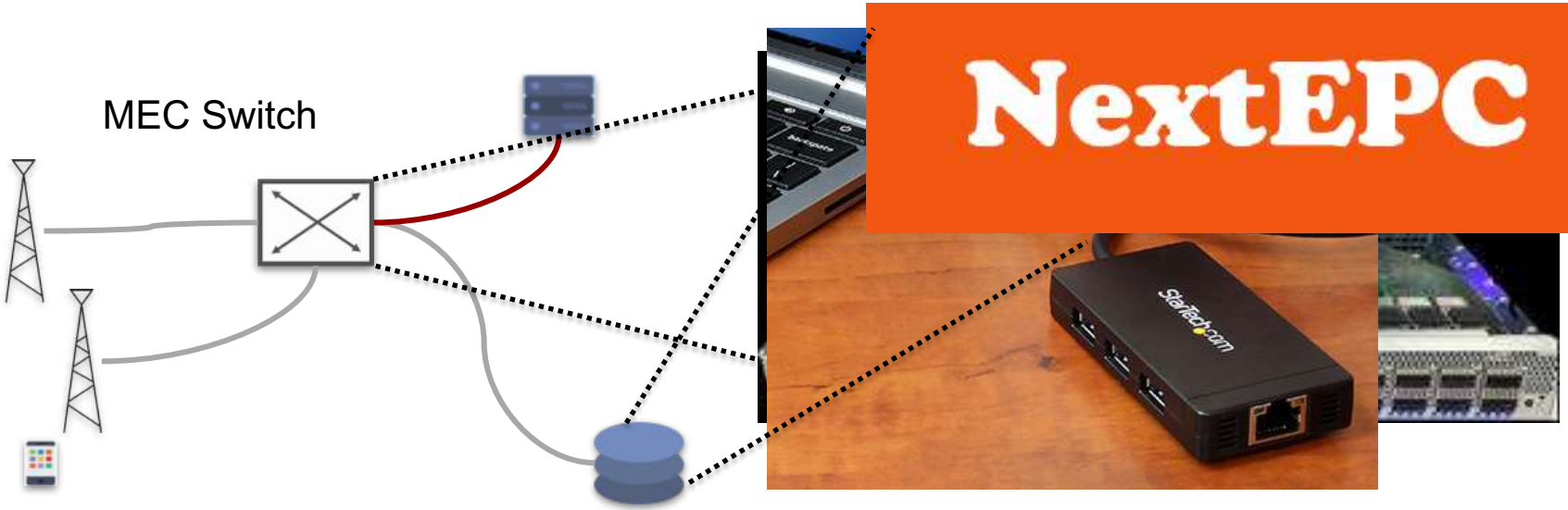
Edge Service Provider (ESP)

- ESP needs to work with multiple MNO's
- Has to identify UE and ESP pairings
- Has to identify the "best" ESP node


Edge Server
Edge Server
ESP
eNodeB
MEC Switch
eNodeB
MEC Switch
EPC
MNO
UE
To Cloud Service⟶

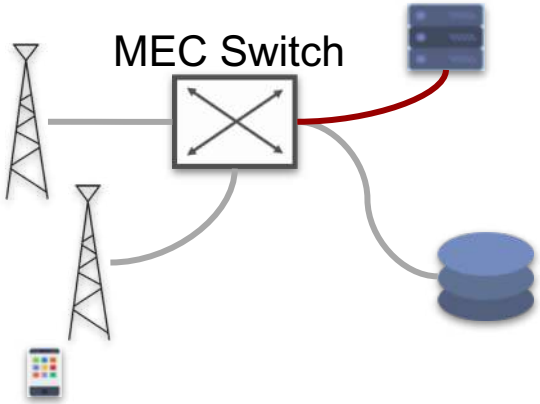
Multi-Mobile Edge Cloud - Prototype System

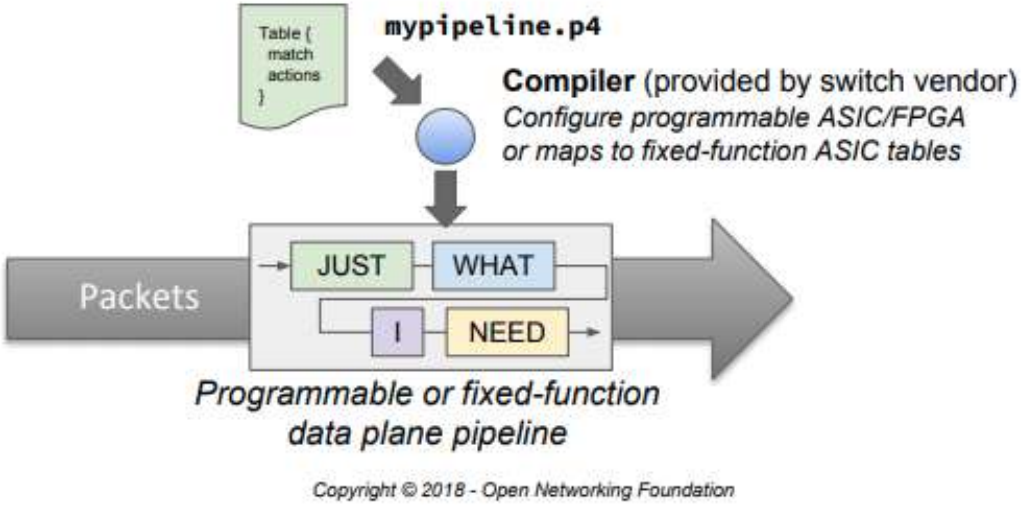
The MEC Switch – A software-defined switch using P4
We use and contribute to the NextEPC project



MEC Switch - Flow Tables

We intercept just the right traffic between UE and PGW to redirect to the edge





Within the switch are Match-Action tables that specify the matching and forwarding actions of the switch.

Sample Packet Intercepted by the MEC

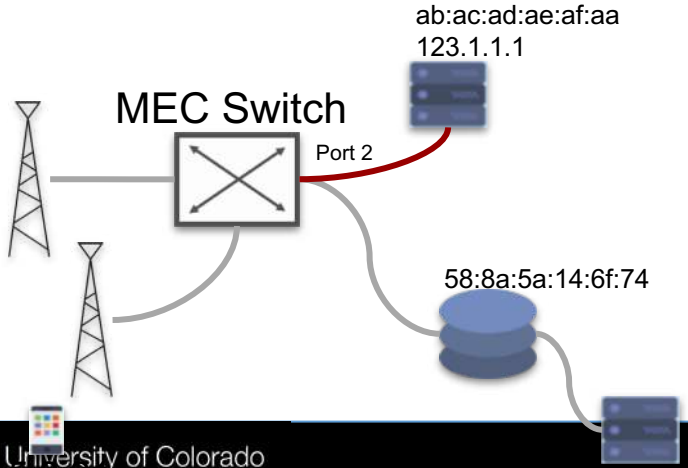
Dest. MAC

```
---------START PACKET:---------
MAX:: 1 proto ethernet(dst='58:8a:5a:14:6f:74',ethertype=2048,src='64:a8:37:26:01:99')
MAX:: 2 proto
ipv4(csum=46581,dst='192.168.1.254',flags=2,header_length=5,identification=0,offset=0,option=None,proto=17,src='192.168.1.2',tos=56,total_length=111,ttl=64,version=4)
MAX:: 3 proto udp(csum=58576,dst_port=2152,src_port=39339,total_length=91)
MAX:: 4 proto gtp(ext_type=None,flags=0,msg_length=75,msg_type=255,npdu_num=None,proto_type=1,seq_num=None,teid=83,version=48)
MAX:: 5 proto
ipv4(csum=8520,dst='8.8.8.8',flags=2,header_length=5,identification=56328,offset=0,option=None,proto=17,src='45.45.0.21',tos=0,total_length=75,ttl=64,version=4)
MAX:: 6 proto udp(csum=13571,dst_port=53,src_port=41630,total_length=55)
MAX:: 7 proto connectivitycheckgstaticcom
-------- -END- --------
```

Dest. IP

UDP Port

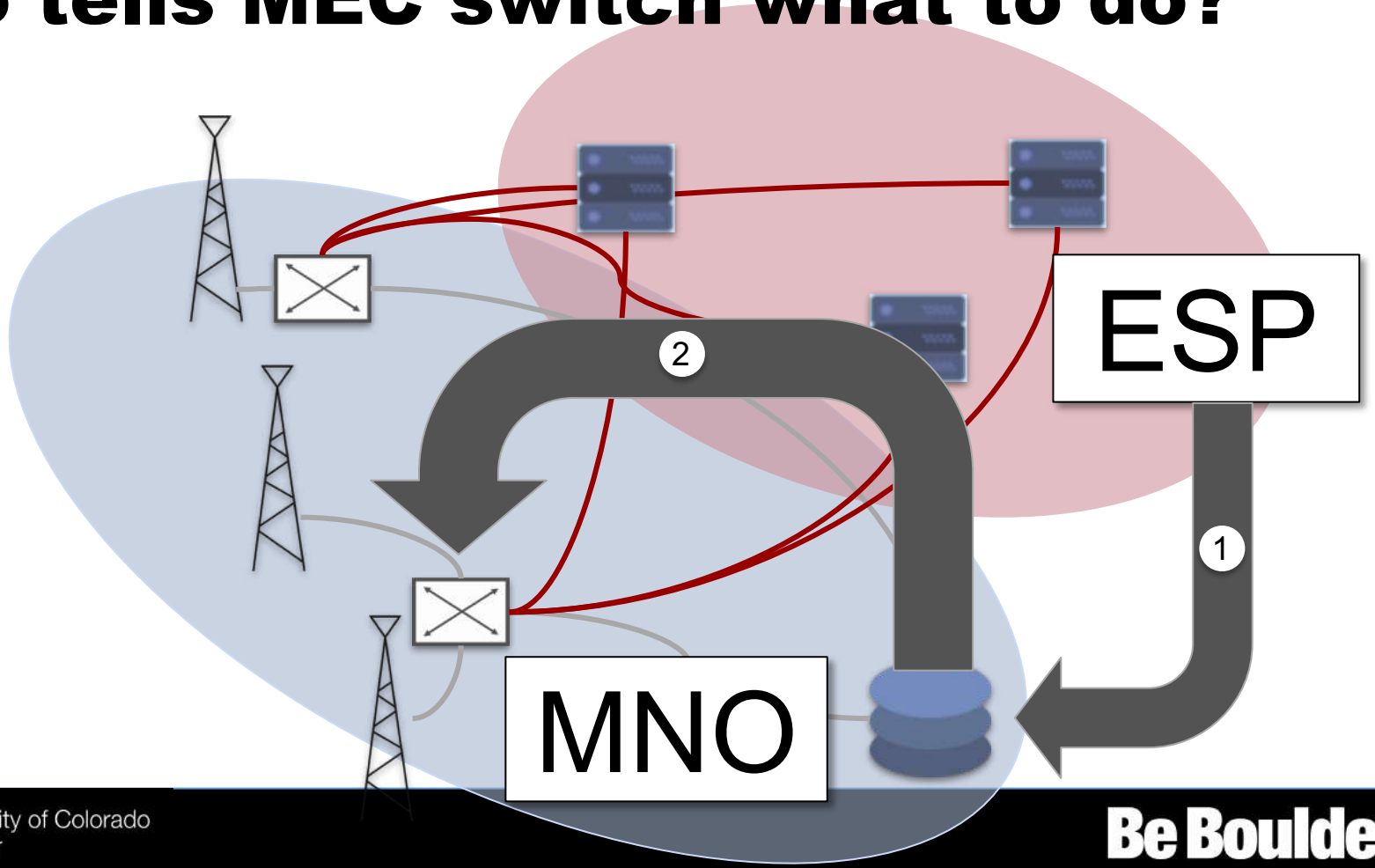
Cell Phone IP



MEC Flow Table Rule

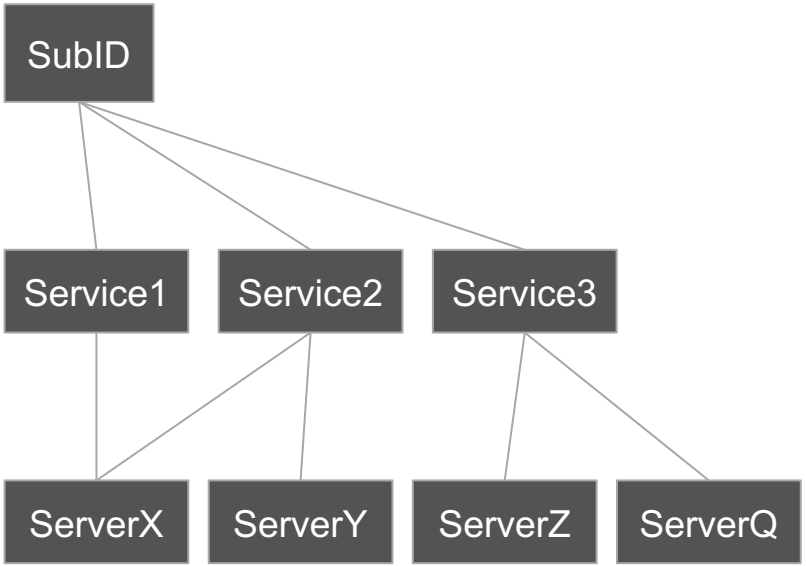
MATCH	ACTION
src=45.45.0.21, dst=8.8.8.8:53	eth_dst=ab:ac:ad:ae:af:aa ip_dst=123.1.1.1 forward_port: 2

Who tells MEC switch what to do?

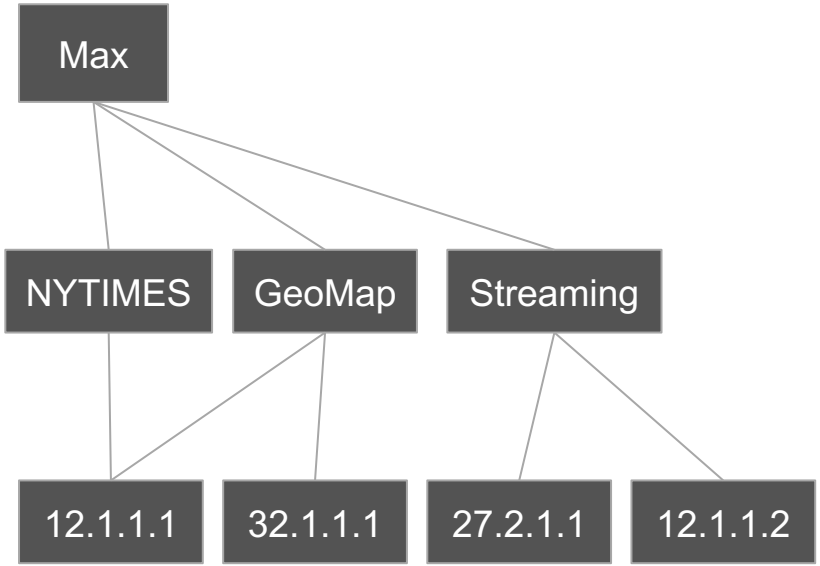


1 of 2 Necessary Protocols

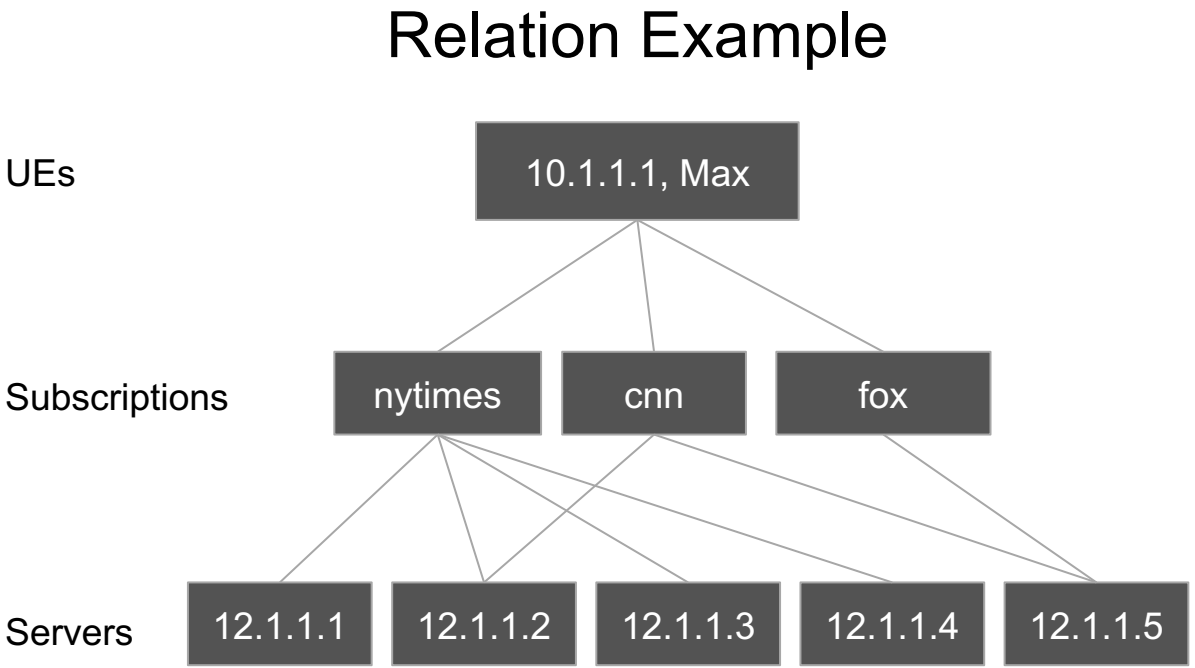
ESP → MNO



Example

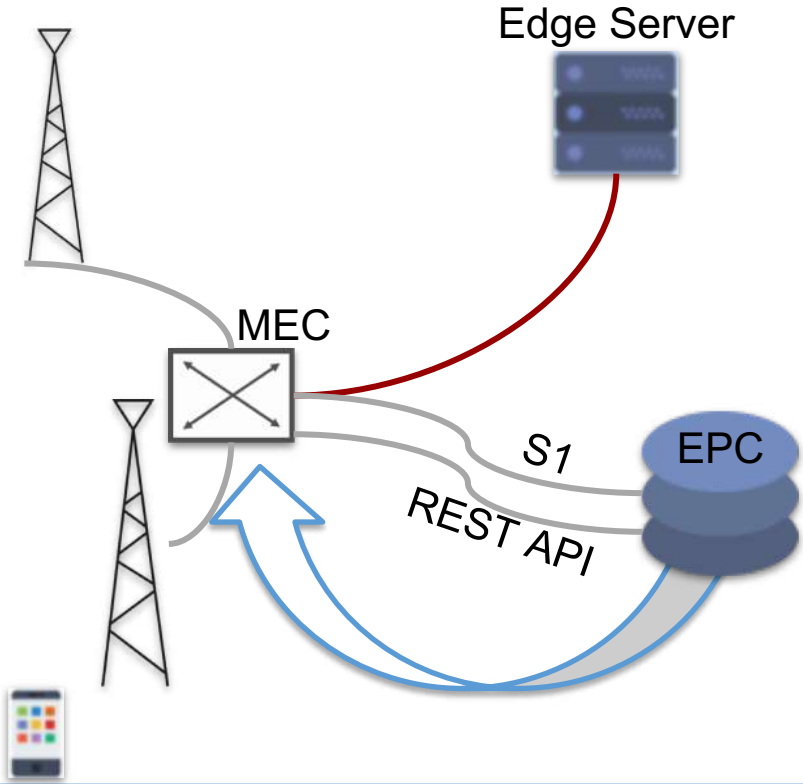


1 of 2 Necessary Protocols

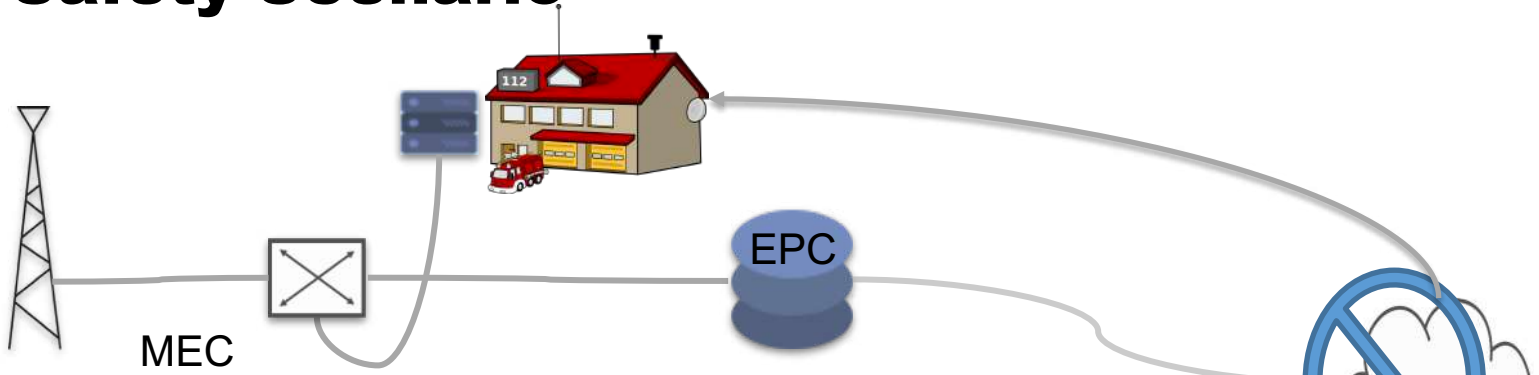


2 of 2 Necessary Protocols

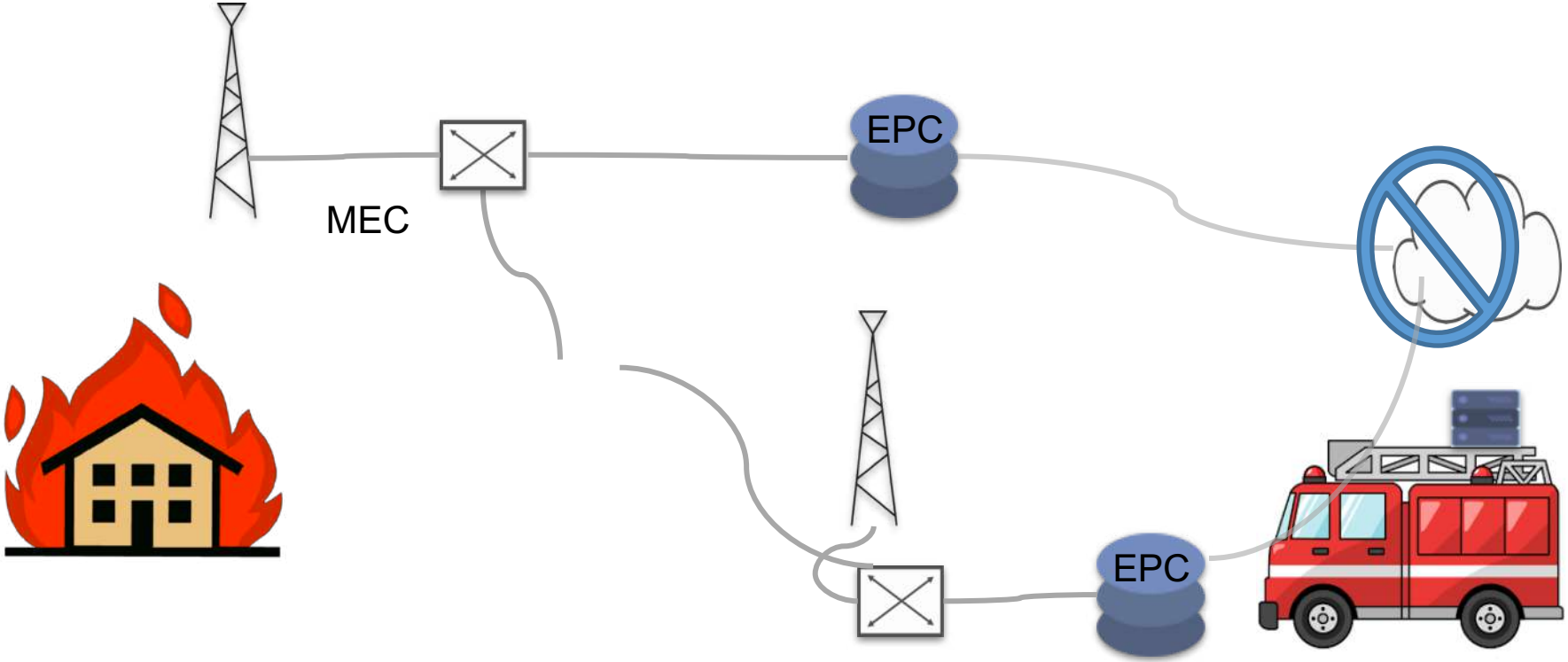
UE's IP	Service Name	List of dest IPs
<45.45.0.21	nytimes	[8.8.8.1, 8.8.8.2, 8.8.8.7]>
<45.45.0.21	cnn	[8.8.8.1, 123.12.3.9]>
<45.45.0.21	fox	[8.8.8.1, 5.5.8.2, 1.1.1.2]>
<45.45.1.2	fox	[8.8.8.1, 5.5.8.2, 1.1.1.2]>



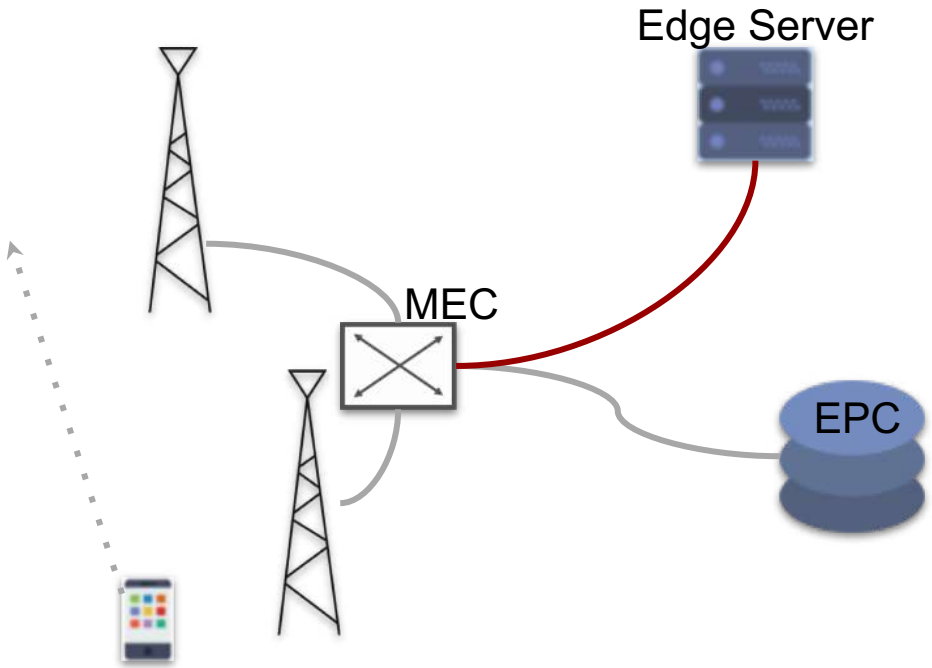
Public Safety Scenario



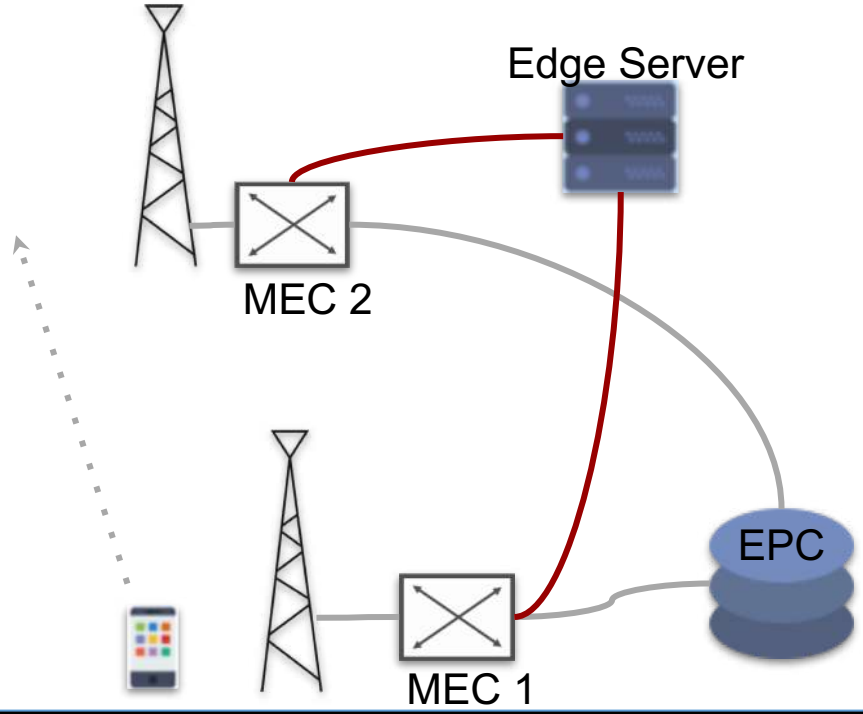
Public Safety Scenario



Scenario 1
UE travels from Cell1 to Cell2

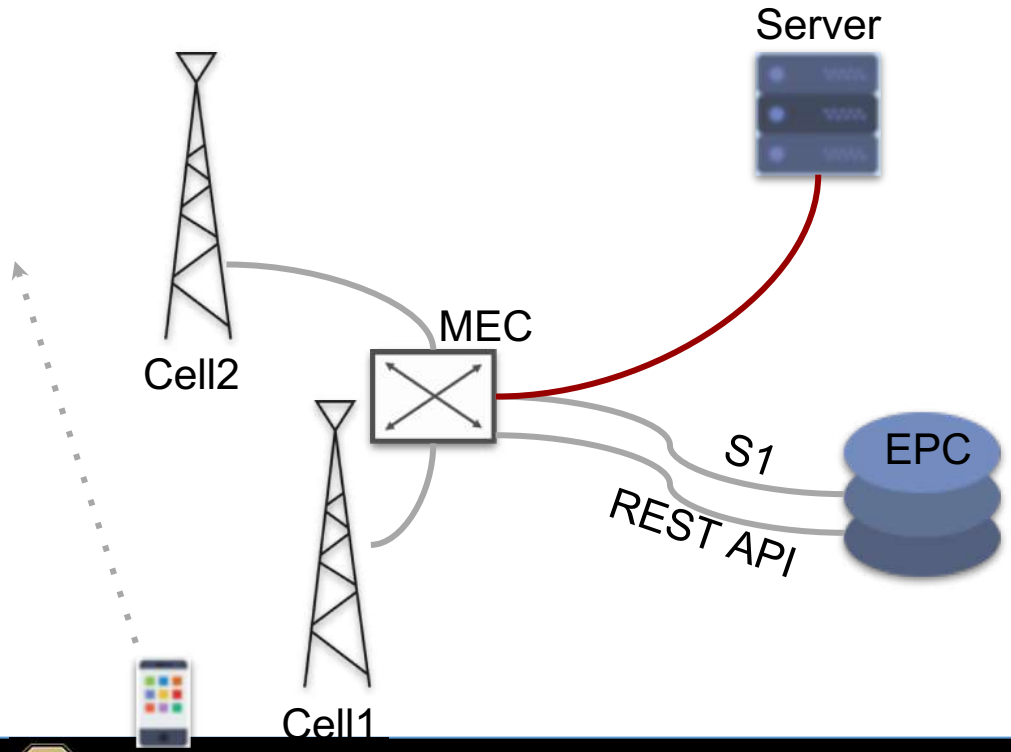


Scenario 2
UE travels from MEC 1 to MEC 2



Scenario 1

UE travels from Cell1 to Cell2



MEC

- Knows UE's
  - IP
  - Assoc. Cell1
- Maps <UE IP, Cell>
- Matches traffic for reroute:
  - 1st - UE's IP
  - 2nd - Dest IP and port

EPC

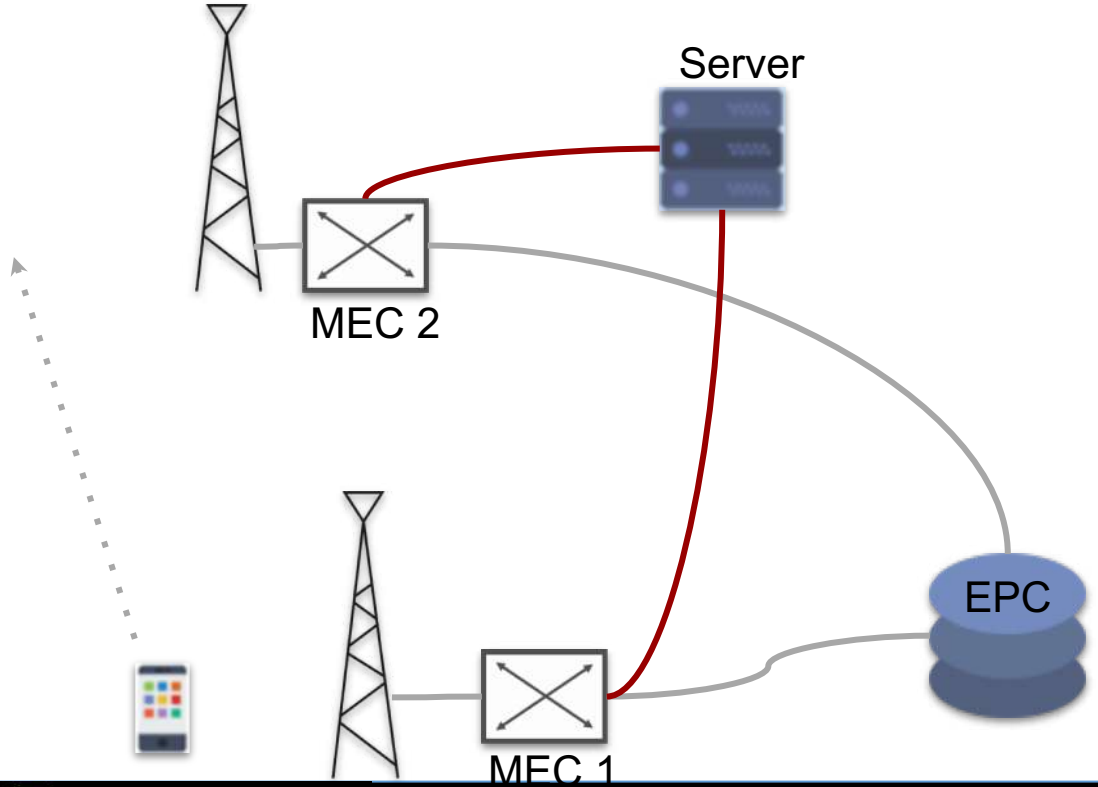
- EPC to MEC (REST API)
  - Notify new Assoc. Cell2

MEC

- Update mapping
- Route Downlink to Cell2

Scenario 2

UE travels from MEC 1 to MEC 2



MEC 1

- Knows UE's
  - IP
  - Assoc. CellID
- Maps <UE IP, Cell>
- Matches traffic for reroute:
  - 1st - IP
  - 2nd - Dest IP and port

EPC

- EPC to MEC 2 (REST API)
  - IP
  - Assoc CellID

MEC 2

- Continues service

Project status

- Current system is “bump in the wire”
- Measures latency to different ESP servers
- Only redirects data for designated UE
- Edge Service Provider does not need to know about GTP

- Come see demo!

University of Colorado Boulder

Thank You!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Come back for the
Next
Session
2:40 PM