



Aalto University
School of Electrical
Engineering



Towards 6G – New Breeze of Networking

Prof. Tarik Taleb

Director & Founder of MOSA!C LAB

www.mosaic-lab.org

Aalto University and Oulu University, Finland

Outline

- **5G Current Stand**
- **Beyond 5G Use Cases & Requirements**
- **Beyond 5G Networking**

MOSA!C LAB

Mobile Network Softwarization & Service Customization

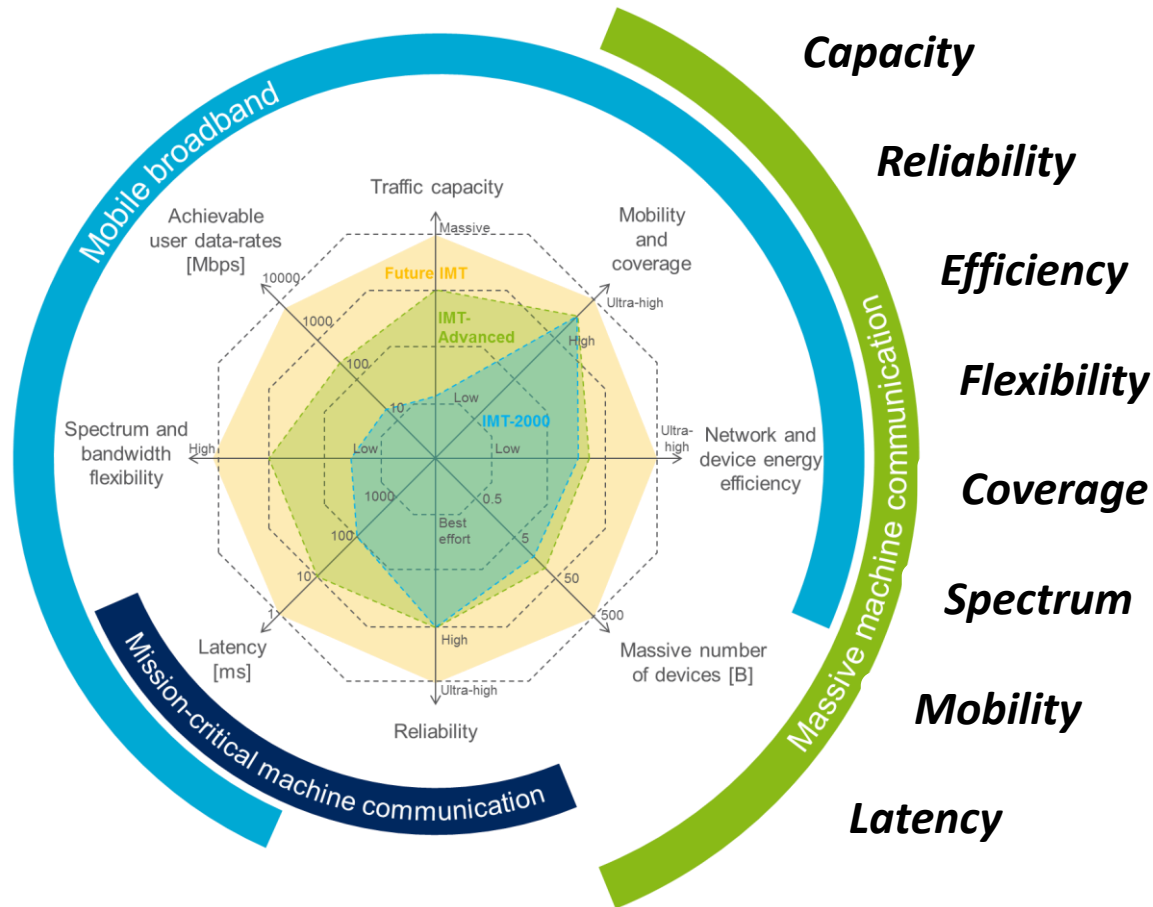
5G: Current Stand

Current State of 5G

- **Challenging Biz Models**
 - Verticals/OTT do not buy/pay



5G Requirements



Current Stand of 5G Use Cases

eMBB
5G

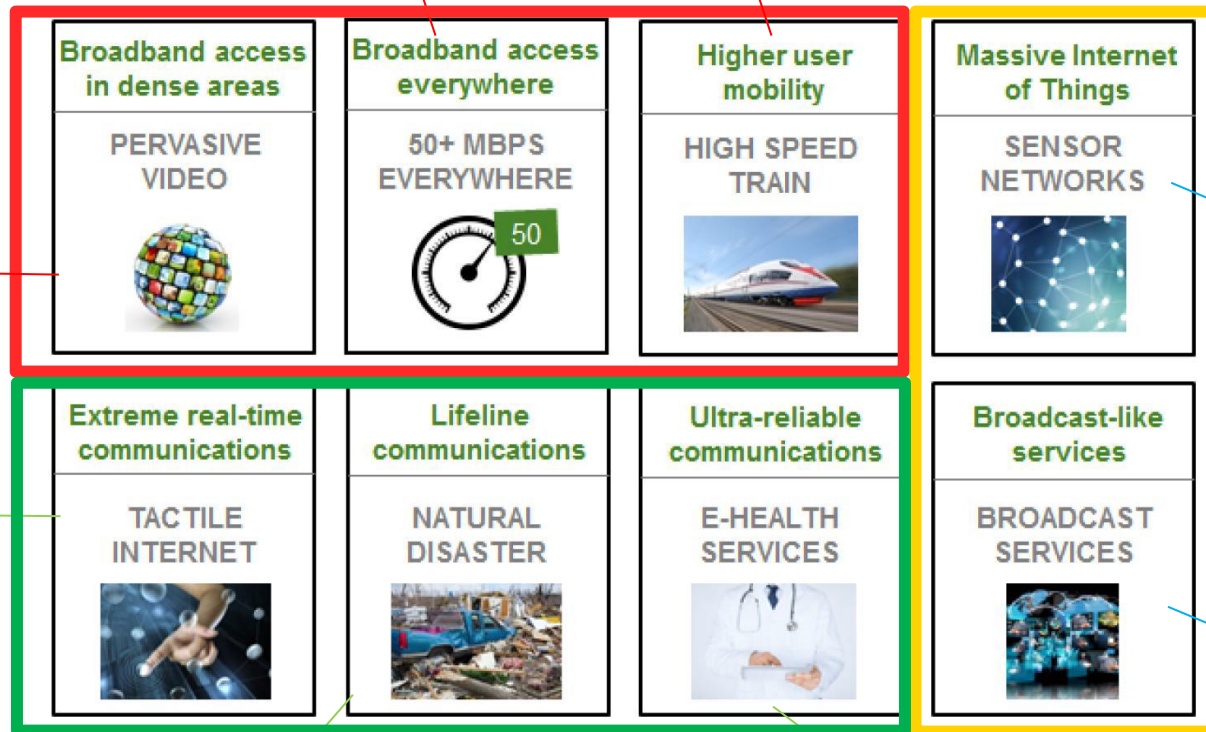
CUP Separation/
C-RAN functional
split

Higher speeds x10 /
Wider coverage

mmWave Backhaul /
Multi-Service / Slicing

4G
mIoT

Radio: LTE-M/NB-IoT
Business Model-Open



eMBMS – 3GPP Rel.14
Business Model-Open

3GPP Rel.14 Mission Critical Services
UAV enhancements

Reliability of 99.999%
not feasible

Meeting the Required
Latency challenging
B5G/6G
URLLC

Beyond 5G Use Cases

NEW

- Holographic Teleportation
- Augment Projection Surfaces
- Situational Awareness - Analytics
- Internet-of-Everything (IoE)
- Internet of Intelligence
- Digital Twin

OLD

- Vehicular – Autonomous Driving
- UAV Services
- Deterministic Services
 - Tactile Internet
 - eHealth
 - Industry 4.0



MOSA!C LAB

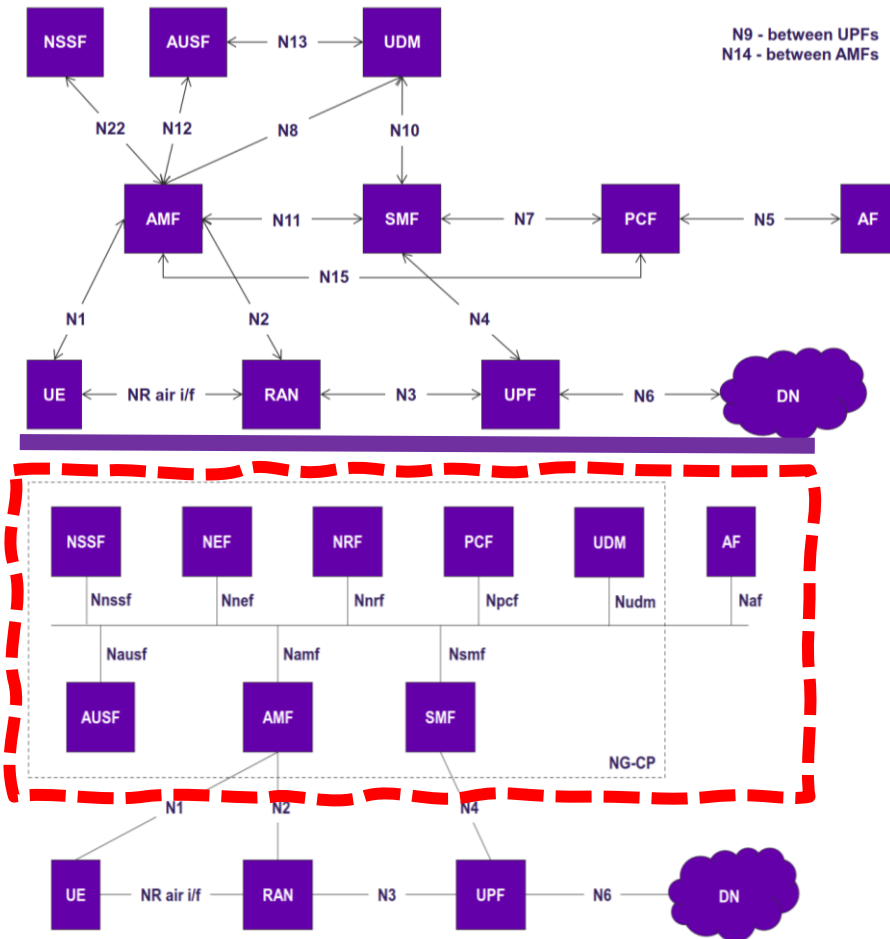
Mobile Network Softwarization & Service Customization

6G: Network of Networks?

IT Principles in 5G

- **Heavy involvement of Cloud Computing**
 - IaaS
 - PaaS
 - SaaS
- **Strong Adoption of IT principles**
 - Micro Service Concept
 - Integration Fabric Concept
 - Network Function Virtualization
 - Network Slicing & Softwarization
 - Service Based Architecture

Some SBA Principles Adopted ...

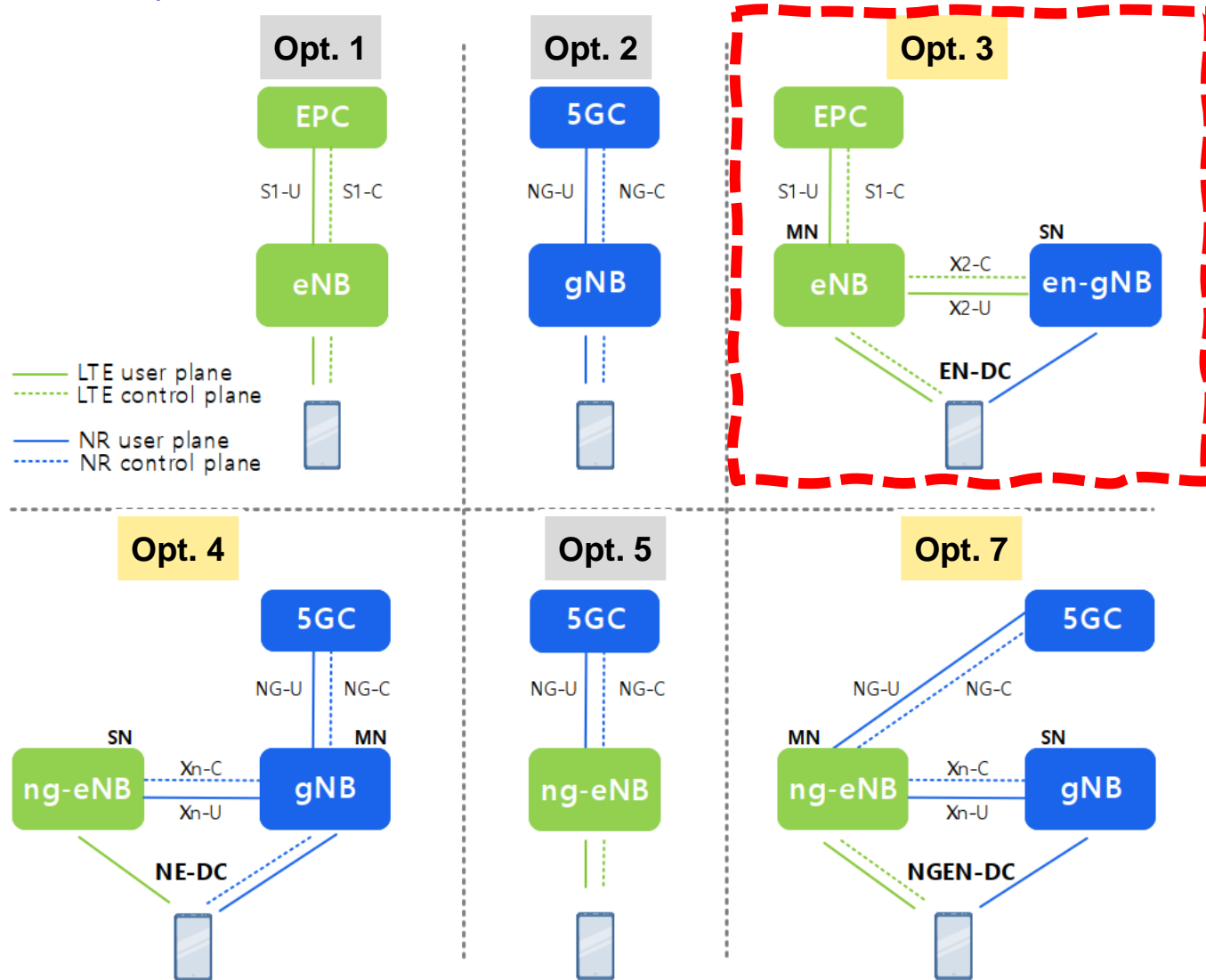


- **Loosely coupled** services, flexibility in service oriented control plane

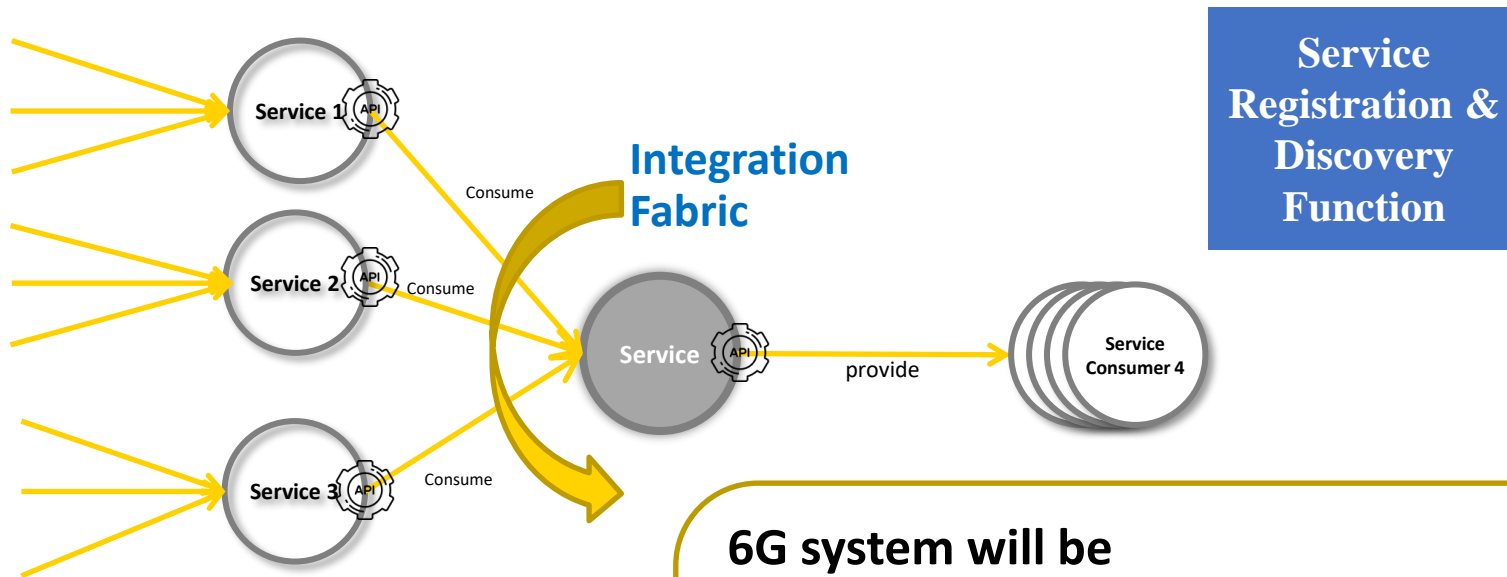
The network architecture shall be truly cloud-native!

- **Openness** to 3rd parties via Northbound APIs

... Hence, NSA 5G Deployment ... 5G Core under work progress!



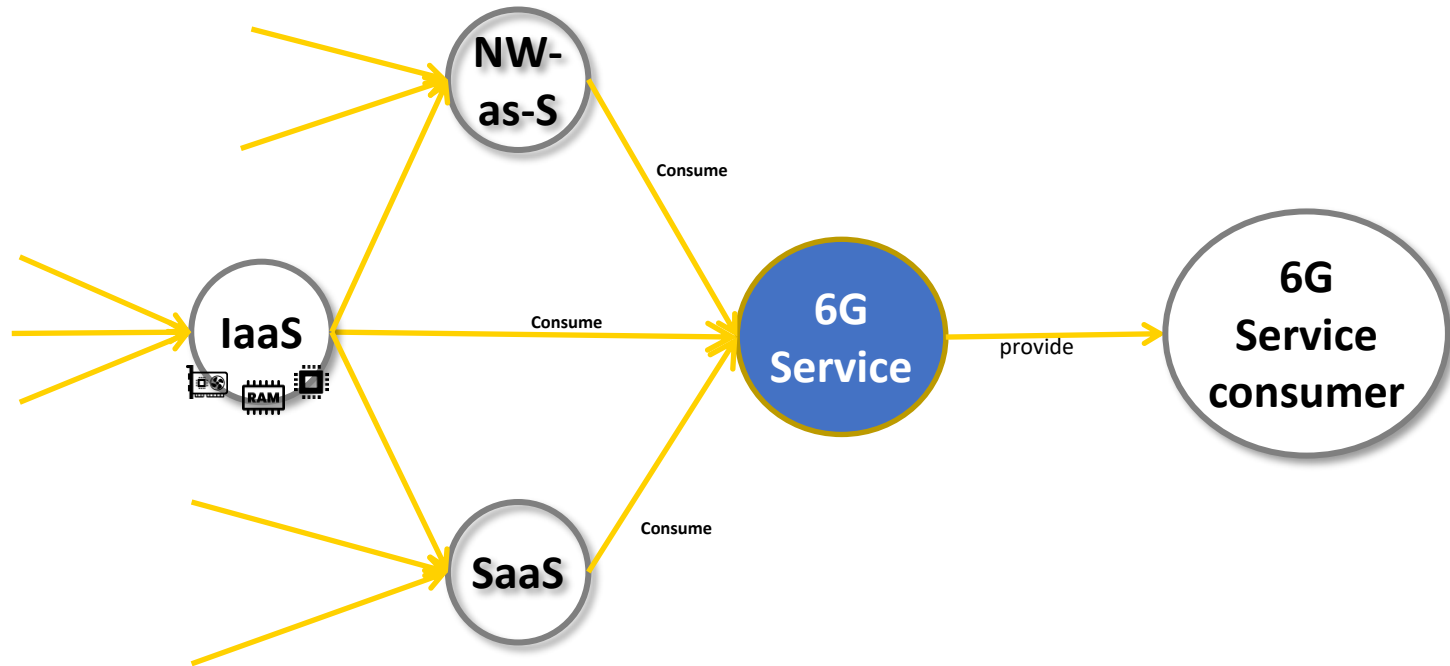
6G System Architecture - What kind?



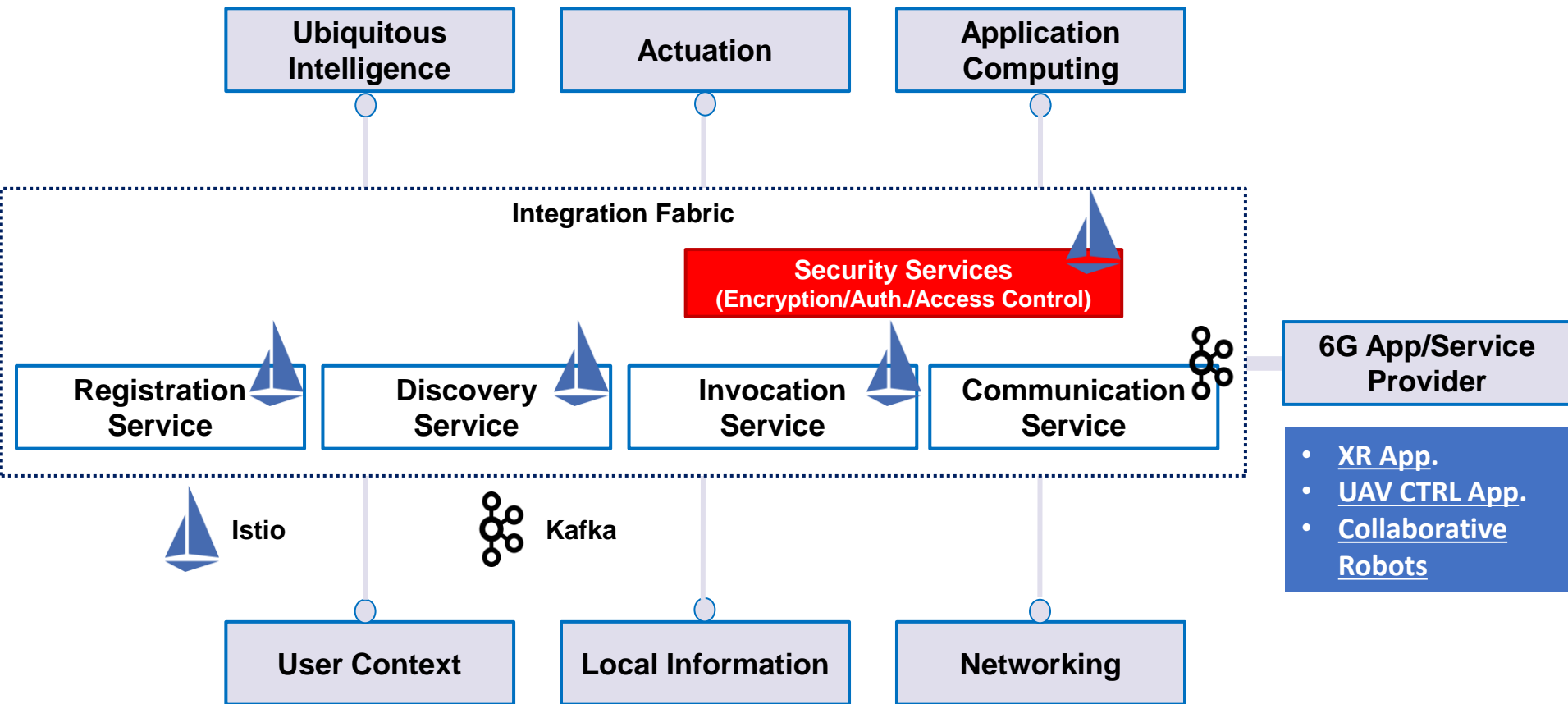
6G system will be

- truly cloud native,
- entirely SBA-based,
- composed of a set of services,
discoverable & able to provide services
to other authorized services through
specified APIs.

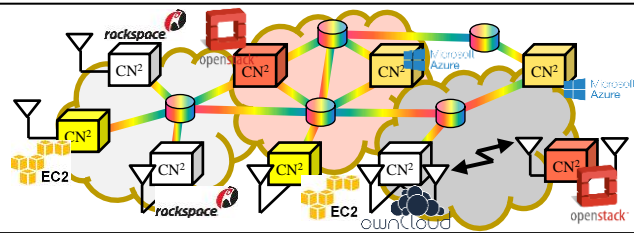
6G System Architecture - What kind?



6G System Architecture: Service of Services



6G System Architecture - Components

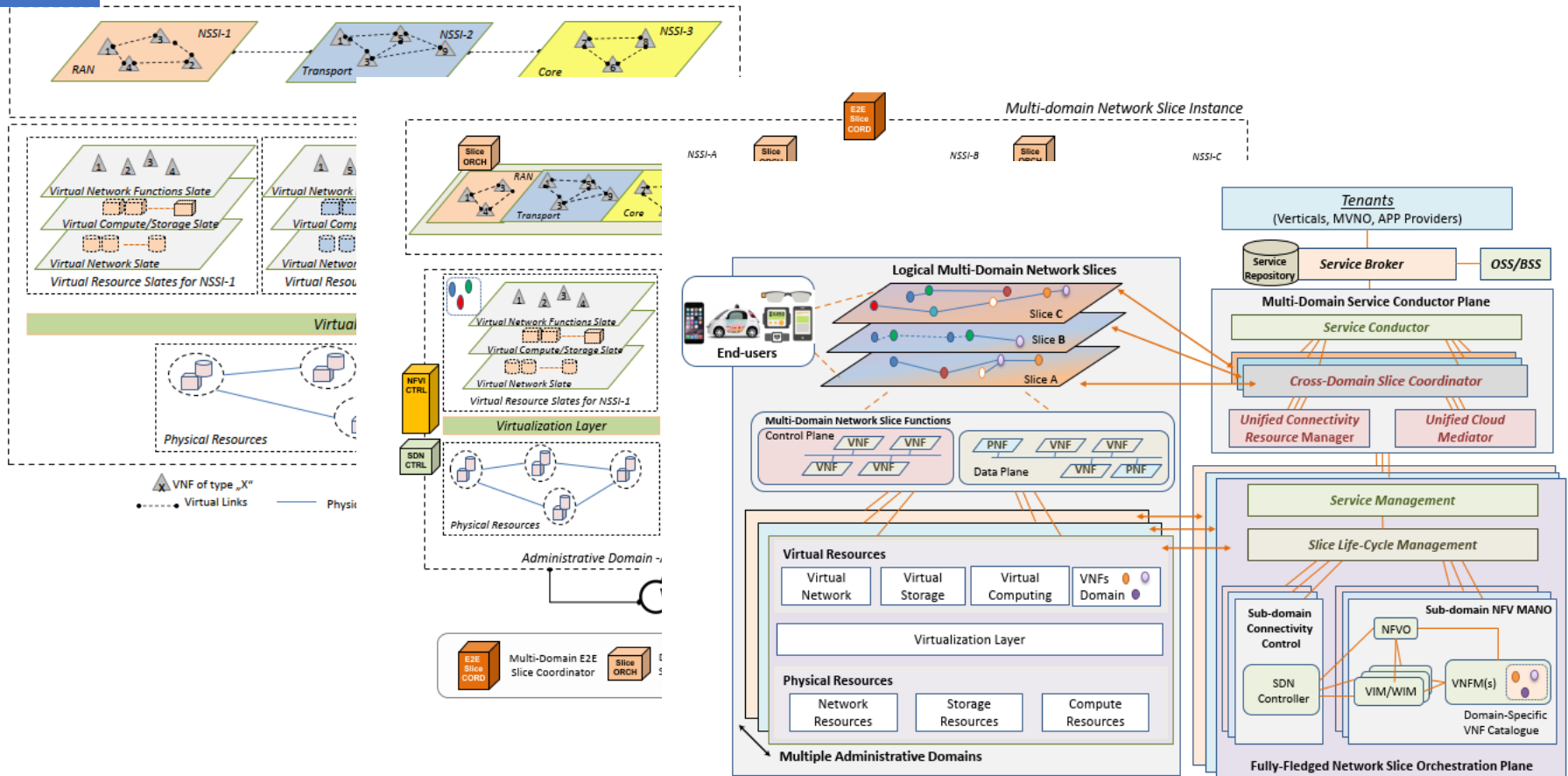


Cross-Domain
Resource
MANO

Multi-Tech/Admin Domains of Physical Computing and Network Infrastructure

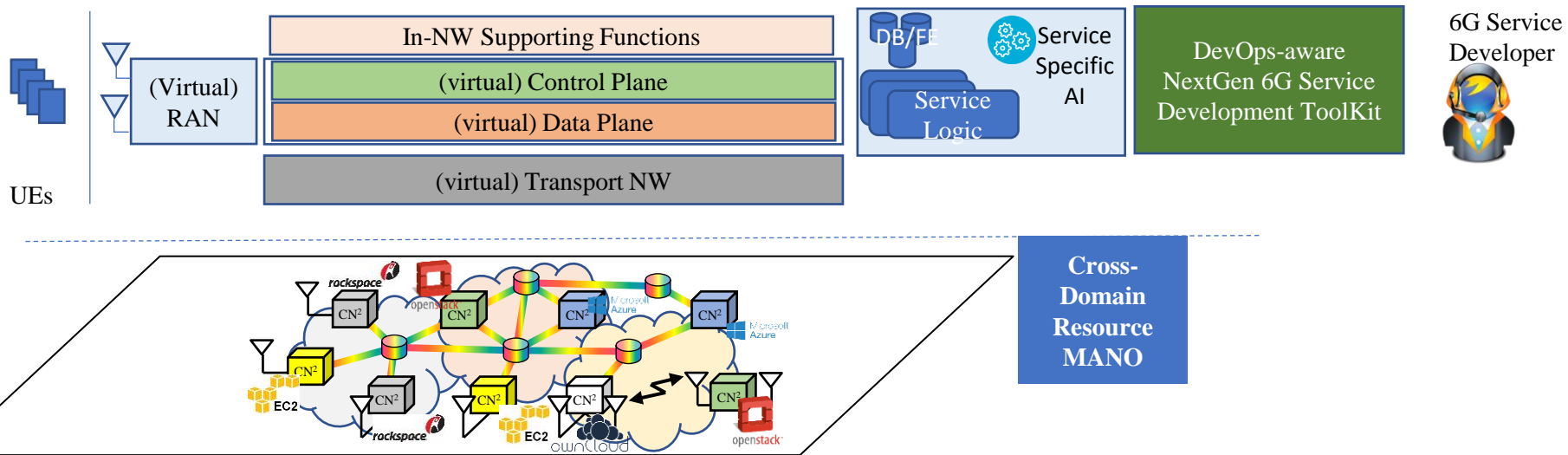
6G System Components

Cross-Domain Resource MANO



T. Taleb, I. Afolabi, K. Samdanis and F. Z. Yousaf, "On Multi-domain Network Slicing Orchestration Architecture & Federated Resource Control," in IEEE Network Magazine, Vol. 33, No. 5, Sep. 2019, pp. 242 - 252

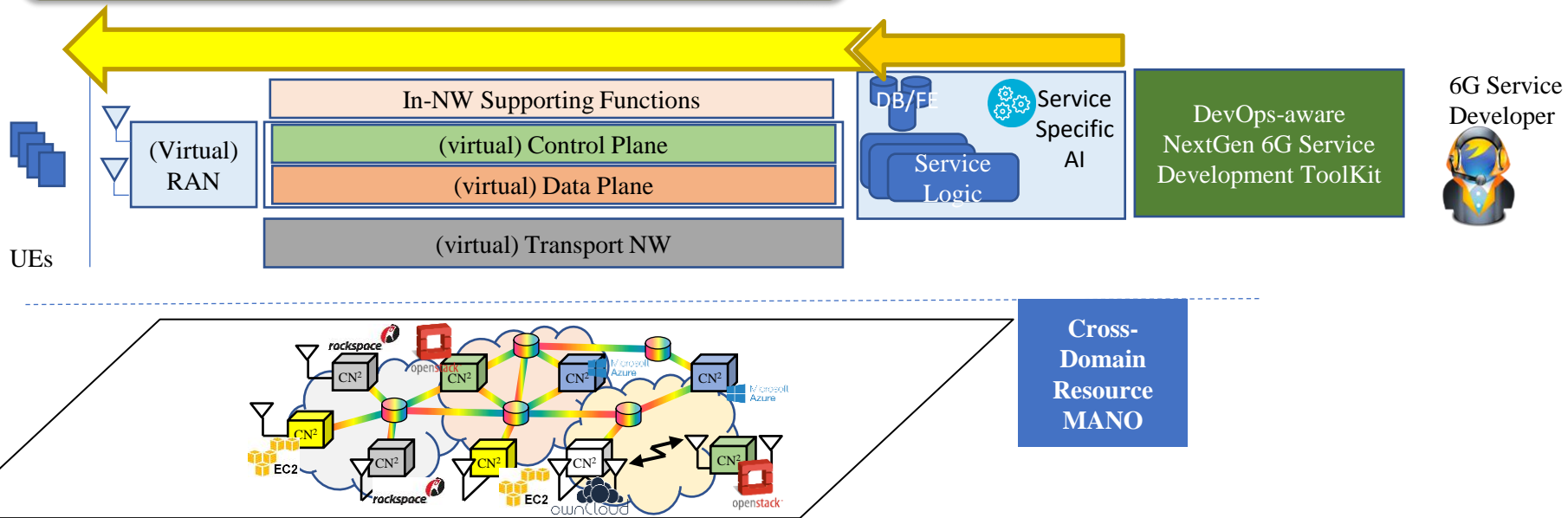
6G System Components



Multi-Tech/Admin Domains of Physical Computing and Network Infrastructure
Each Infra with its own Physical Infra Manager

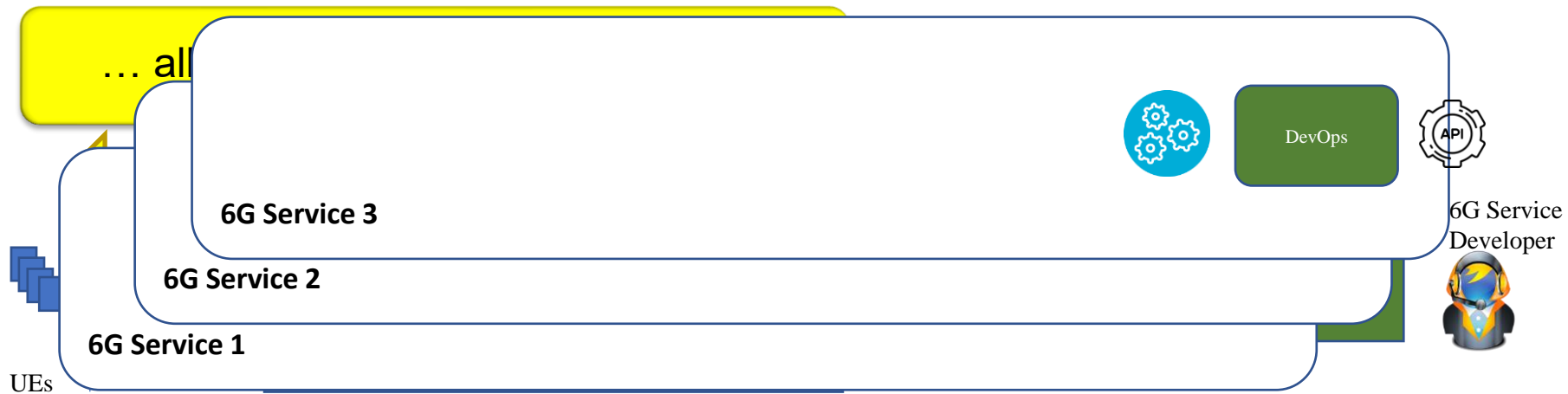
Extend the concept of cloud computing beyond DCs

... all the way towards mobile users



Multi-Tech/Admin Domains of Physical Computing and Network Infrastructure
Each Infra with its own Physical Infra Manager

Extend the concept of cloud computing beyond DCs



Mobile Connectivity + Transport Networking + In Networking Computing + Decentralized Computing + Smart Storage + DevOps offered as One E2E Service (atomic)

- On-Demand
- Elastic
- Multi-Tenant, and
- Pay-As-You-Go

MOSA!C LAB

Mobile Network Softwarization & Service Customization

6G: Deterministic Networking

Current Stand of 5G Use Cases

eMBB
5G

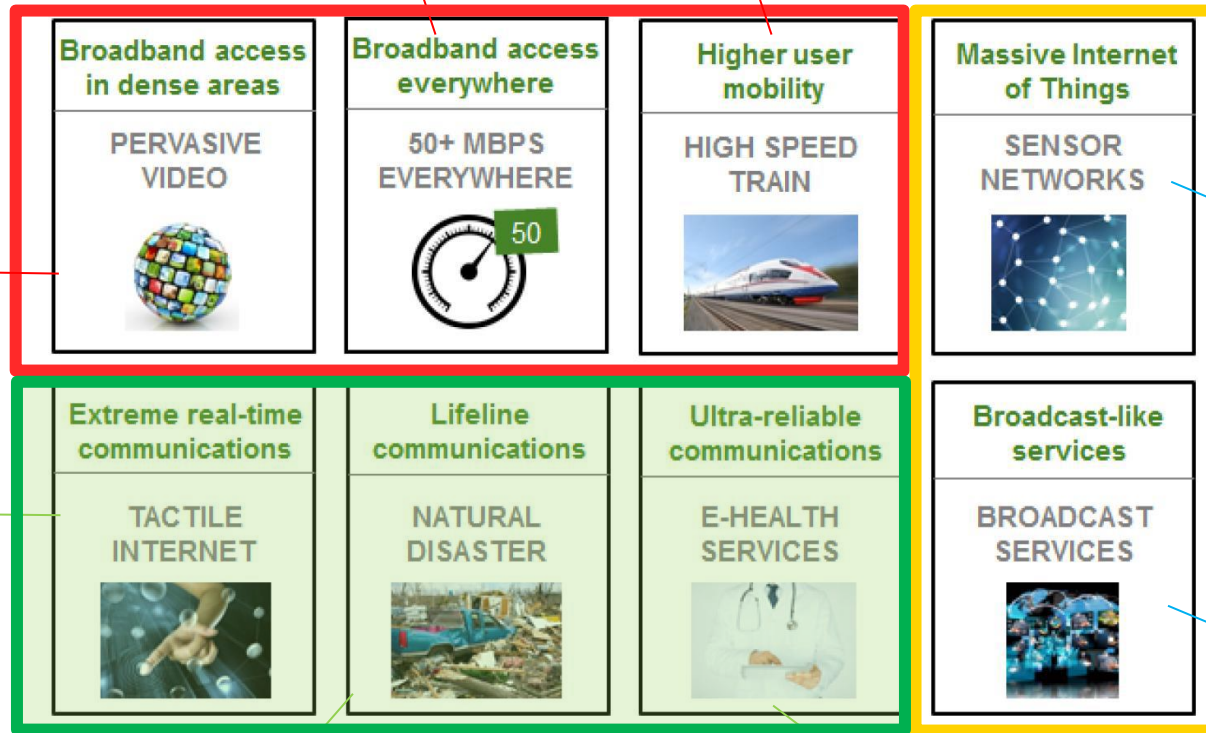
CUP Separation/
C-RAN functional
split

Higher speeds x10 /
Wider coverage

mmWave Backhaul /
Multi-Service / Slicing

4G
mIoT

Radio: LTE-M/NB-IoT
Business Model-Open



eMBMS – 3GPP Rel.14
Business Model-Open

3GPP Rel.14 Mission Critical Services
UAV enhancements

Reliability of 99.999%
not feasible

Meeting the Required
Latency challenging
B5G/6G
URLLC

Deterministic Networking: Future Trend!

Voice service

Circuit switch, TDM
eg: 64 Kbit/s
Constant bit rate (CBR)



Consumer Internet

packet switch, statistic multiplexing
eg: image, video, search
Best-effort



Production Internet

Real-time Ethernet
eg: event alarm
Punctual, accurate

Use case (high level)		Availability	Cycle time	Typical payload size	# of devices	Typical service area
Motion control	Printing machine	>99.9999%	< 2 ms	20 bytes	>100	100 m x 100 m x 30 m
	Machine tool	>99.9999%	< 0.5 ms	50 bytes	~20	15 m x 15 m x 3 m
	Packaging machine	>99.9999%	< 1 ms	40 bytes	~50	10 m x 5 m x 3 m
Mobile robots	Cooperative motion control	>99.9999%	1 ms	40-250 bytes	100	< 1 km ²
	Video-operated remote control	>99.9999%	10 – 100 ms	15 – 150 kbytes	100	< 1 km ²
Mobile control panels with safety functions	Assembly robots or milling machines	>99.9999%	4-8 ms	40-250 bytes	4	10 m x 10 m
	Mobile cranes	>99.9999%	12 ms	40-250 bytes	2	40 m x 60 m
Process automation (process monitoring)		>99.99%	> 50 ms	Varies	10000 devices per km ²	

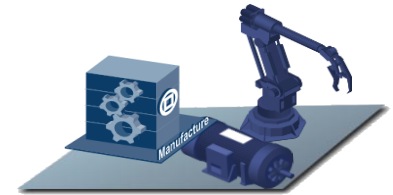
White Paper. "5G for Connected Industries and Automation," 5G Alliance for Connected Industries and Automation (5G ACIA)

AR/VR



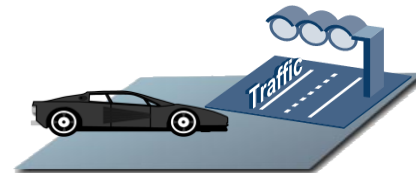
E2E latency: ≤10ms
reliability: 99.99%
jitter: ~10 us

Industry Automation



E2E latency: 25us-2ms
reliability: 99.999%
jitter: 1 us

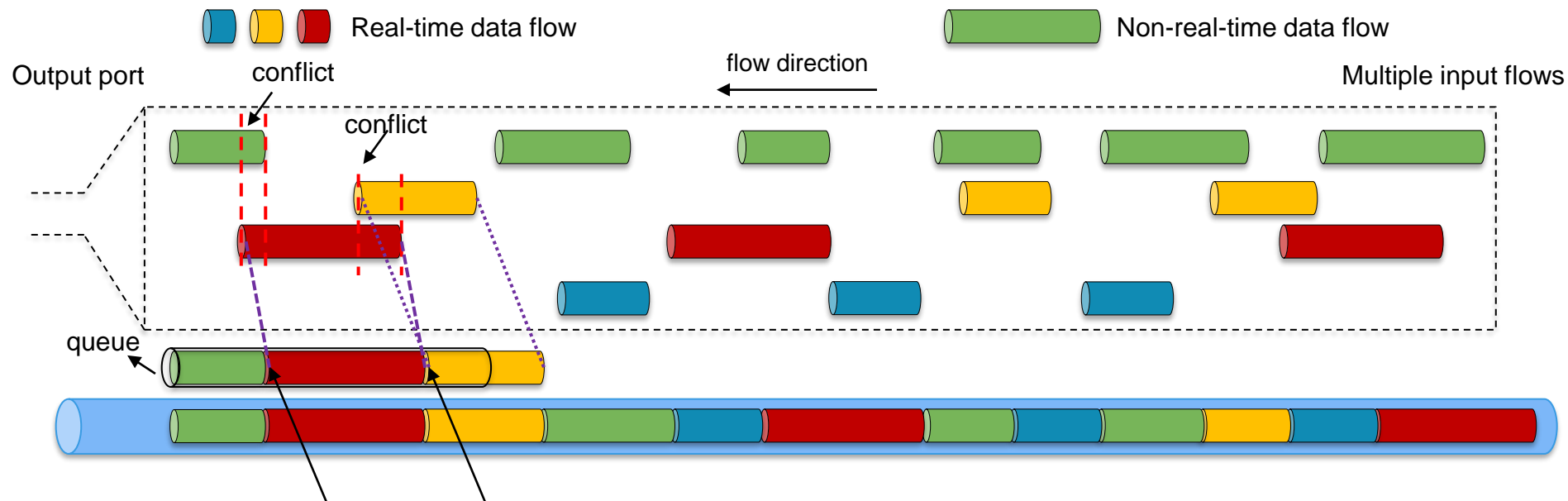
Automatic Driving



E2E latency: ≤5ms
reliability: 99.999%
jitter: 1 us

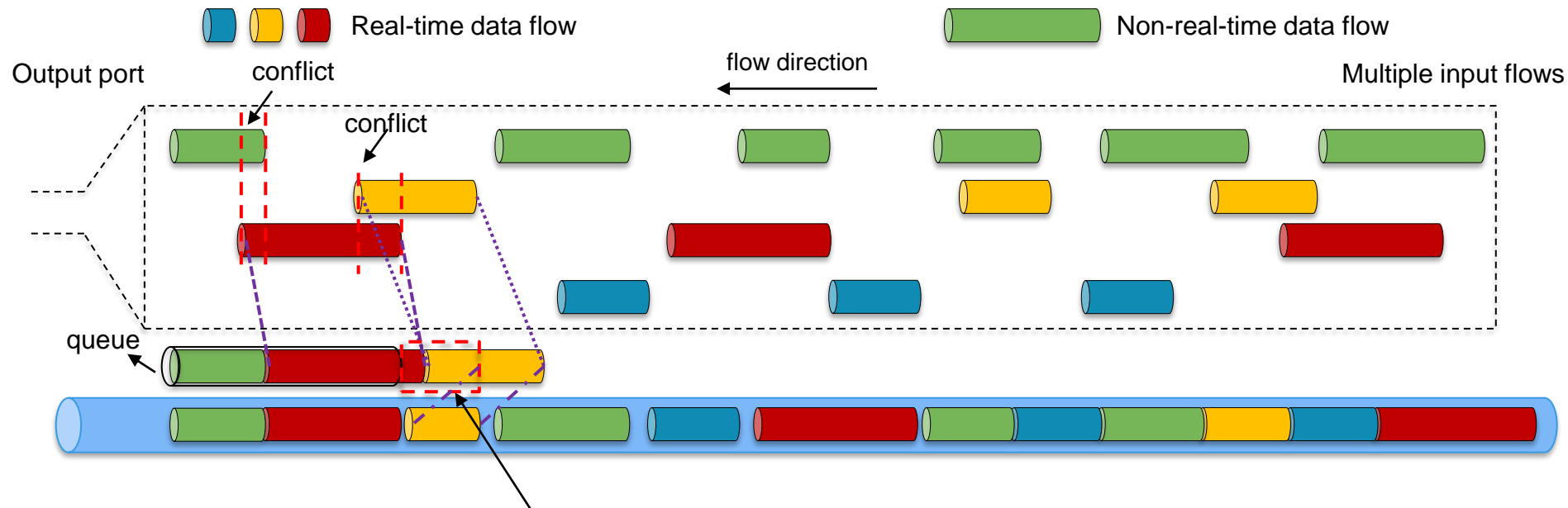
Deterministic Networking: Future Trend!

Conflicts result in *queueing delay, or packet drops*



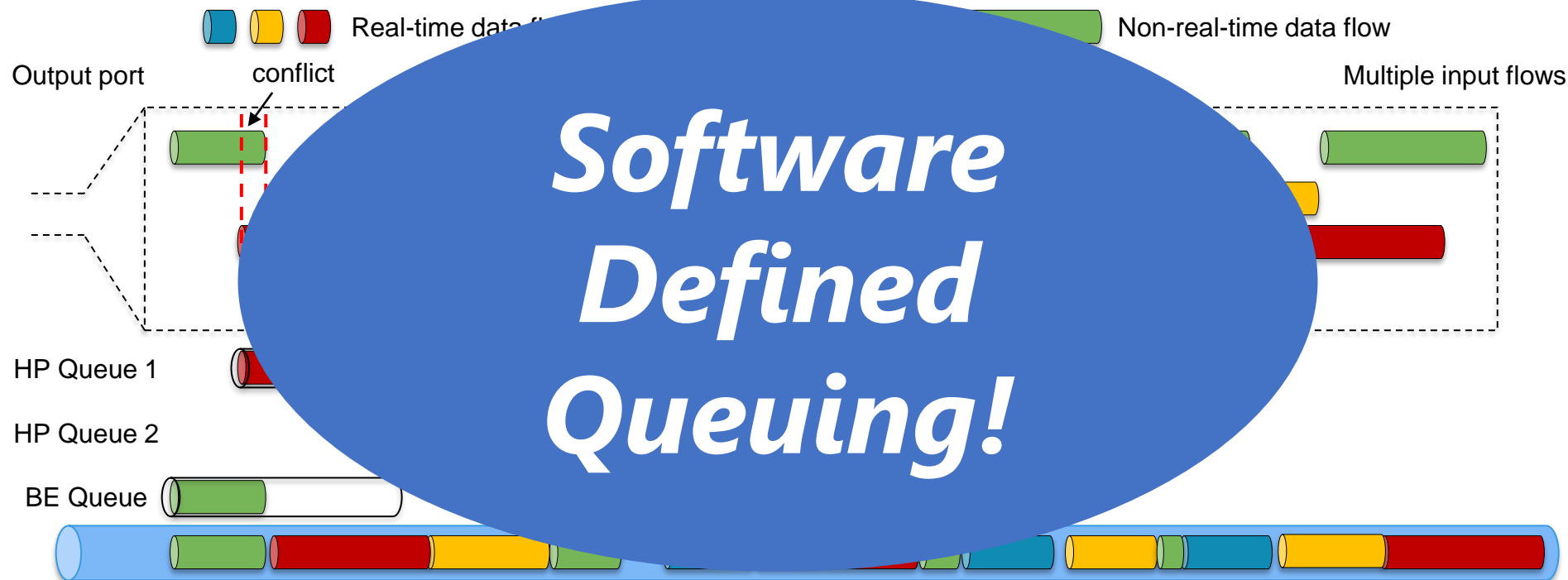
Deterministic Networking: Future Trend!

Conflicts result in *queueing delay, or packet drops*



Deterministic Networking: Future Trend!

Proper queue management
minimizes *queueing delays and
packet drops*



HP: High Priority
BE: Best Effort

A. Nait Abbou, T. Taleb, and J. Song, "A Software-Defined Queuing Framework for QoS Provisioning in 5G and Beyond Mobile Systems," in IEEE Network Magazine, Vol. 35, No. 2, Mar. 2021, pp. 168 - 173

Deterministic Networking: Future Trend!

Proper flow scheduling & traffic shaping ensures *deterministic* QoS

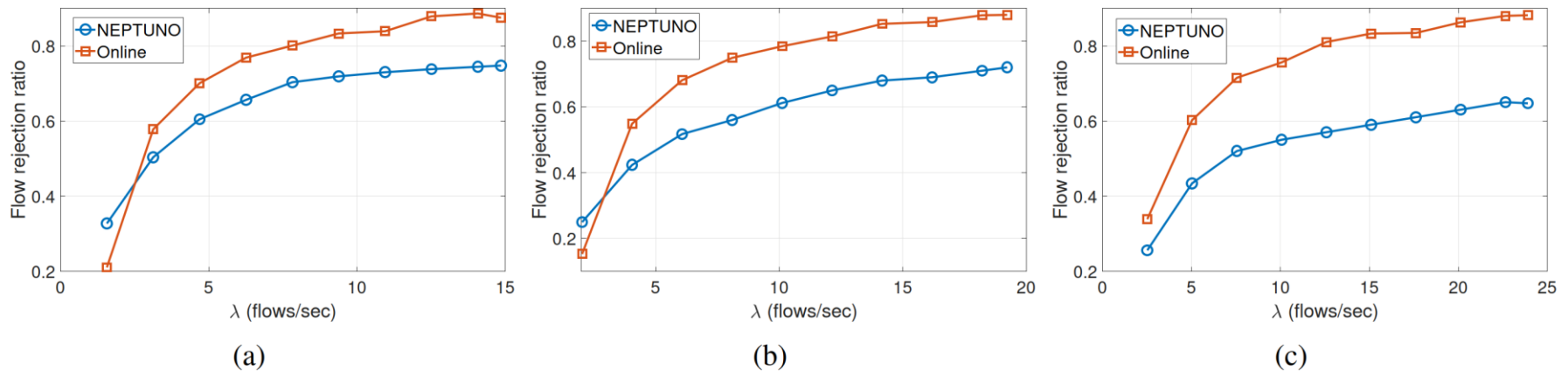


Fig. 9: Comparison of the flow rejection ratio for each solution and different number of 5QIs.

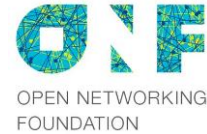
With RL-based flow scheduling & traffic shaping, more flows can be admitted while meeting their respective *deterministic* QoS.

Computing. (to appear)

- J. Prados-Garzon and T. Taleb, "Asynchronous Time-Sensitive Networking for 5G Backhauling," in IEEE Network Magazine, Vol. 35, No. 2, Mar. 2021, pp. 144 – 151.
- J. Prados-Garzon, T. Taleb, and M. Bagaa, "LEARNET: Reinforcement Learning Based Flow Scheduling for Asynchronous Deterministic Networks," in Prof. IEEE ICC'20, Dublin, Ireland, Jun. 2020.

Extreme LLC - Deterministic Latency

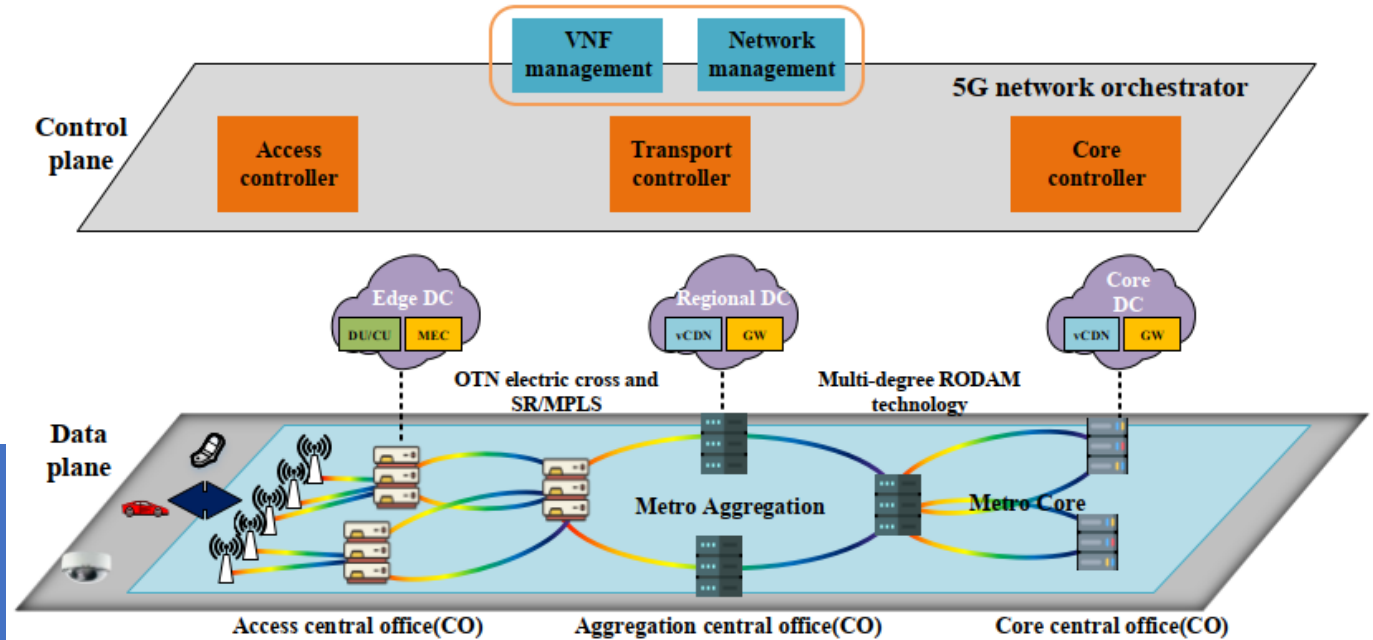
***Tighter
Integration
with Transport
Network***



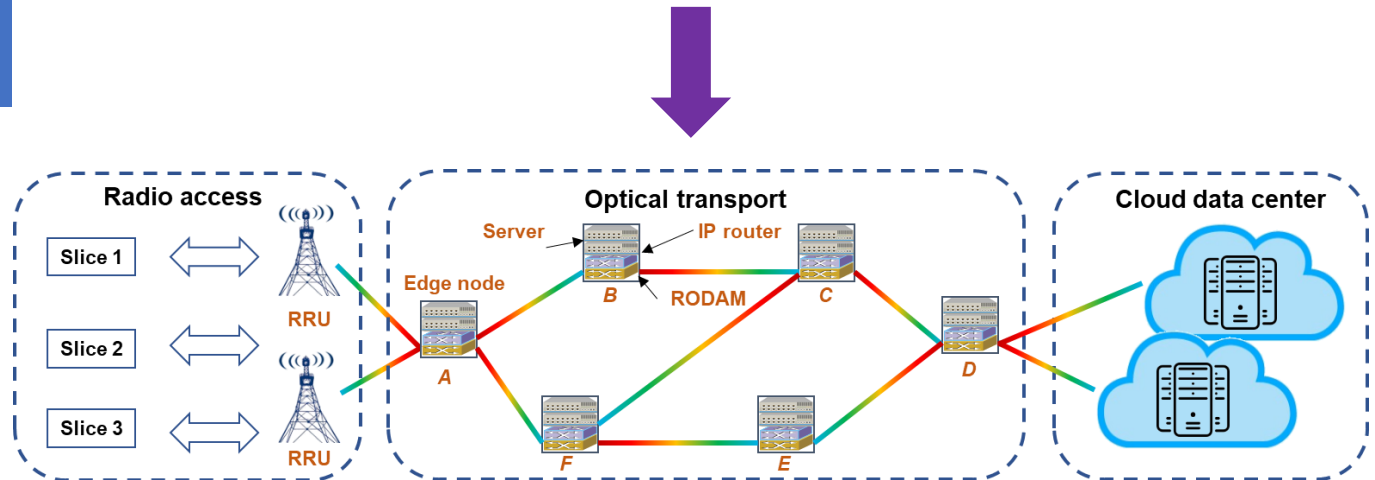
MEF



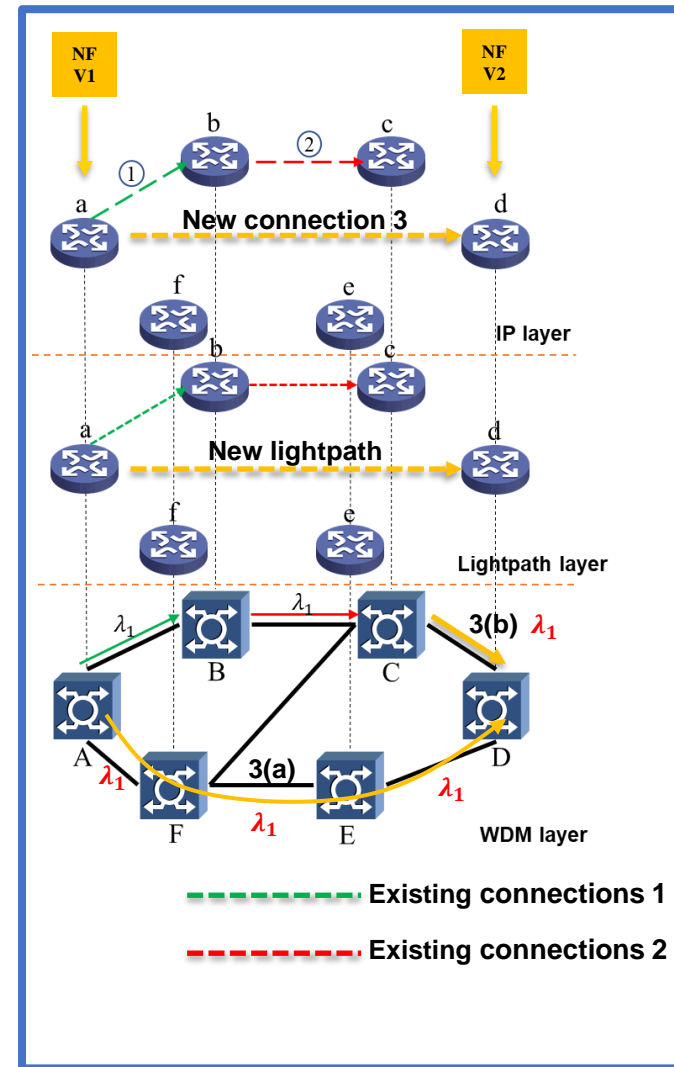
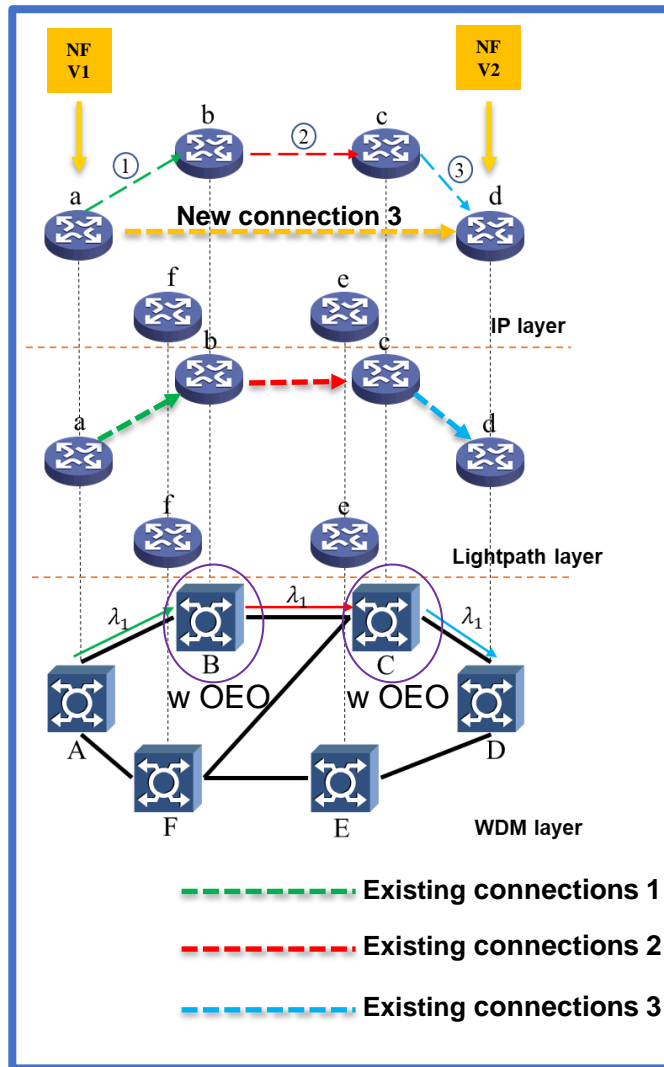
Extreme LLC - Tighter Integration with TN



Latency-aware
SFC
placement on
Transport
Network

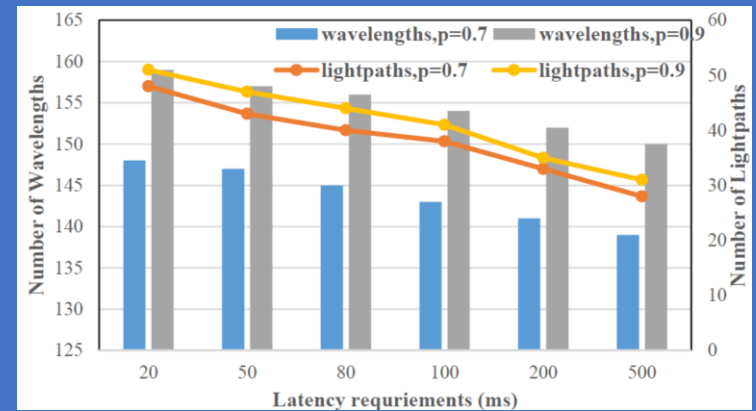
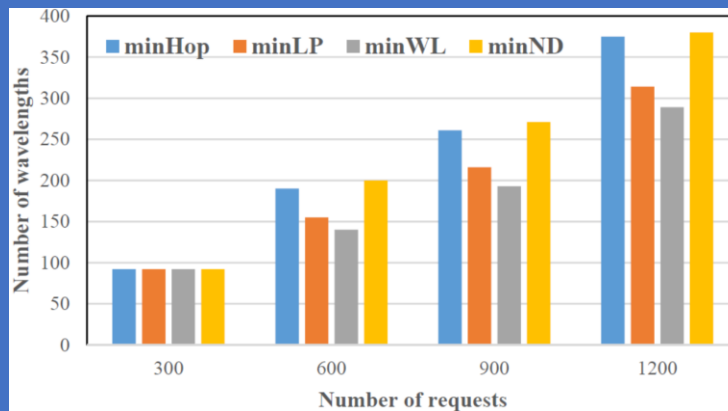
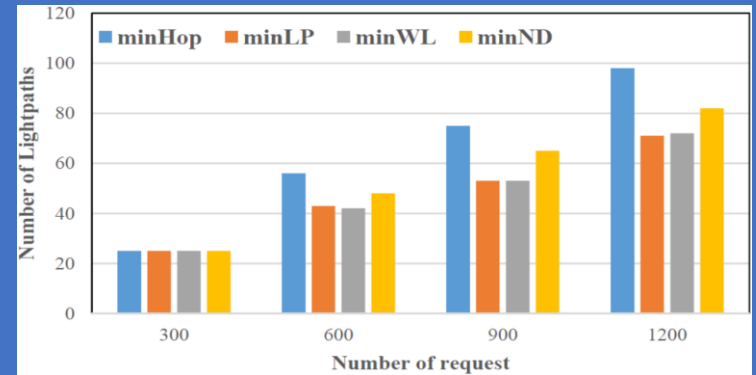
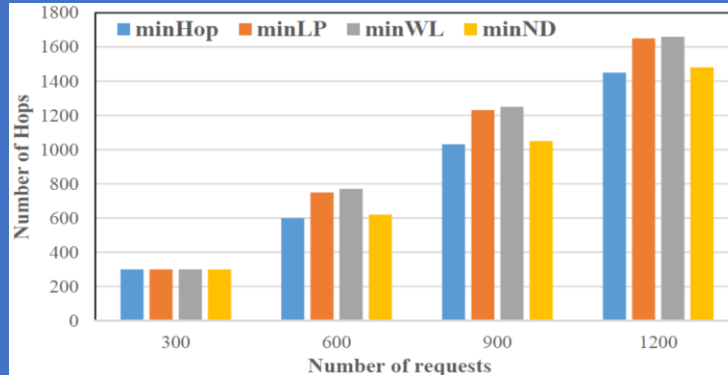


Extreme LLC - Tighter Integration with TN



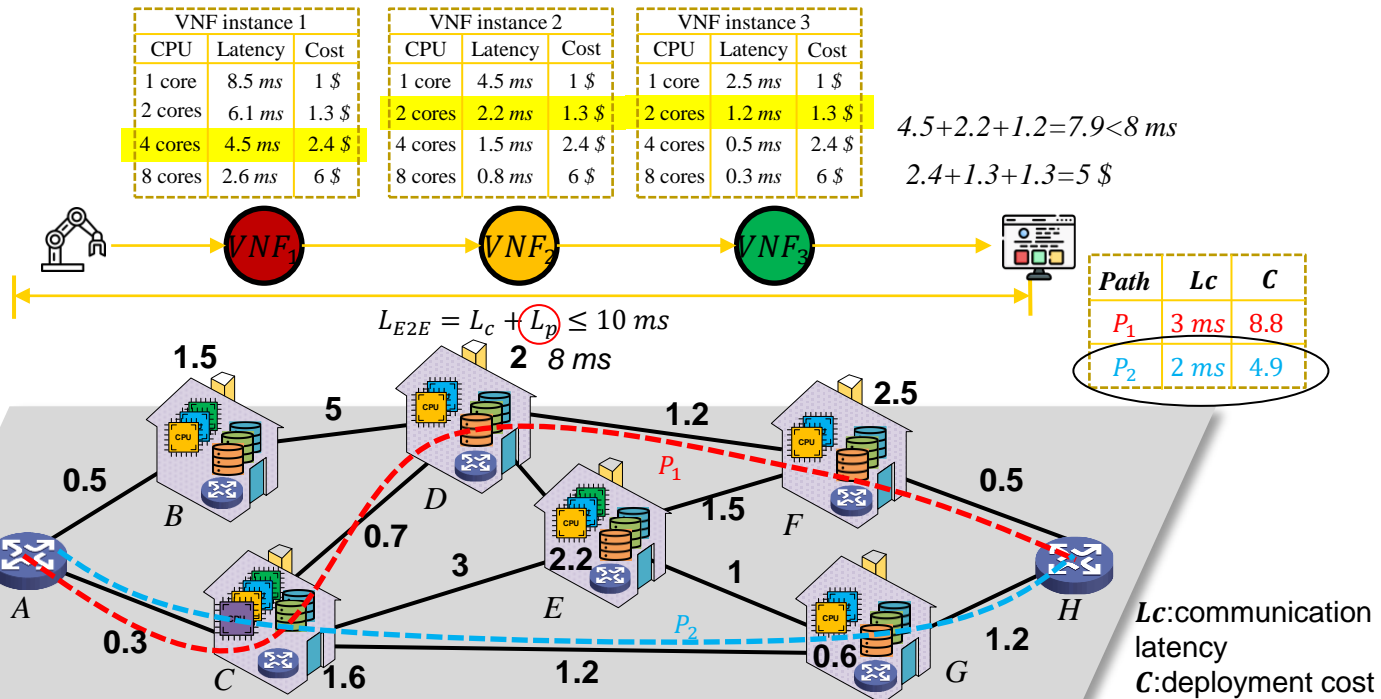
Different strategies: minimize nodes/hops, minimize lightpath, minimize wavelength, etc

Extreme LLC - Tighter Integration with TN



T. Taleb, et. al., "Deterministic Latency Bounded Network Slice Deployment in IP-over-WDM based Metro-Aggregation Networks," submitted to Transaction on Network Science Engineering.

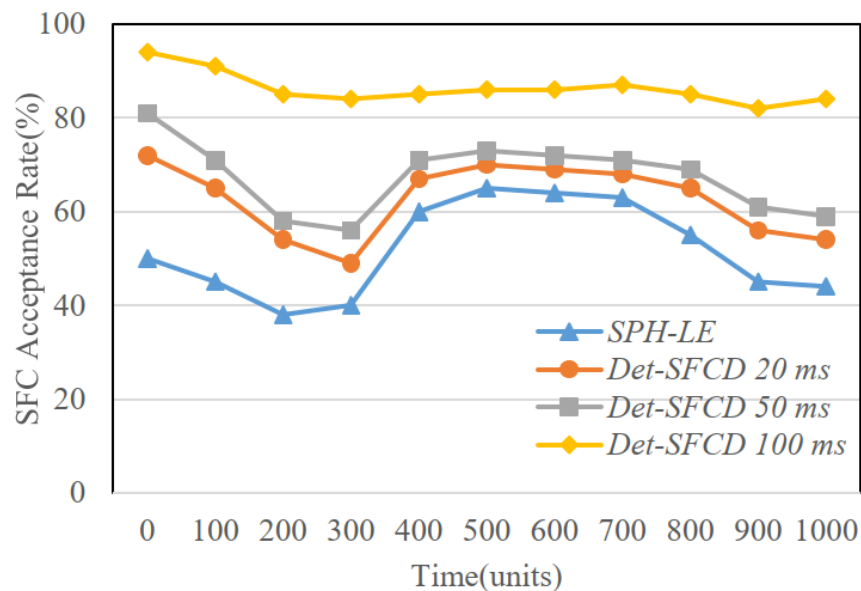
Extreme LLC - Latency/Cost-Aware SFC



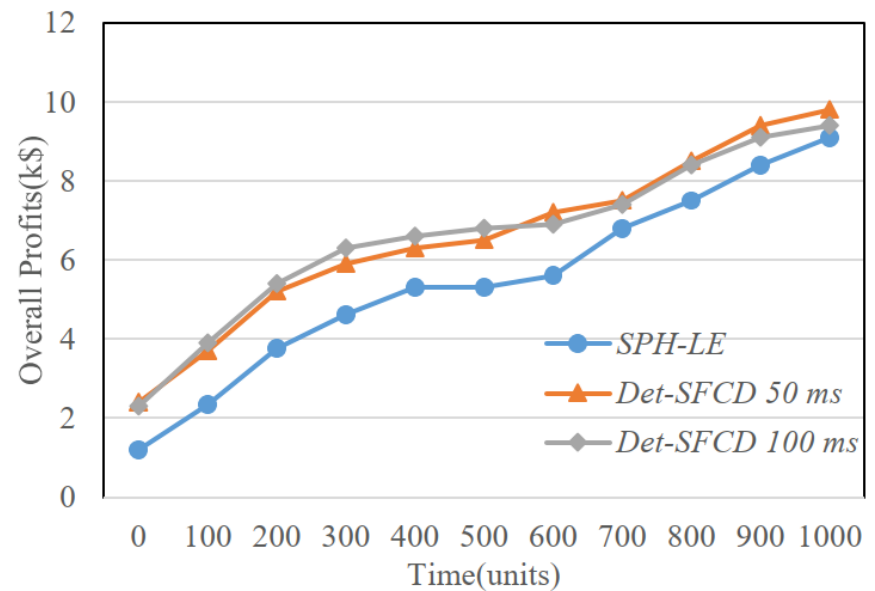
T. Taleb, et. al., "Deterministic Service Function Chaining over Beyond 5G Edge Fabric," submitted to Globecom 2021.

Extreme LLC - Latency/Cost-Aware SFC

Services with looser e2e latency requirement have higher acceptance rate



Optimal selection of communication path and cloud resources yields high profits



T. Taleb, et. al., "Deterministic Service Function Chaining over Beyond 5G Edge Fabric," submitted to Globecom 2021.

Extreme LLC - Deterministic Latency

*Not any
Routing ...*

Select SFC

*Segment
Routing,
DynCast*

Select ... and
node resources

New IP?

Some take away for B5G/6G networking ...

- **True Cloud Nativeness**
- **“NW of Networks” vs “Service of Services”**
- **“DevOps” in Networking**
- **Extreme LLC in 6G**
 - Deterministic networking
 - SW Defined Queuing
 - Tight integration with transport network
 - Segment routing

**Thank you for your
attention!**

Visit us at
www.mosaic-lab.org

MOSA!C LAB
Mobile Network Softwarization & Service Customization