Integrated Optical-Wireless Reliable Slicing

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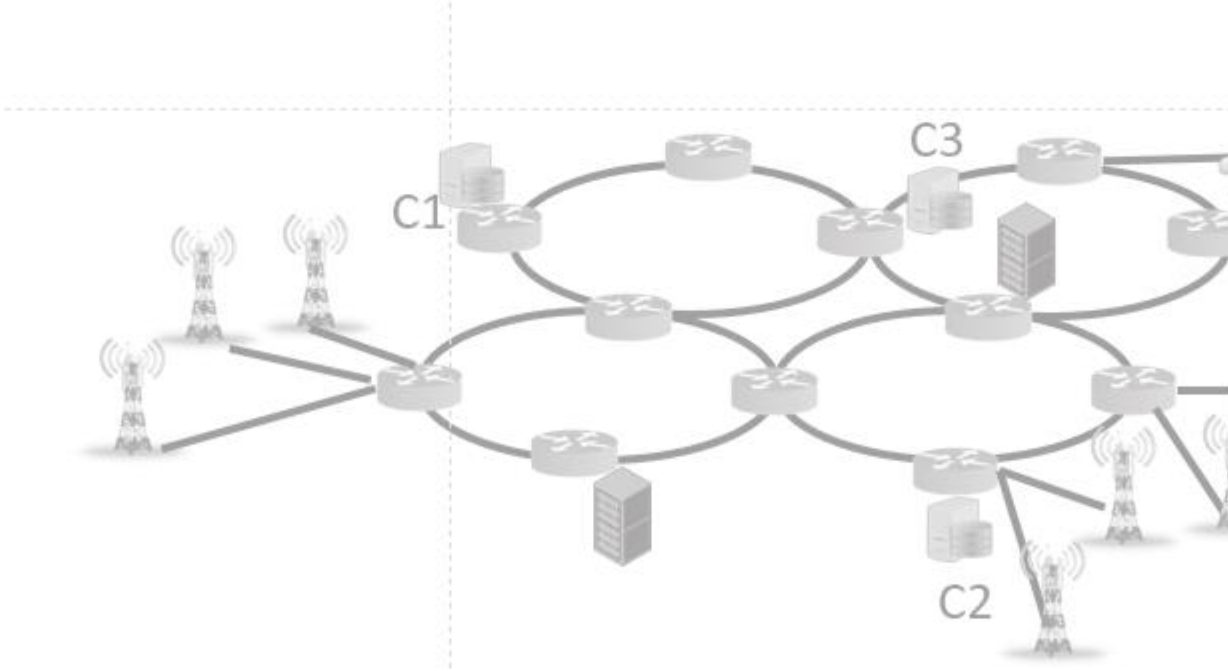
Group Meeting
March 29th 2019

UCDAVIS
UNIVERSITY OF CALIFORNIA

Outline

- Slicing deployment strategies
- Radio Access Network Slicing
- Virtual service chaining for mobile network slicing
- Problem definition



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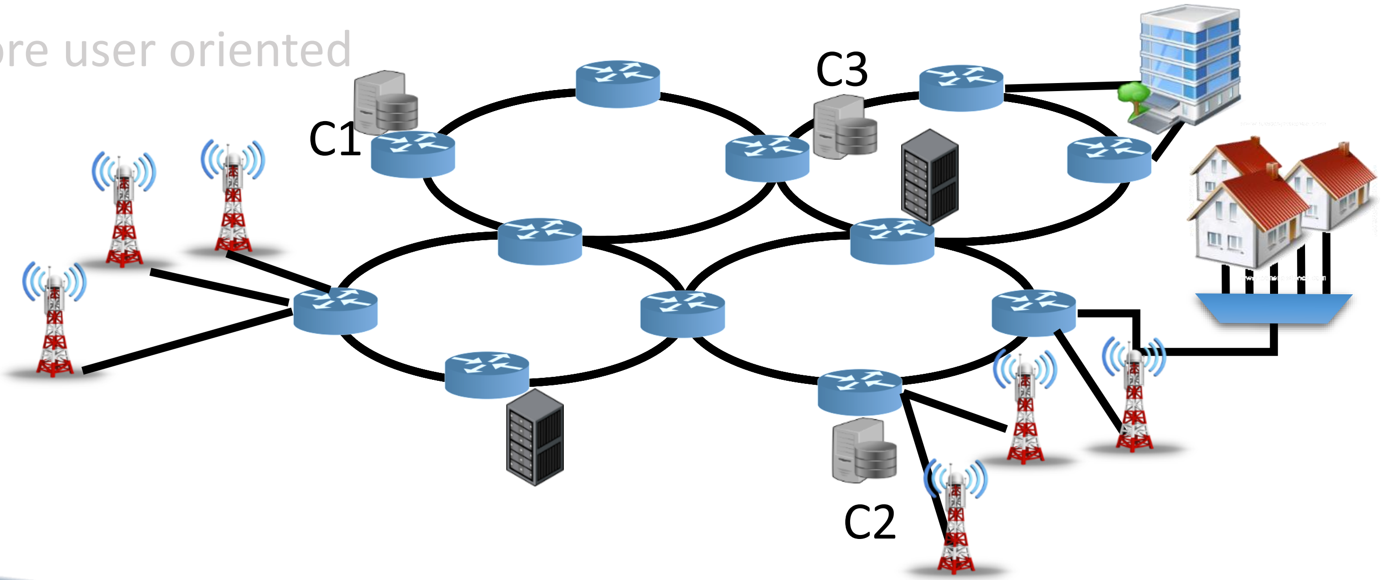
Few considerations on network slicing

- Two slicing deployment strategies:
  - Per service category
    - Requires configuration of the whole metro network
  - Per service:
    - Finer granularity, more user oriented

eMBB ready
uRLLC ready
mMTC ready



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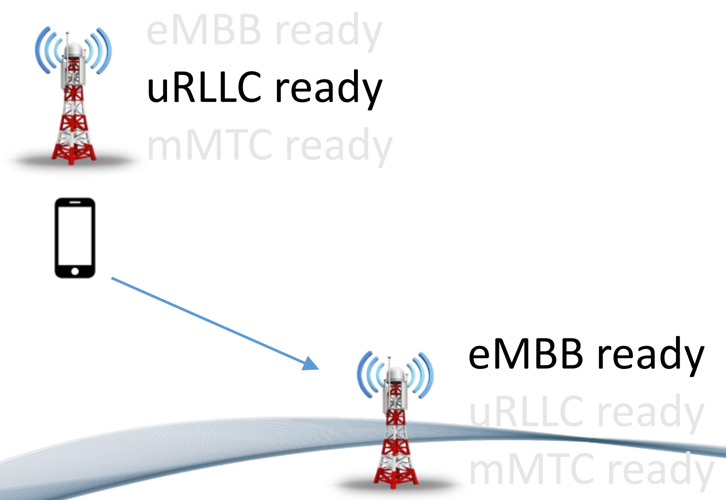

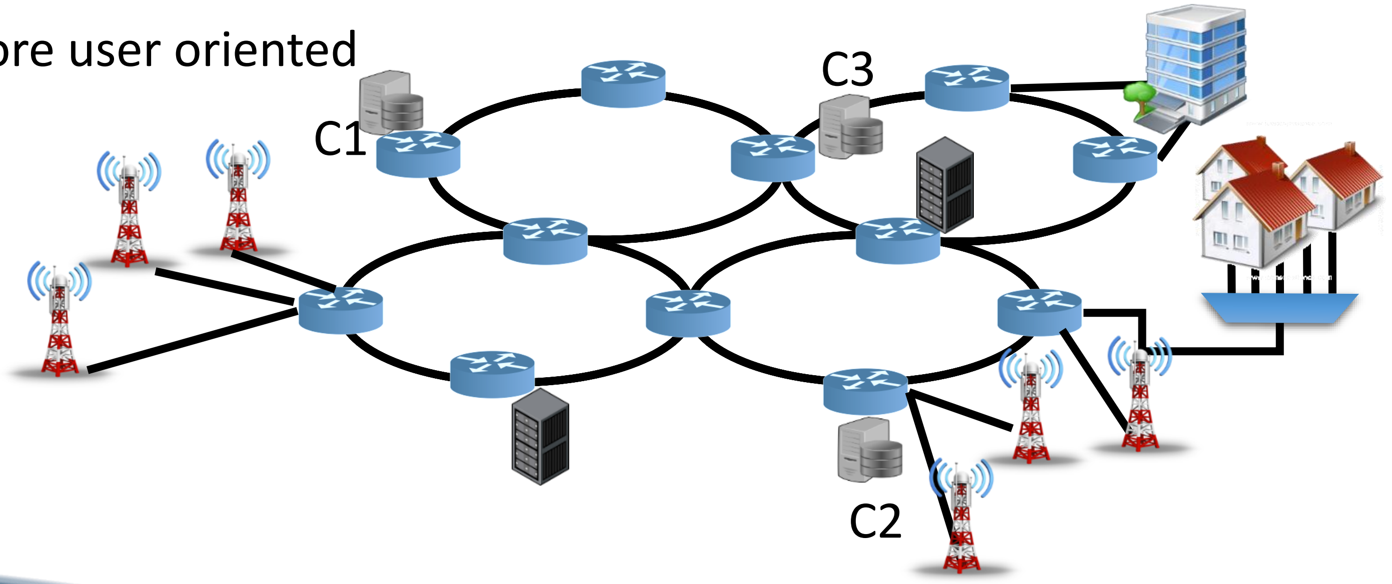

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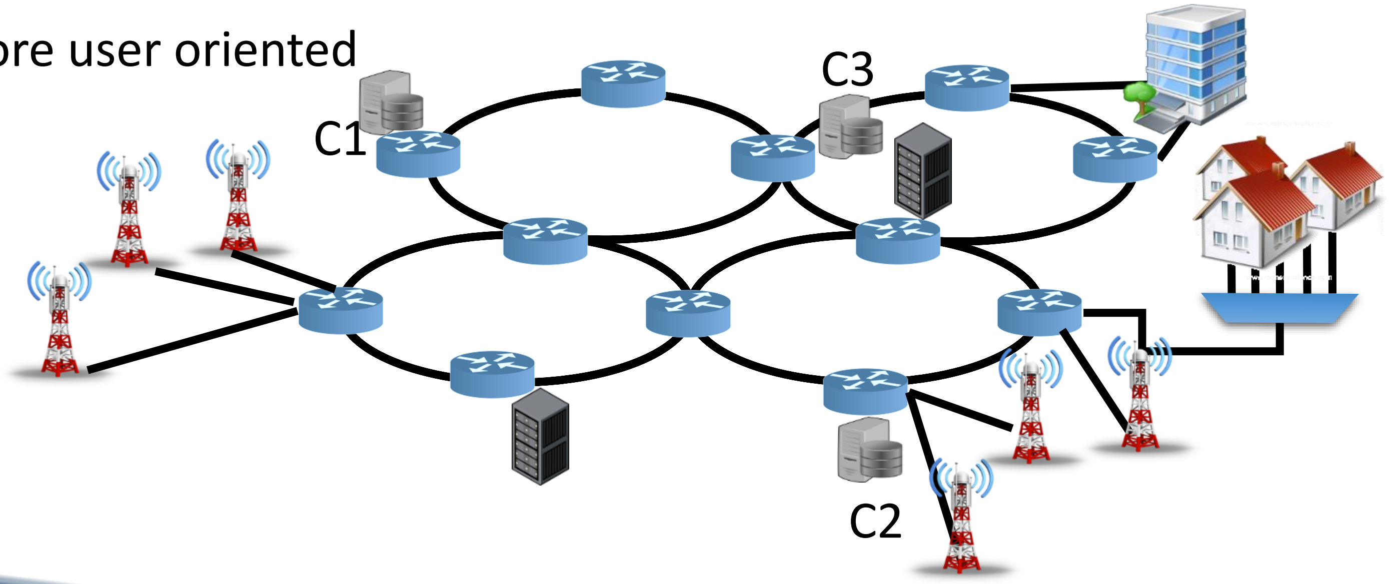
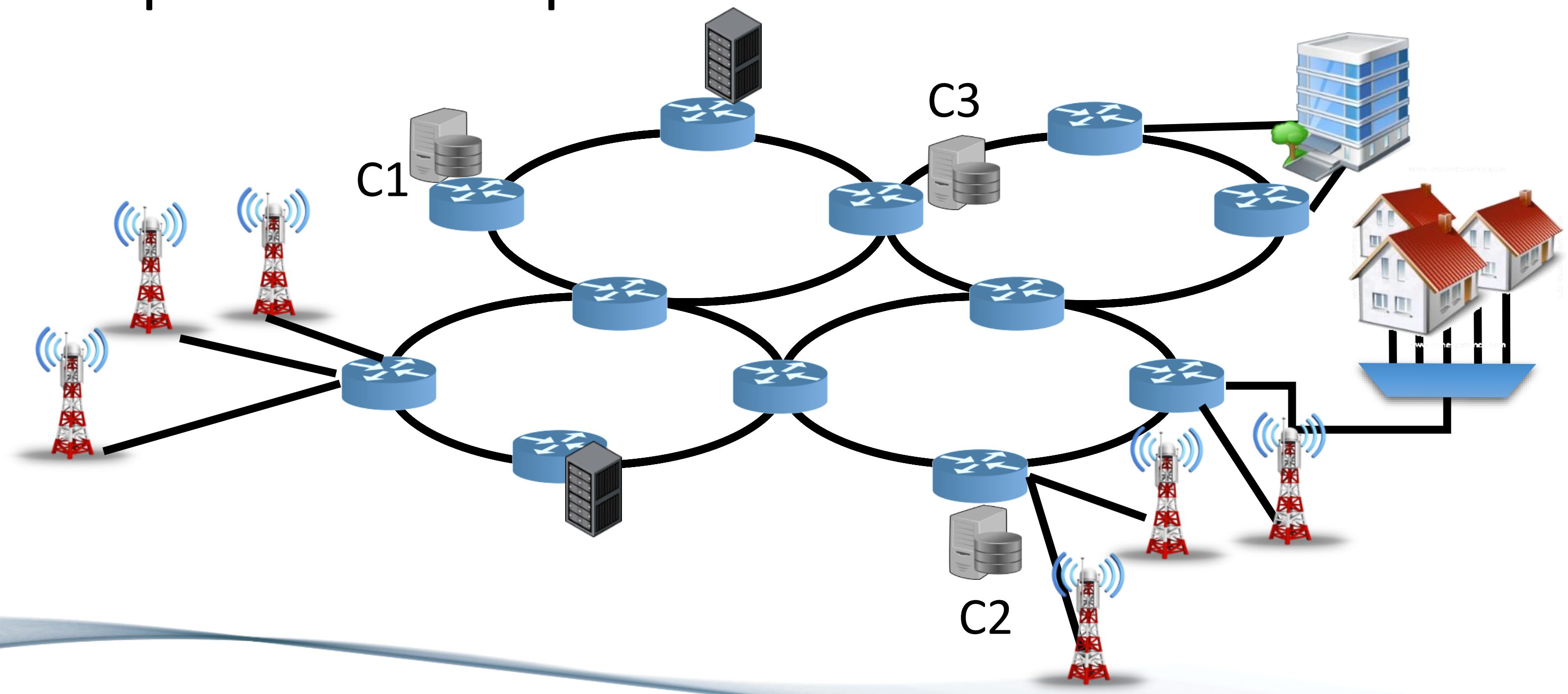


User behavior relevance

- When users belonging to slices requiring different level of reliability move in the Radio Access Network, the Metro-Access network should adapt to their requirements



User behavior relevance

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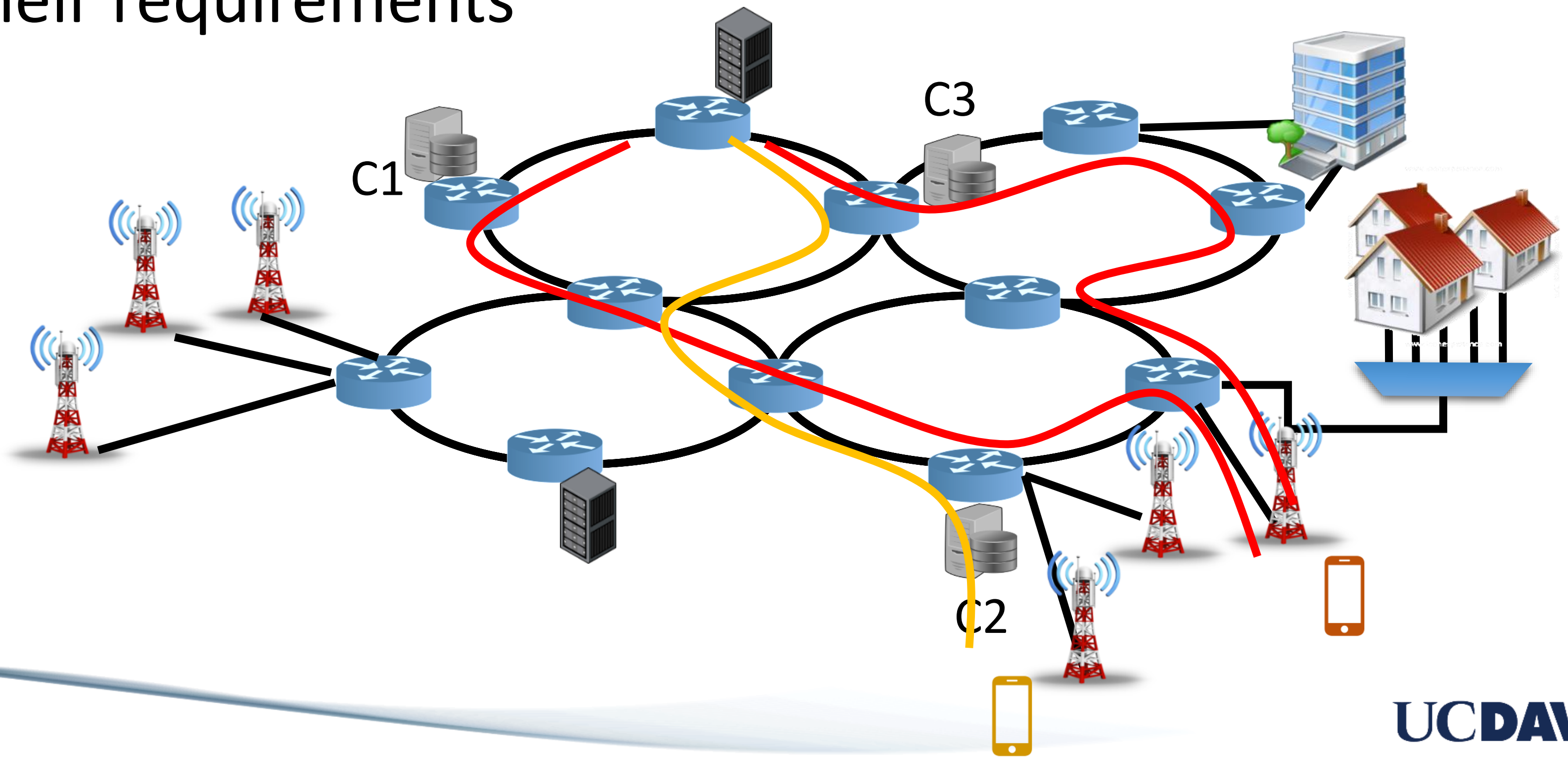
Very high reliability

No reliability



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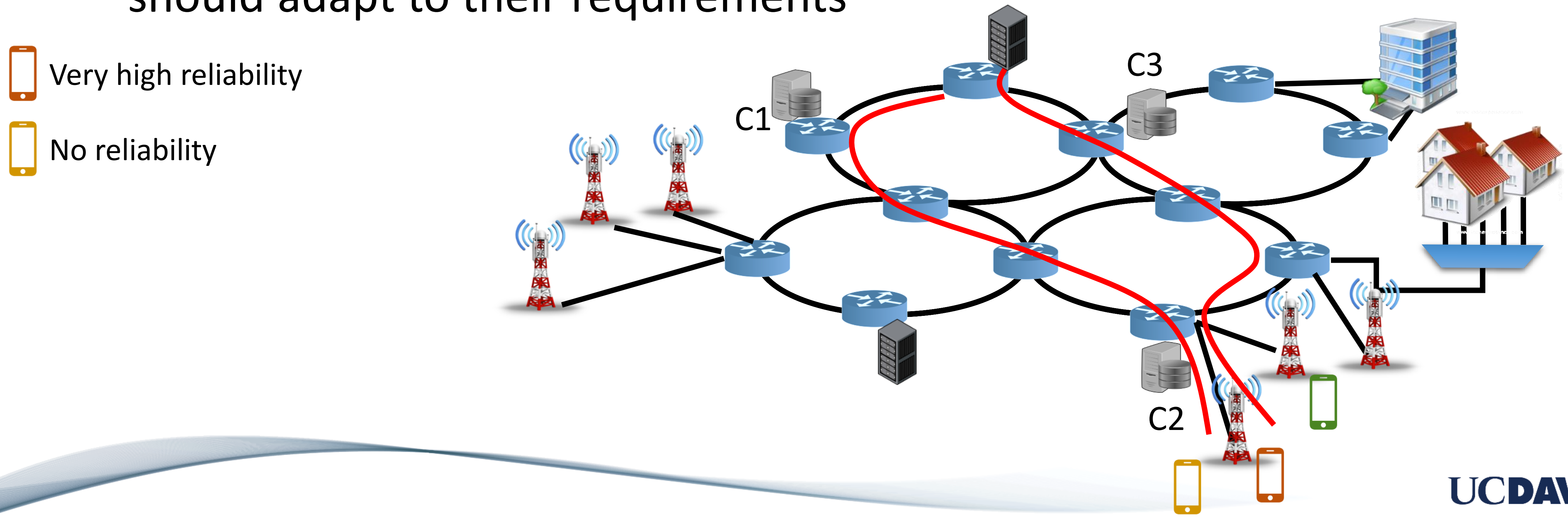
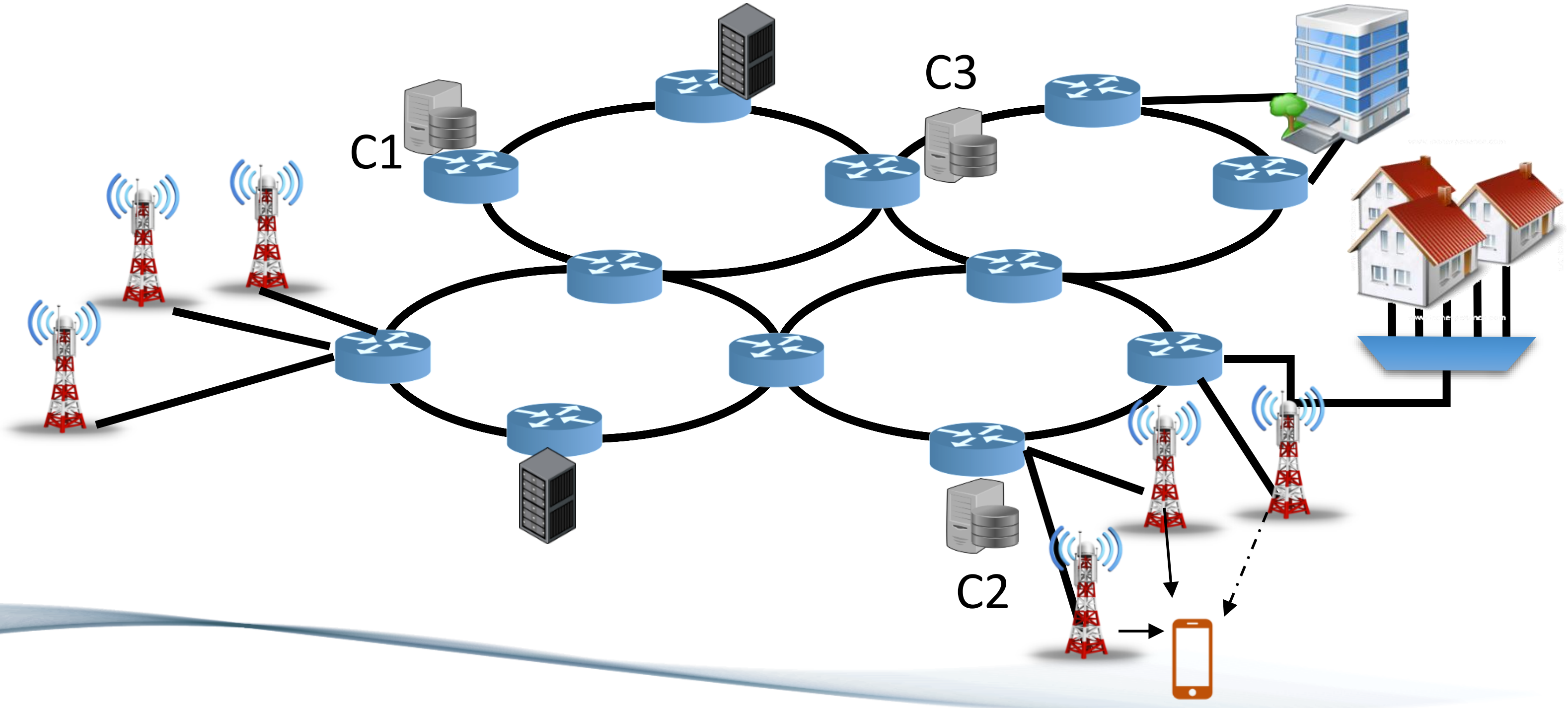


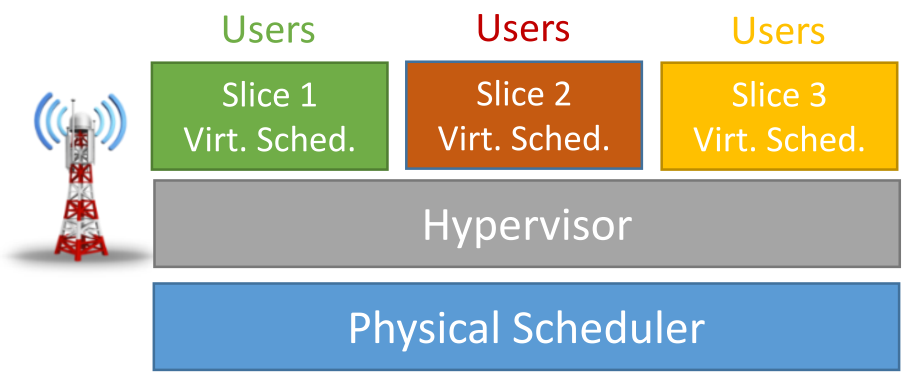
Integrated Optical-Wireless Reliable Slicing

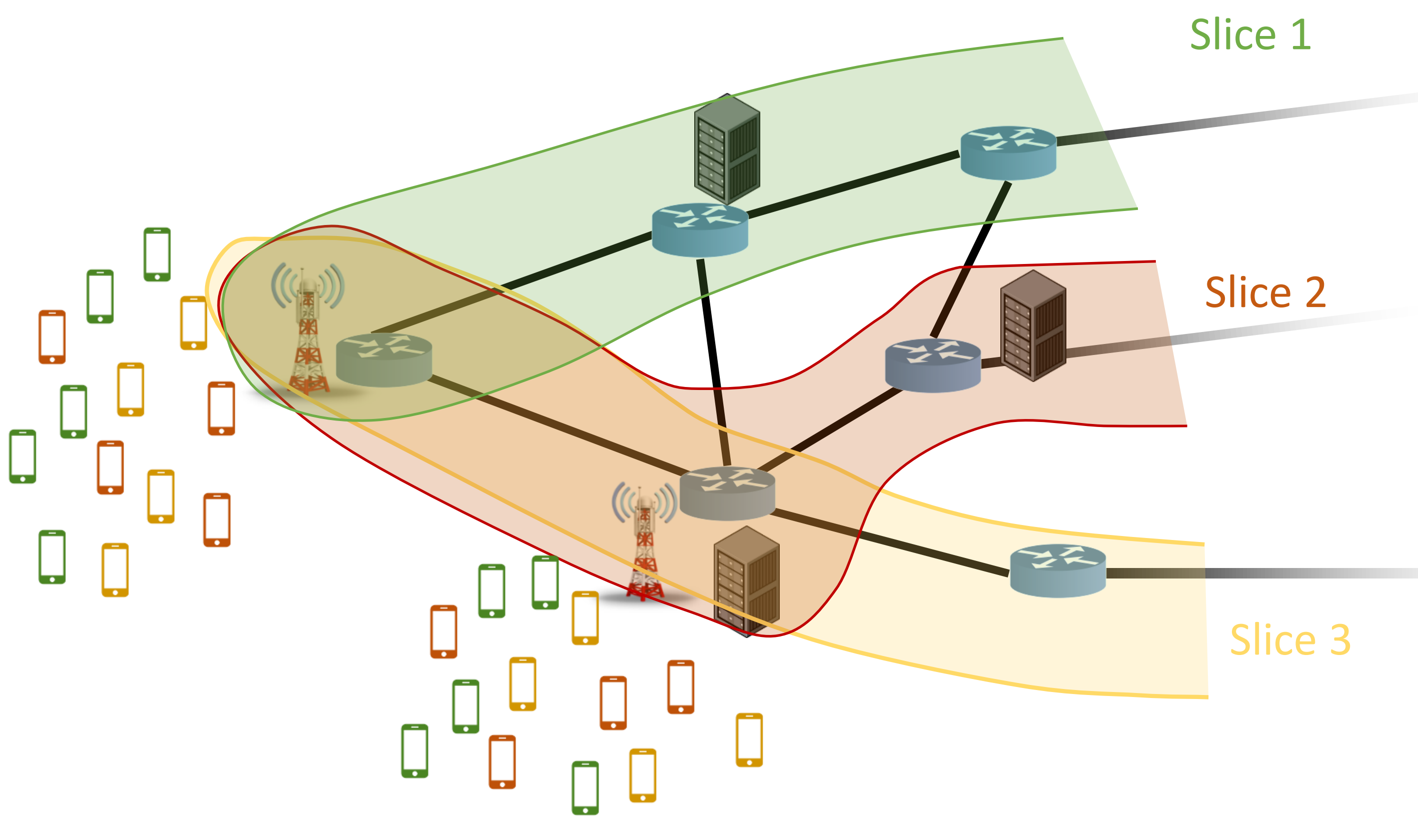
- Can we integrate mobile network resiliency and Metro-Access network protection in mobile multi-connectivity scenarios?



Slicing in Radio Access Networks (1)

- Radio Access Network (RAN) slicing is implemented at the radio scheduler
- Each Radio Access Point should support more than one slice





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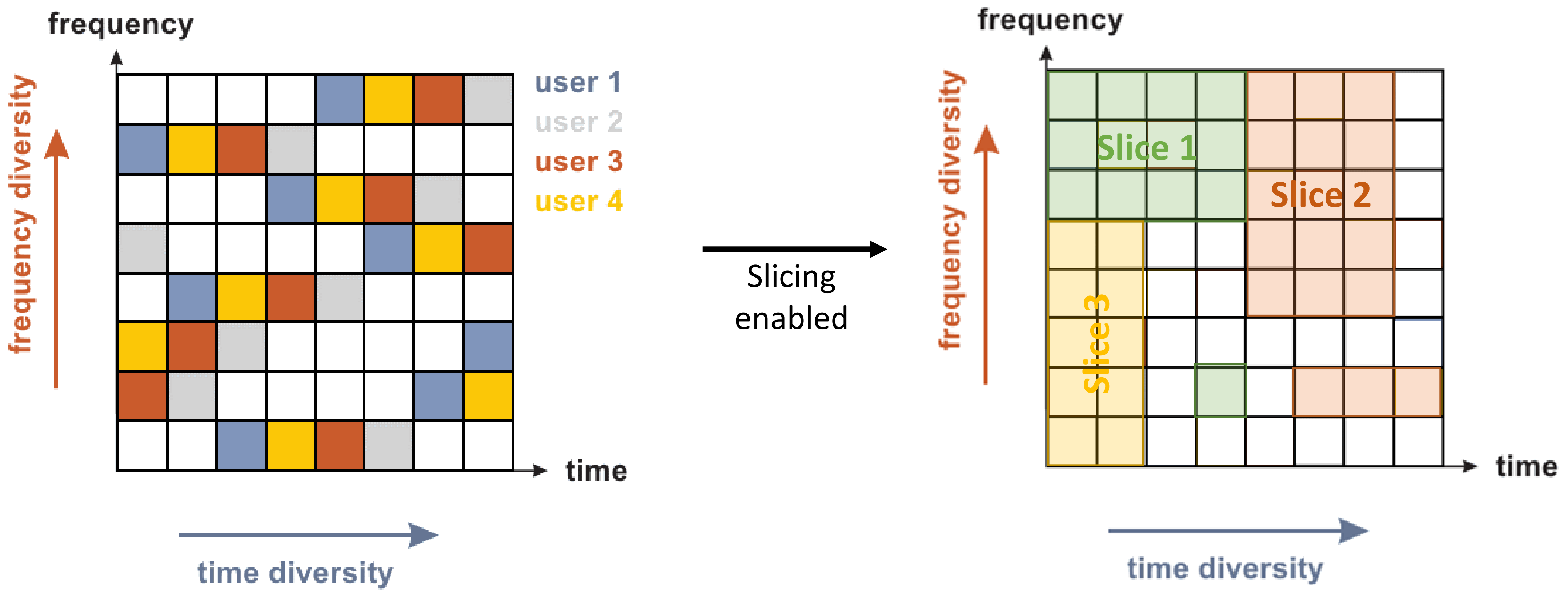
Slicing in Radio Access Networks (2)

- MAC in mobile networks is based on Orthogonal Frequency Division Multiple Access (OFDMA)



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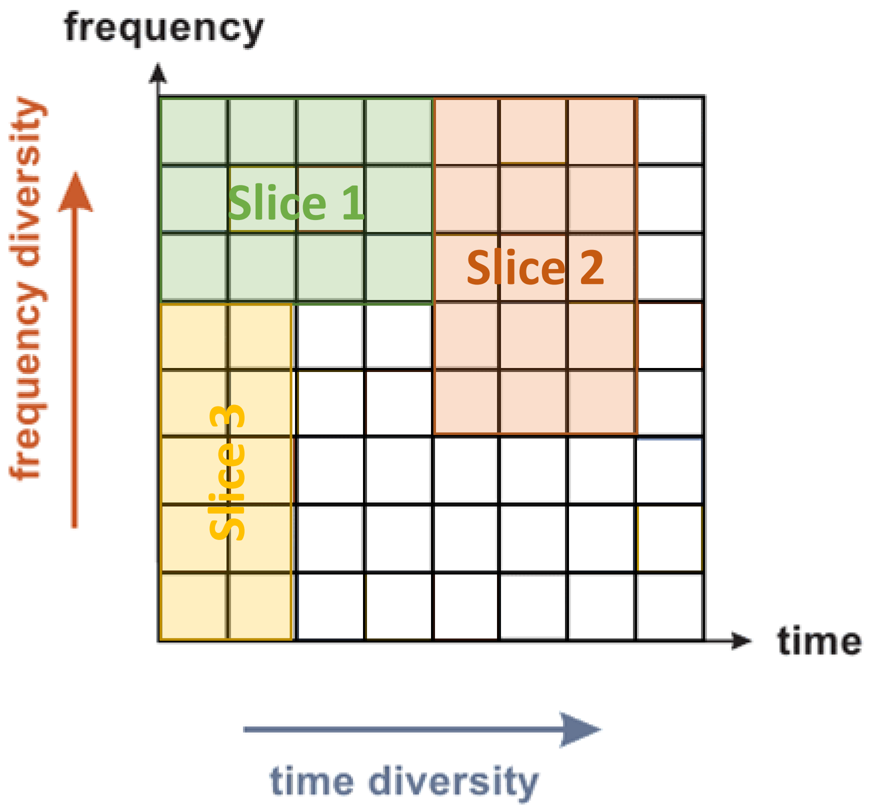
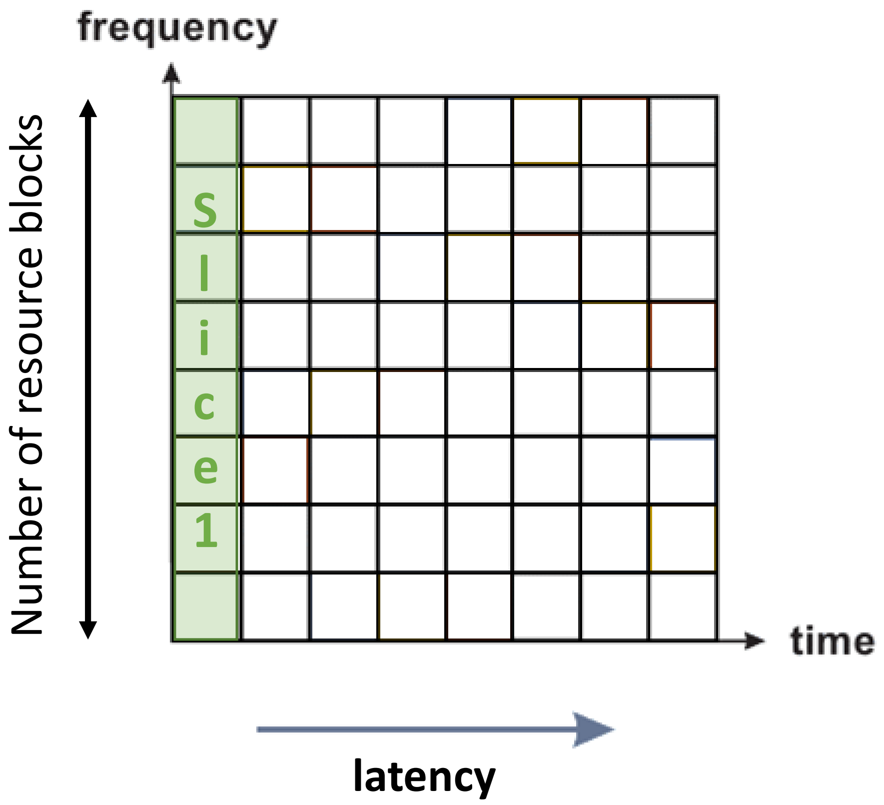
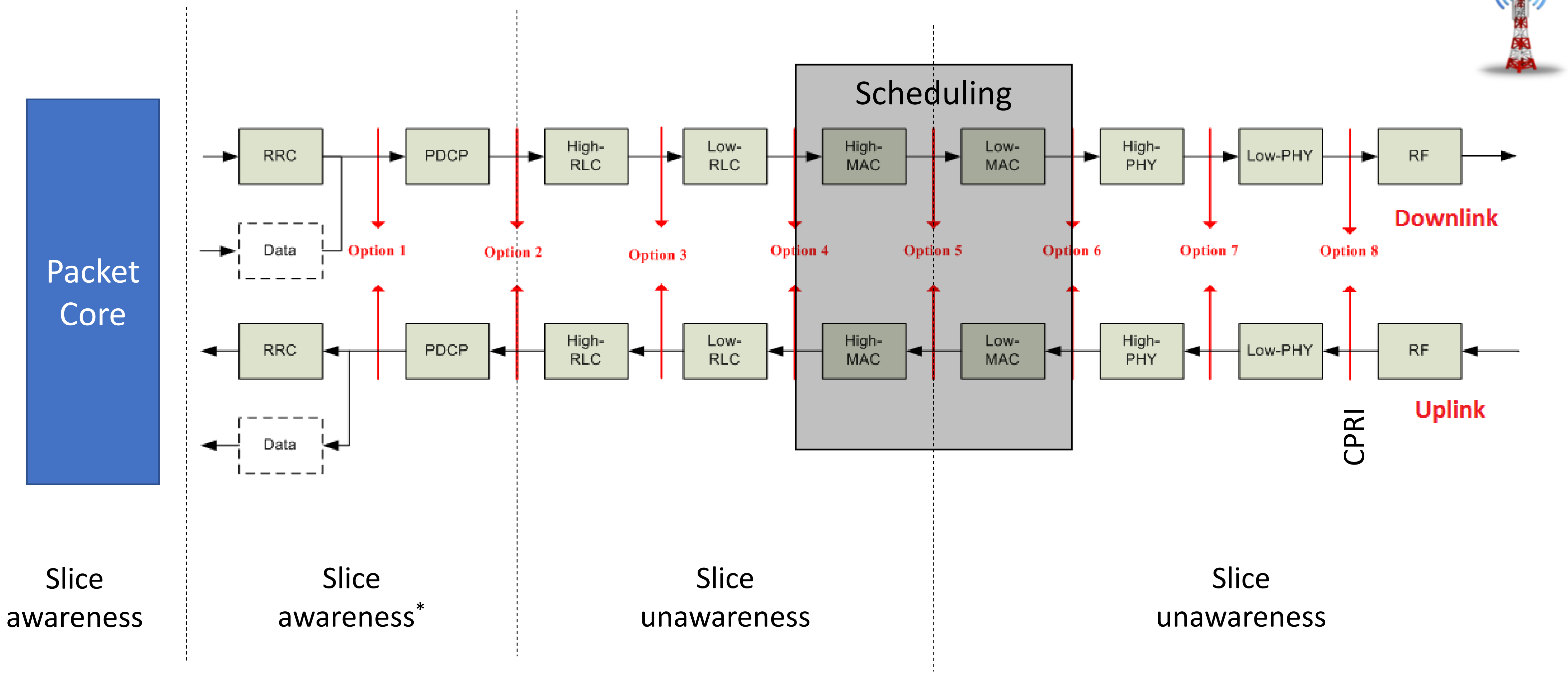
Slicing in Radio Access Networks (3)

- How many users can we serve under Ultra Reliable Low Latency Communications (URLLC) requirements?



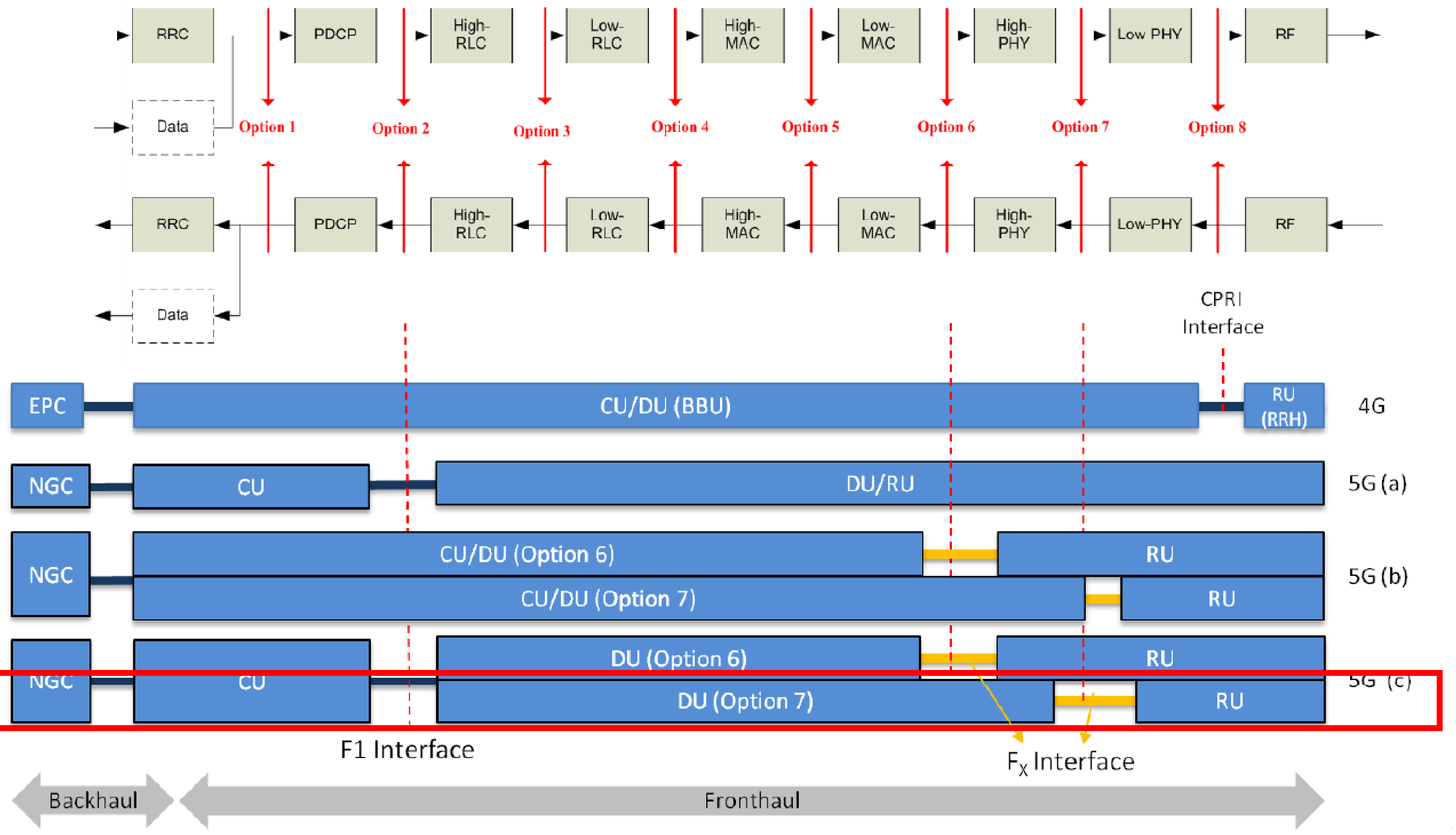


Virtual service chains for mobile network slicing (1)



3GPP, "Study on new radio access technology: Radio access: architecture and interfaces", Technical Report, Mar. 2017

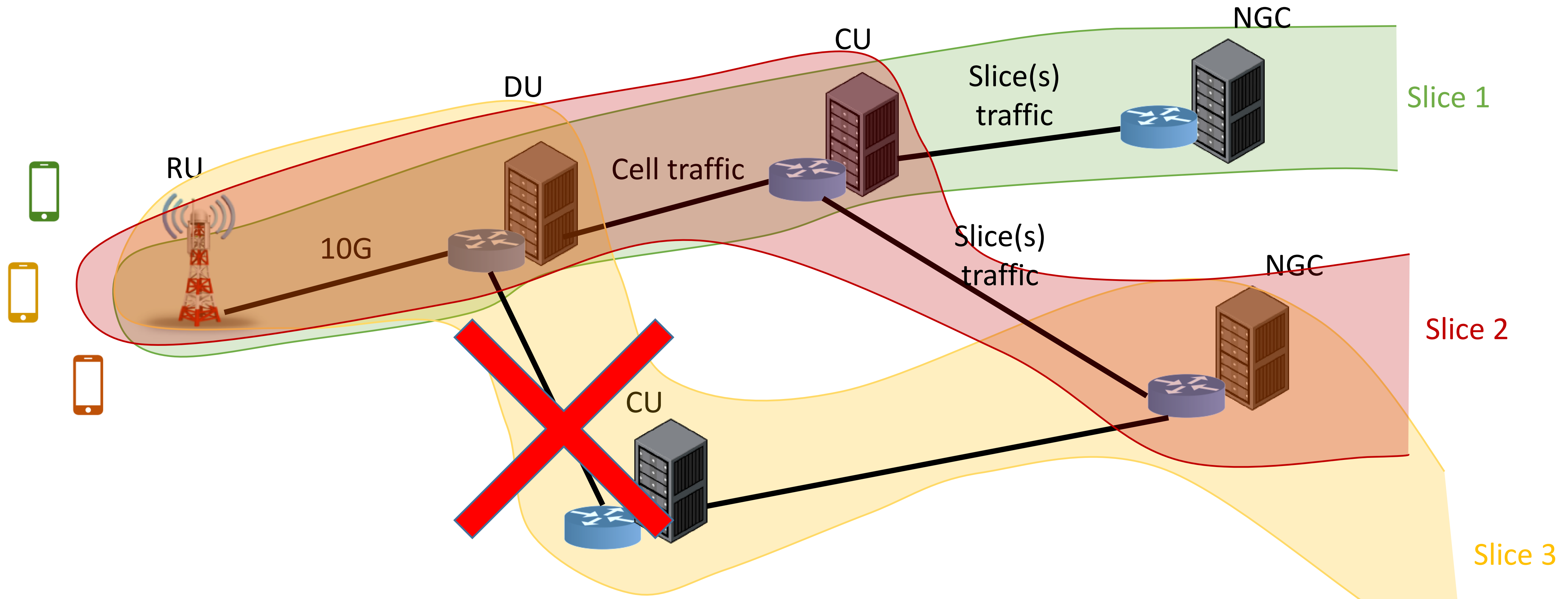
Virtual service chains for mobile network slicing (2)



ITU-T, "Transport network support of IMT-2020/5G", Technical Report, Feb. 2018

Virtual service chains for mobile network slicing (3)

- Chaining constraints



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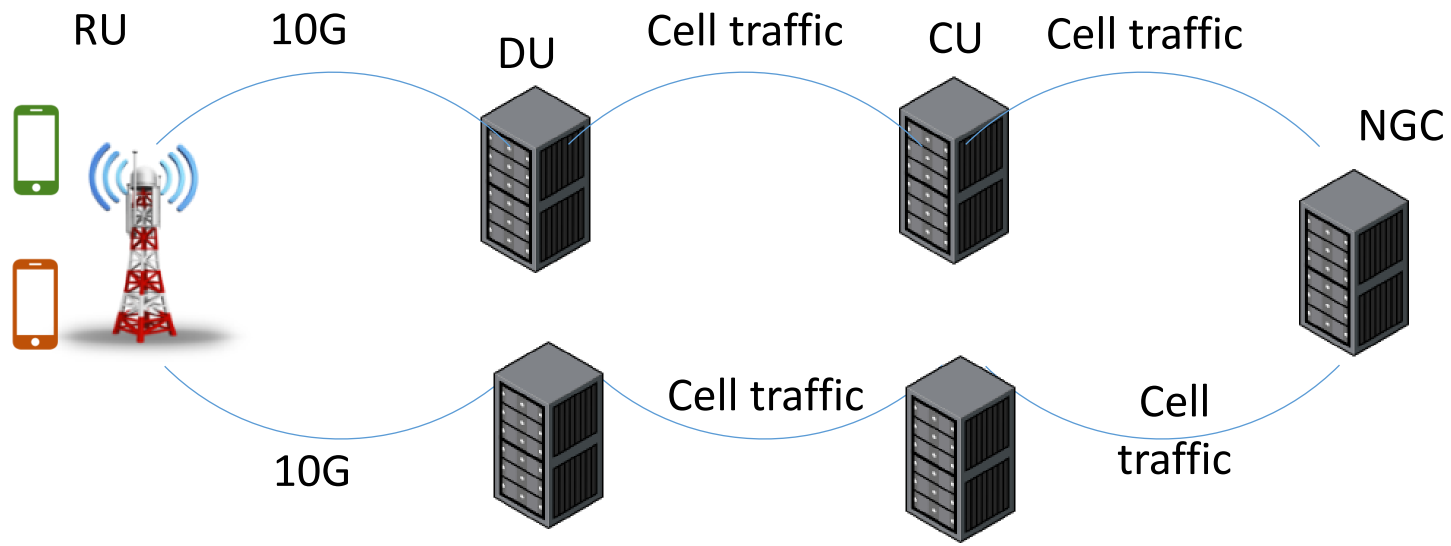
Service chains protection

- Whenever a RU hosts a slice with reliability requirements we need to implement a protection mechanism for the service chain the RU belongs to



End-to-end protection
- Node disjointness
- Link disjointness

Reliability requirements

No reliability requirements

Service chains protection

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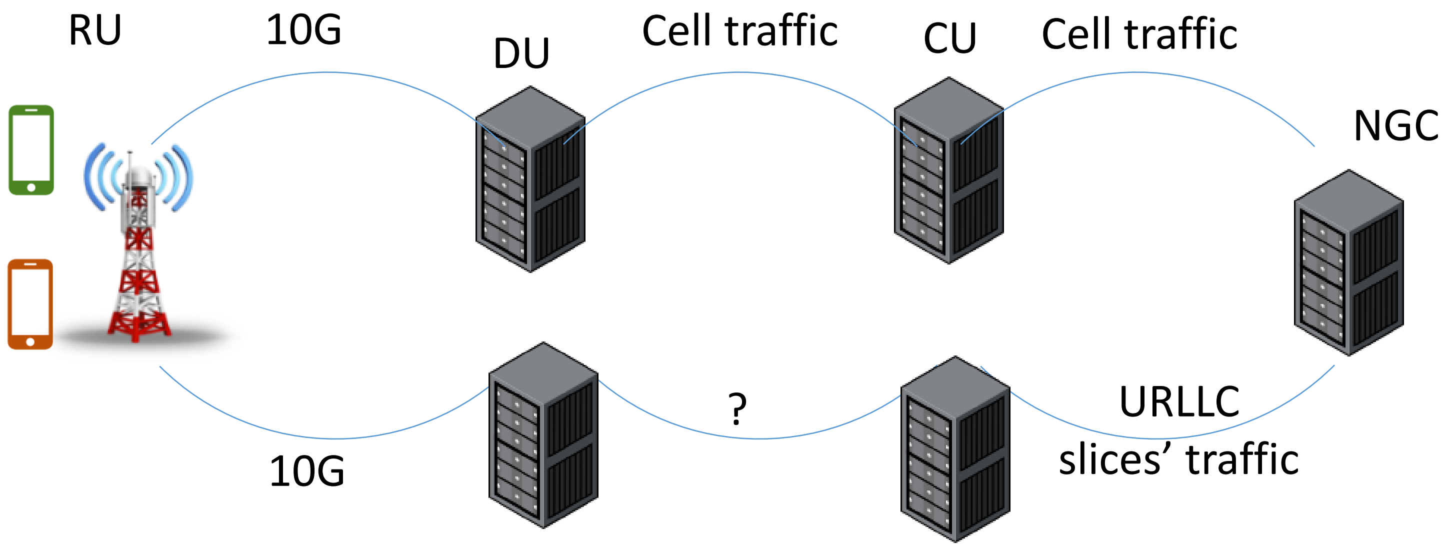

End-to-end protection

- Node disjointness
- Link disjointness

Reliability requirements

No reliability requirements

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Problem definition (1)

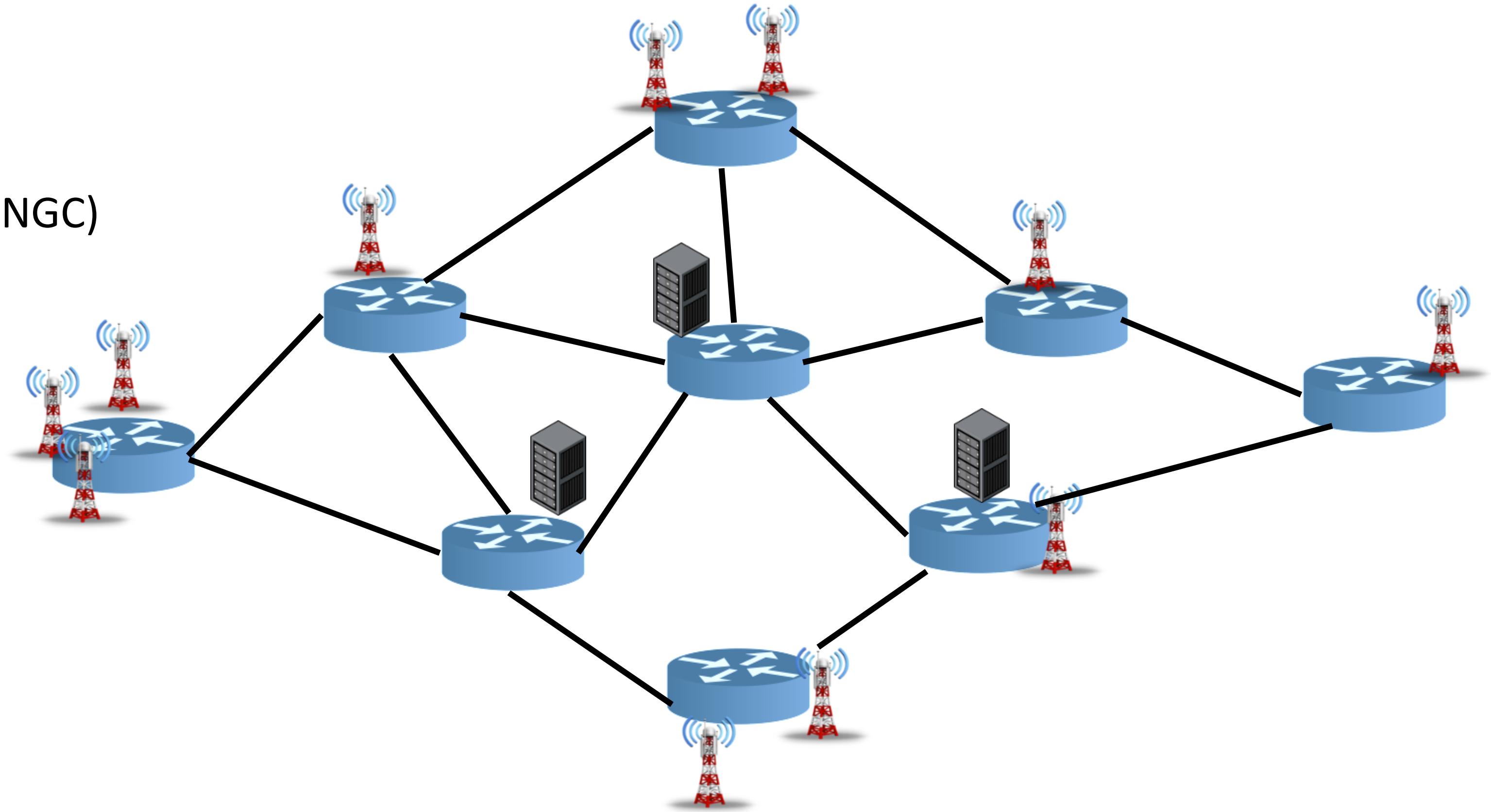
We focus on static design

- Input
    - Substrate network
    - Slicing requests
        - Users
        - A set of service chains (RRU-DU-CU-NGC)
    - Wireless connectivity of users

- We provision a primary path for all the service chains for all the slices
- We provision a backup path for all the chains with reliability requirements

- We individuate User-RU assignment

- Objective
    - Maximize the number of protected users



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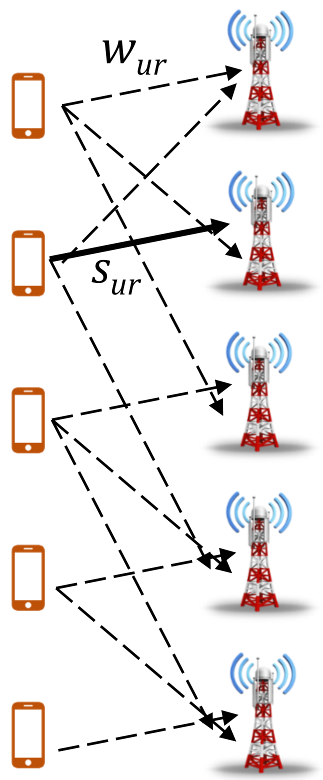
Problem definition (2)

- Objective:
  - Maximize the number of protected users
- Such that:
  - Each RU has a primary path
  - RUs serving reliable users have backup path
  - Placement constraints
    - VNF disjointness
  - Routing constraints
    - Link disjointness
    - Flow-conservation constraints virtual-links
    - Flow-conservation constraints lightpaths
  - Capacity constraints
    - Lightpaths capacity
    - Computational capacity
  - Wireless network constraints



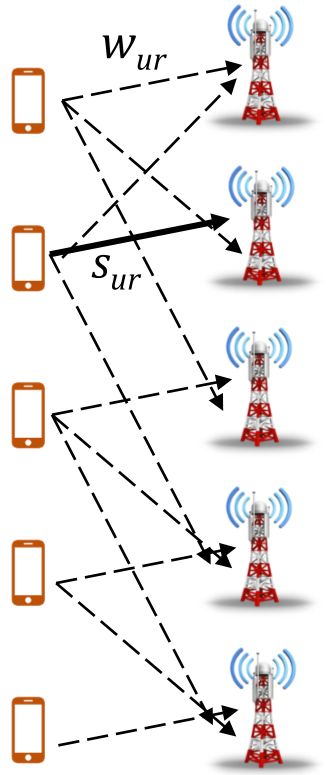
Thank you

Backup slides

ILP Modelling (1)

- Input and variables

$G^s(N^s, E^s)$	Substrate Network
$G^c(N^c, E^c)$	Service chain demands
X_{ij}	An integer variable denoting the number of lightpaths from substrate node i to j
$pf_{ij}^{c,l}$	A nonnegative variable denoting the traffic flow of the primary virtual link l in service chain c going through lightpath(s) or meta-edge (i, j)
$bf_{ij}^{c,l}$	A nonnegative variable denoting the traffic flow of the backup virtual link l in service chain c going through lightpath(s) or meta-edge (i, j)
$p_{a\omega}^{c}$	A binary variable denoting whether virtual primary node a of service chain c is mapped onto substrate node ω
$b_{a\omega}^{c}$	A binary variable denoting whether virtual backup node a of service chain c is mapped onto substrate node ω
Z_{mn}^{ij}	An integer variable denoting the number of lightpaths from substrate node *i* to substrate node *j* going through the fiber link *(m,n)*
π_u	A binary variable denoting whether user u is protected
$s_{u,r}$	A binary variable denoting whether user u is served by RU r
$w_{u,r}$	A binary parameter denoting whether user u has connectivity tu RU r
N_{RB}	Maximum number of users with reliability requirements per RU



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ILP Modelling (2)

- Objective:

$$Maximize \sum_{u} \pi_u$$

S. Zhang, L. Shi, C. S. K. Vadrevu, and B. Mukherjee, "Network virtualization over WDM and flexible-grid optical networks," *Optical Switching and Networking*, vol. 10, no. 4, pp. 291–300, 2013.

A. Hmaity, M. Savi, F. Musumeci, M. Tornatore, and A. Pattavina, "Protection strategies for virtual network functions placement and service chains provisioning", *Networks,* vol. 70, no. 4, pp. 373–387, 2017.

ILP Modelling(3)

- Placement constraints

$$\sum_{\omega} p_{a\omega}^{c} = 1 \; \forall \, c, a$$

$$\sum_{\omega} b_{a\omega}^{c} \leq 1 \; \forall \, c, a$$

$$p_{a\omega}^{c} + b_{a\omega}^{c} \leq 1 \quad \forall \, c, \forall \, a: a \neq EP(c)$$

$$b_{a\omega}^{c} = 1 \; \rightarrow R_{\omega} = 1 \; \forall \, a: a = SP(c)$$

$$p_{a\omega}^{c} = p_{\omega a}^{c} \forall \, c, a, \forall \, \omega \in N^{s}$$

$$b_{a\omega}^{c} = b_{\omega a}^{c} \; \forall \, c, a, \forall \, \omega \in N^{s}$$

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ILP Modelling(4)

- Routing constraints

$$\sum_i pf_{ij}^{c,l} - \sum_i pf_{ji}^{c,l} = \begin{cases} b_l^c & if\ (sink\ of\ l) = j \\ -b_l^c & if\ (source\ of\ l) = j \\ 0 & otherwise \end{cases} \quad \forall\ c, l, j$$

$$\sum_i bf_{ij}^{c,l} - \sum_i bf_{ji}^{c,l} = \begin{cases} b_l^c & if\ (sink\ of\ l) = j \\ -b_l^c & if\ (source\ of\ l) = j \\ 0 & otherwise \end{cases} \quad \forall\ c, l, j$$

$$\sum_n Z_{mn}^{ij} - \sum_n Z_{nm}^{ij} = \begin{cases} X_{ij} & if\ m = i \\ -X_{ij} & if\ m = j \\ 0 & otherwise \end{cases} \quad \forall\ m, i, j$$

$$pf_{ij}^{c,l} > 0 \rightarrow bf_{ji}^{c,l} = 0 \quad \forall\ i, j, c, l$$

$$bf_{ji}^{c,l} > 0 \rightarrow pf_{ij}^{c,l} = 0 \quad \forall\ i, j, c, l$$

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ILP Modelling(5)

- Capacity constraints

$$\sum_{c,l} pf_{ij}^{c,l} + \sum_{c,l} bf_{ji}^{c,l} \leq C \times X_{ij} \qquad \forall\, i, j$$

$$\sum_{l} pf_{a\omega}^{c,l} \leq B^c \times p_{a\omega}^{c} \qquad \forall\, c \text{ and metaedge } a\omega$$

$$\sum_{l} bf_{a\omega}^{c,l} \leq B^c \times b_{a\omega}^{c} \qquad \forall\, c \text{ and metaedge } a\omega$$

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ILP Modelling(6)

- Wireless constraints

$$w_{u,r} \geq s_{u,r} \quad \forall\, u, r$$

$$\sum_{r} s_{u,r} = 1 \;\forall\, u$$

$$\sum_{u} s_{u,r} \leq N_{RB} \;\forall\, r$$

$$R_{\omega} = 1 \vee s_{u,\omega} = 1 \rightarrow \pi_u = 1 \;\forall u, \omega$$

Objective:

$$Maximize \sum_{u} \pi_u$$

Thank you

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