Aalto University
School of Electrical
Engineering

MOSA!C LAB
Mobile Network Softwarization & Service Customization

Edge Cloud Continuum: What Potential for B5G?

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Panel on "Edge is the new cloud: vision and perspectives from industry & academia"
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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

5G Latency Requirements – Industry Targets

NGMN 5G Requirements

- 5G E2E Latency (eMBB) = **10ms** (i.e. RTT from UE-Application-UE)
- 5G E2E Latency (URLLC) = **1ms** (i.e. RTT from UE-Application-UE – or just UE-UE)

In both cases, the values are defined as capabilities that should be supported by the 5G System.

GSMA 5G Requirements

- 5G E2E Latency = **1ms** (again, defined as a capability target, not as a universal requirement)

ITU-R IMT-2020 Requirements

- eMBB User Plane Latency (one-way) = **4ms** [radio network contribution]
- URLLC User Plane Latency (one-way) = **1ms** [radio network contribution]
- Control Plane Latency = **20ms (10ms target)** [UE transition from Idle to Active via network]

Low Latency Use Case Requirements (various sources)

- Virtual Reality & Augmented Reality: **7-12ms**
- Tactile Internet (e.g. Remote Surgery, Remote Diagnosis, Remote Sales): < **10ms**
- Vehicle-to-Vehicle (Co-operative Driving, Platooning, Collision Avoidance): < **10ms**
- Manufacturing & Robotic Control / Safety Systems: **1-10ms**

Stricter Latency Requirements

Voice service	Consumer Internet	Production Internet
Circuit switch, TDM eg: 64 Kbit/s Constant bit rate (CBR)	packet switch, statistic multiplexing eg: image, video, search Best-effort	Real-time Ethernet eg: event alarm Punctual, accurate

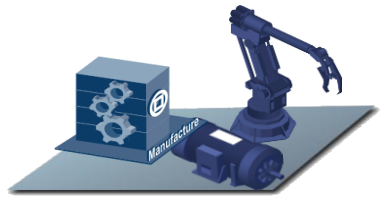
Use case (high level)		Availability	Cycle time	Typical payload size	# of devices	Typical service area
Motion control	Printing machine	>99.9999%	< 2 ms	20 bytes	>100	100 m x 100 m x 30 m
	Machine tool	>99.9999%	< 0.5 ms	50 bytes	~20	15 m x 15 m x 3 m
	Packaging machine	>99.9999%	< 1 ms	40 bytes	~50	10 m x 5 m x 3 m
Mobile robots	Cooperative motion control	>99.9999%	1 ms	40-250 bytes	100	< 1 km²
	Video-operated remote control	>99.9999%	10 – 100 ms	15 – 150 kbytes	100	< 1 km²
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 km²	

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

AR/VR

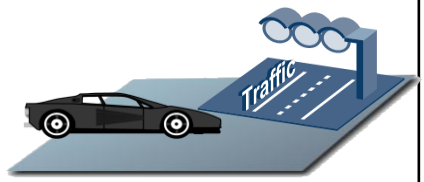
E2E latency: ≤10ms
reliability: 99.99%
jitter: ~10 us

Industry Automation



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

Automatic Driving



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

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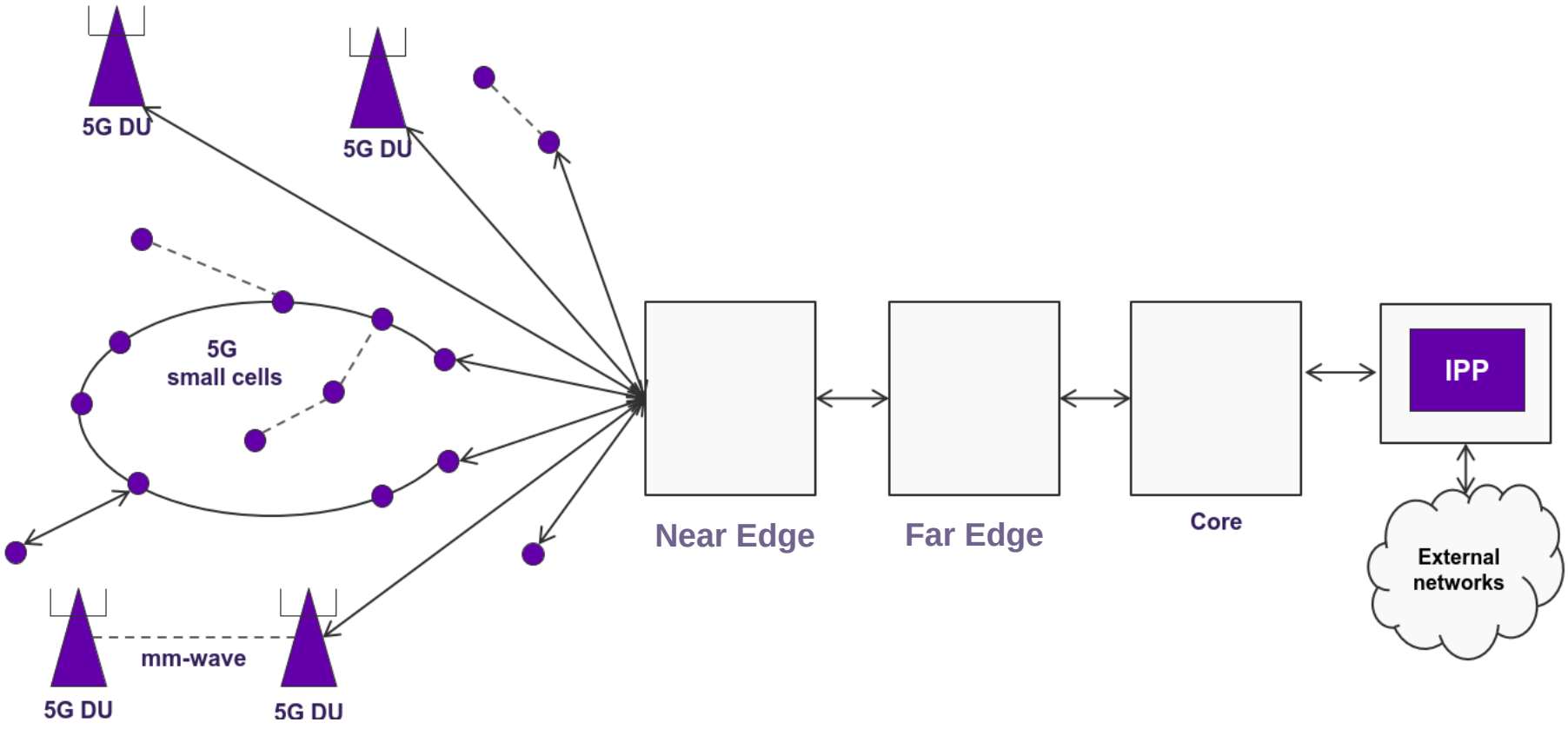
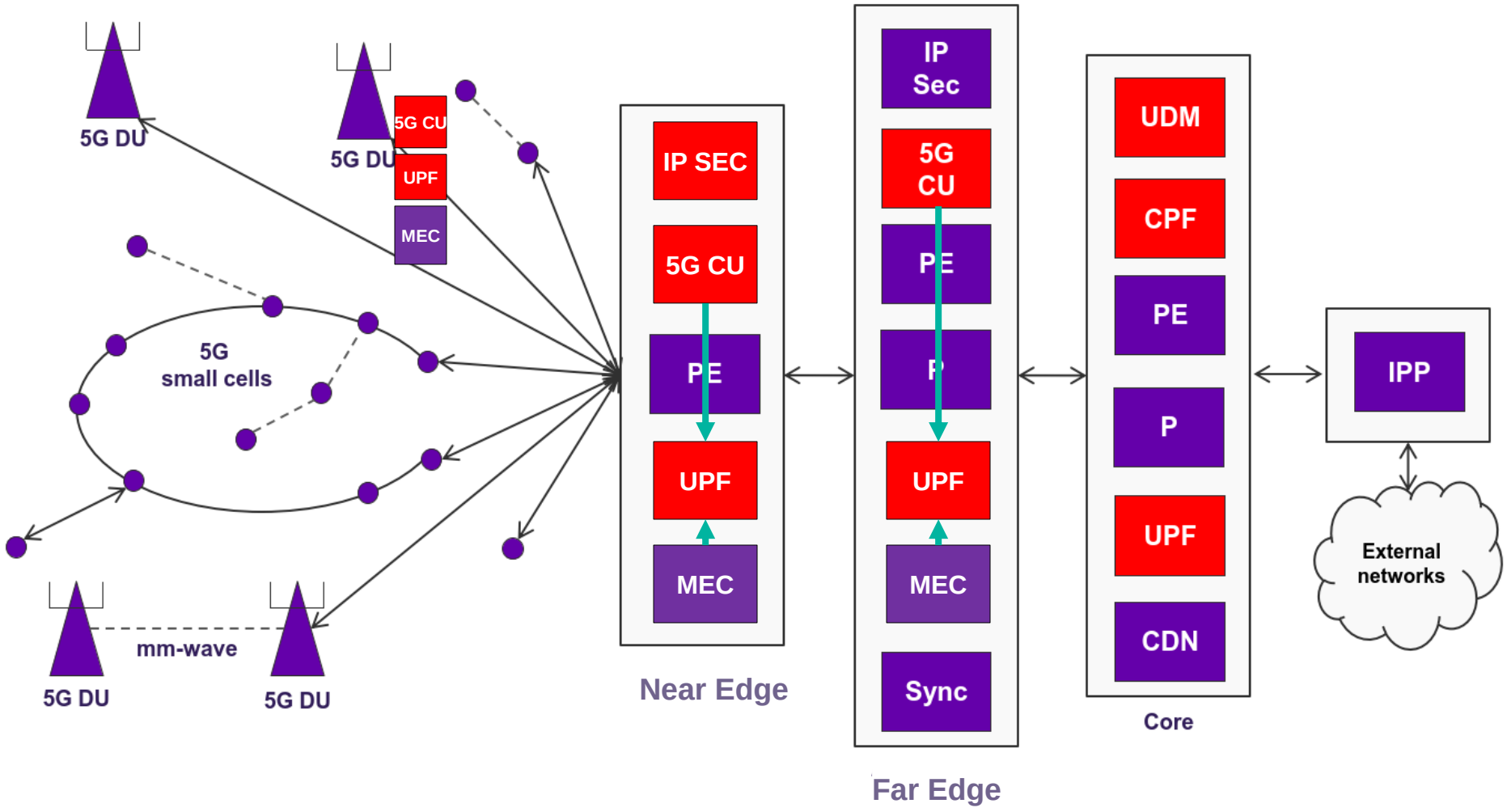
(Extreme) Edge Cloud Potential

NW SW & Edge Cloud: The Right Ingredients!

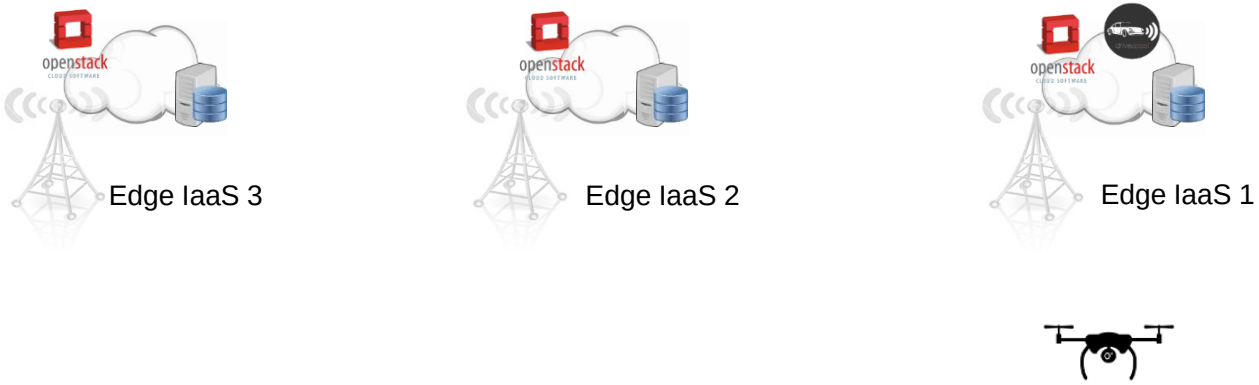


NW SW & Edge Cloud: The Right Ingredients!



B. Mada, M. Bagaa, T. Taleb, and H. Flinck, "Latency-aware Service Placement and Live Migrations in 5G and Beyond Mobile Systems," in Prof. IEEE ICC'20, Dublin, Ireland, Jun. 2020.

"Follow Me Edge" to support ULLC - SFC Migration across IaaS -

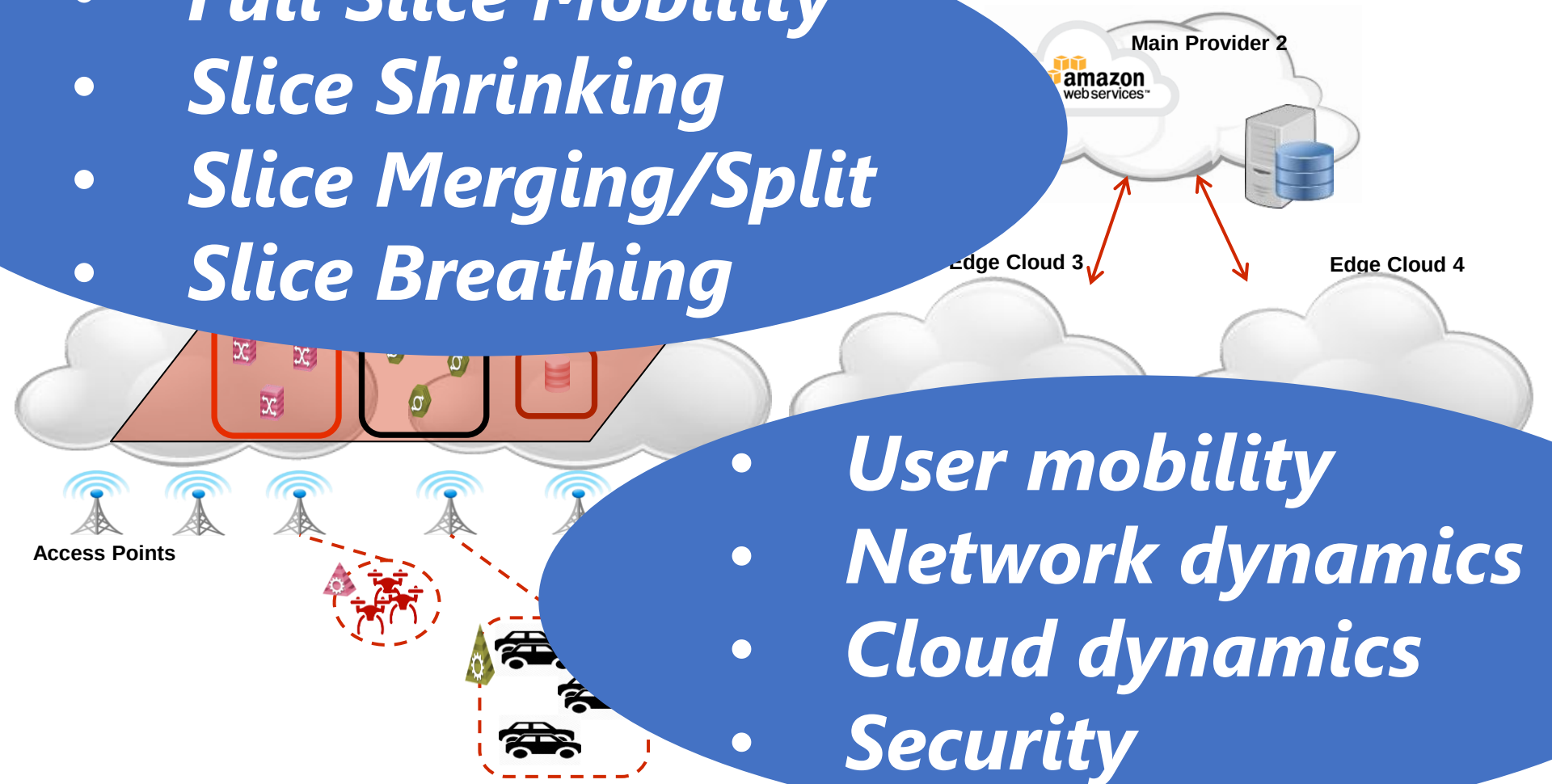


Need for an efficient service migration across multiple IaaS while ensuring ULLC Service Continuity

T. Taleb, A. Ksentini, and P. Frangoudis, "Follow-Me Cloud: When Cloud Services Follow Mobile Users", in IEEE Trans. on Cloud Computing, Vol. 7, No. 2, Jun. 2019 pp. 369 – 382.

"Follow Me Edge": Different Slice Mobility Patterns & Different Triggers

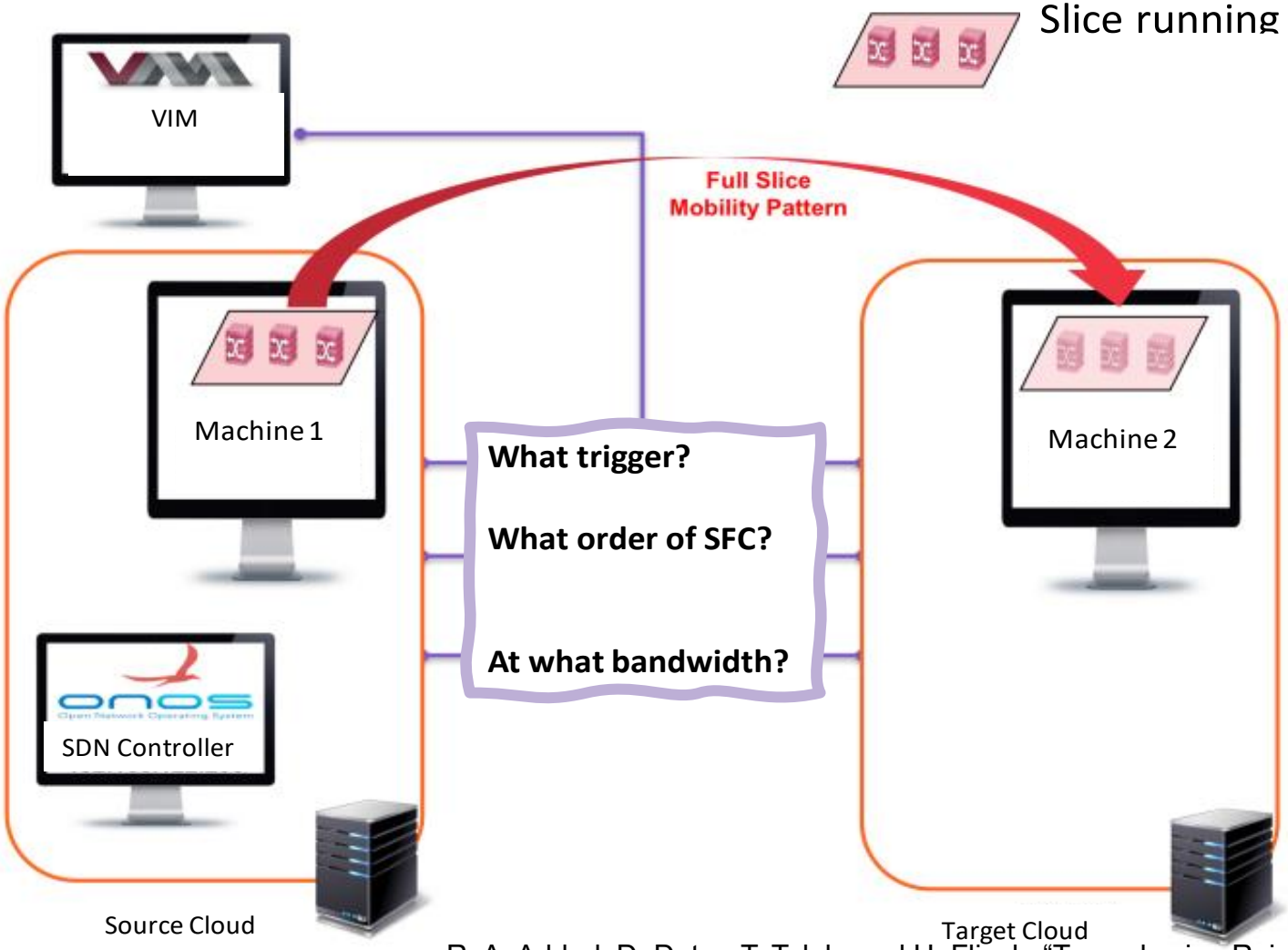
- *Full Slice Mobility*
- *Slice Shrinking*
- *Slice Merging/Split*
- *Slice Breathing*



- *User mobility*
- *Network dynamics*
- *Cloud dynamics*
- *Security*

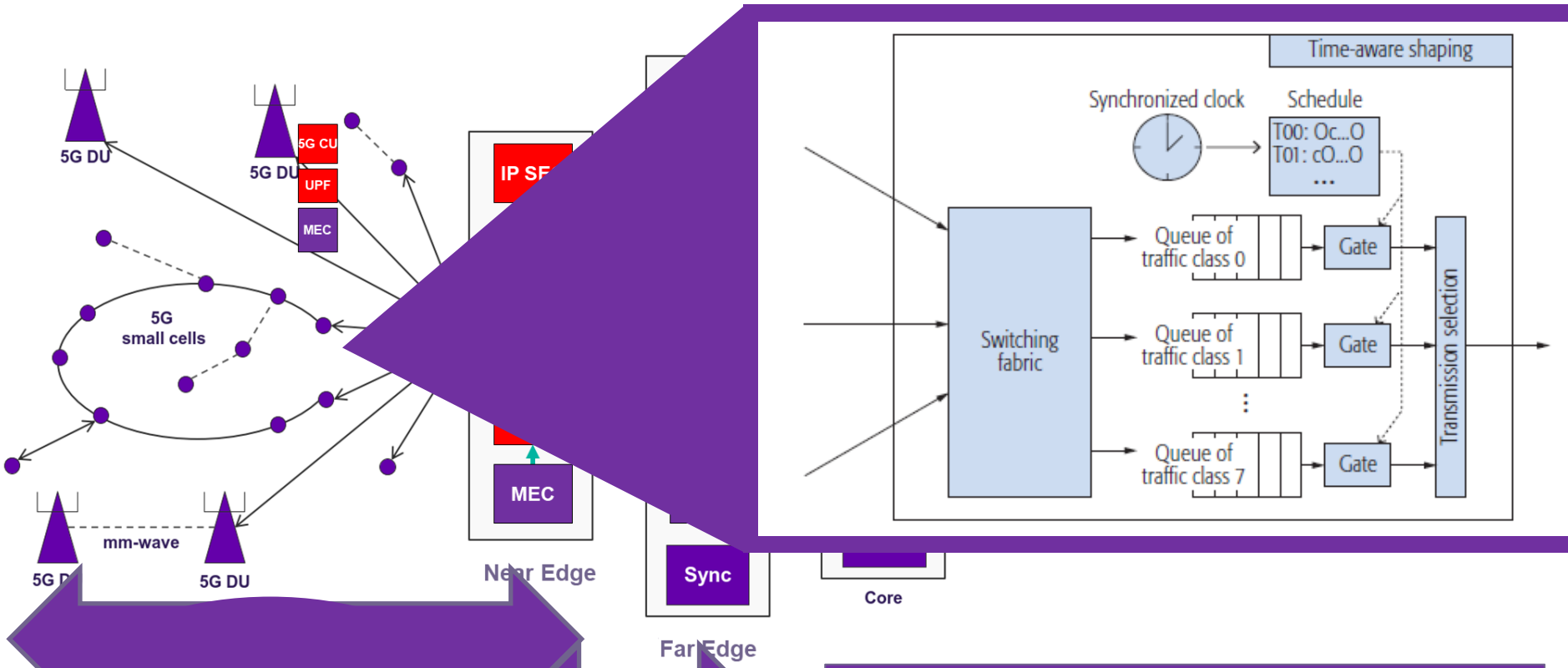
R. A. Addad, T. Taleb, H. Flinck, M. Bagaa and D.L.C. Dutra, "Network Slice Mobility in Next Generation Mobile Systems: Challenges and Potential Solutions," in IEEE Network Magazine, Vol. 34, No. 1, Jan. 2020, pp. 84 – 93.

"Follow Me Edge" to support ULLC - SFC Migration across IaaS -



- R. A. Addad, D. Dutra, T. Taleb, and H. Flinck, "Toward using Reinforcement Learning for trigger selection in Network Slice Mobility," in IEEE JSAC (to appear)
- R. A. Addad, D. Dutra, T. Taleb, and H. Flinck, "AI-based network-aware Service Function Chain migration in 5G and beyond networks," in IEEE Trans on Network and Service Management. (to appear)

Deterministic Networking to Edge Cloud



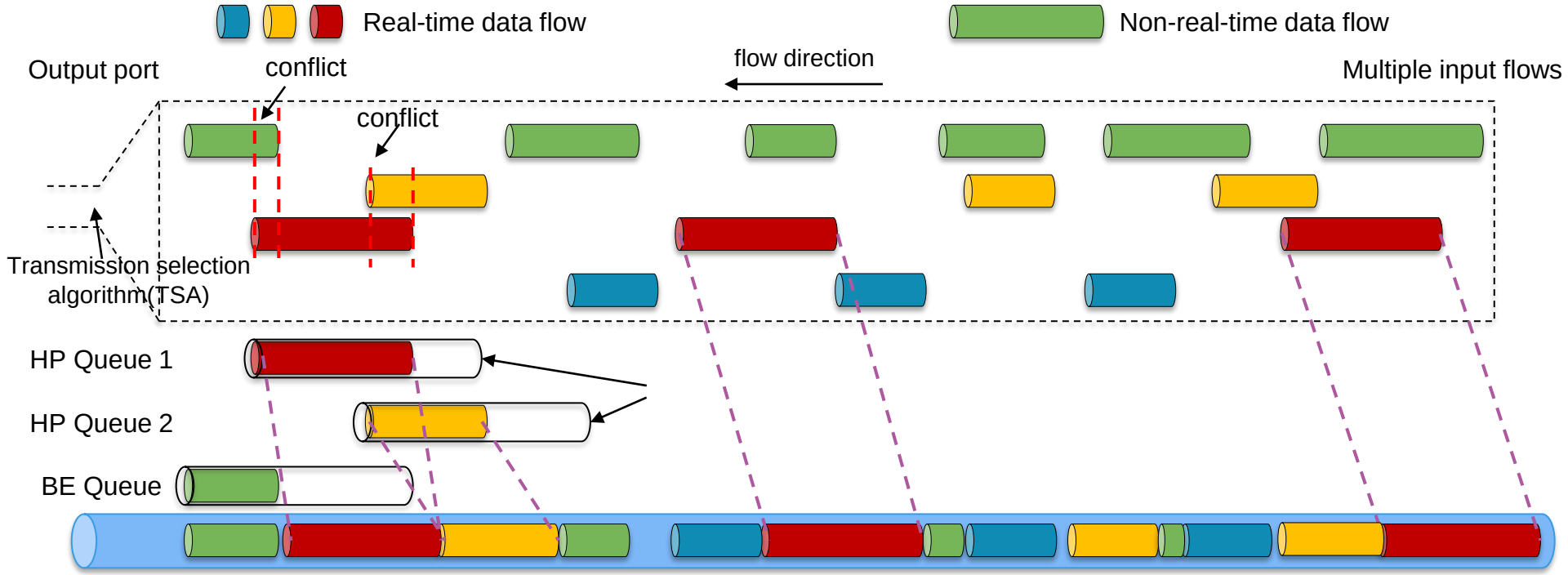
Software Defined Queuing!

Proper queue management minimizes queueing delays and packet drops

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 to Edge Cloud

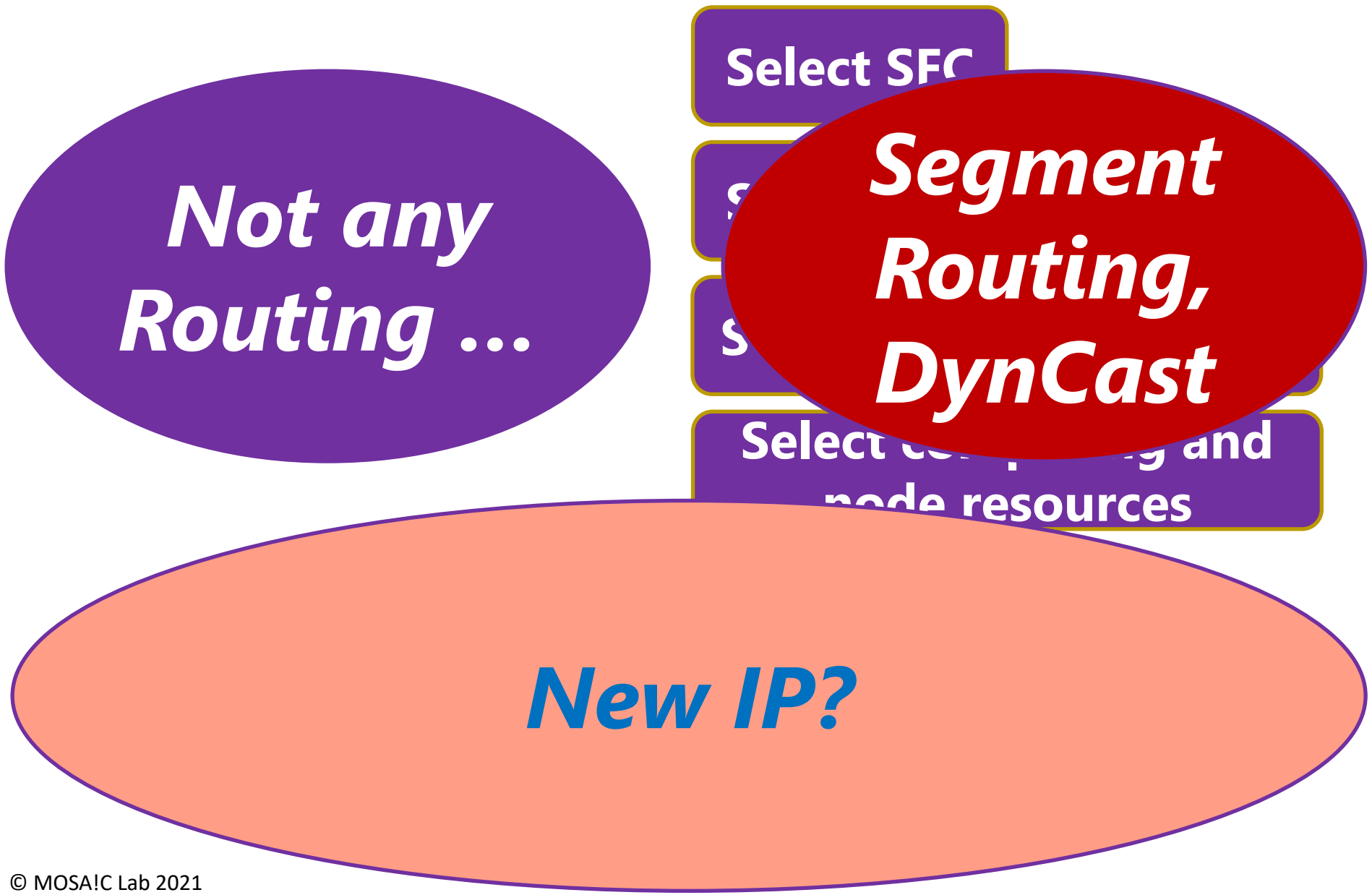
Proper flow scheduling & traffic shaping ensures deterministic QoS



HP: High Priority
BE: Best Effort

- J. Prados-Garzon, T. Taleb, and M. Bagaa, “Optimization of Flow Allocation in Asynchronous Deterministic 5G Transport Networks by Leveraging Data Analytics,” in IEEE Trans. on Mobile 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



Some take away

- **Latency matters and will matter more in B5G**
- **Edge cloud has big potential**
- **Many interesting research problems to tackle to support extreme LLC**
  - Deterministic networking
  - SW Defined Queuing
  - Tight integration with transport network
  - Segment routing
  - Security & Trust

Thank you for your attention!

Visit us at www.mosaic-lab.org

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Readings on Security and Trust

- C. Benzaid and T. Taleb, “AI for Beyond 5G Networks: A Cyber-Security Defense or Offense Enabler?” in IEEE Network Magazine, Vol. 34, No. 6, Nov. 2020, pp. 140 - 147.
- C. Benzaid, T. Taleb, M. Z. Farooqi. Trust in 5G and Beyond Networks. IEEE Network Magazine, Early Access, Feb. 2021.
- C. Benzaid and T. Taleb, “ZSM Security: Threat Surface and Best Practices,” in IEEE Network Magazine, Vol. 34, No. 3, Jun. 2020, pp. 124 - 133.
- C. Benzaid and T. Taleb, “AI-driven Zero Touch Network and Service Management in 5G and Beyond: Challenges and Research Directions,” in IEEE Network Magazine, Vol. 34, No. 2, Mar. 2020, pp. 186-194
- C. Benzaid, M. Boukhalfa, and T. Taleb, “Robust Self-Protection Against Application-Layer (D)DoS Attacks in SDN Environment,” in Proc. IEEE WCNC 2020, Seoul, Korea, Apr. 2020.

- C. Benzaid, T. Taleb, C.T. Phan, C. Tselios, and G. Tsolis, “Distributed AI-based Security for Massive Numbers of Network Slices in 5G & Beyond Mobile Systems,” in Proc. of 2021 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit), Porto, Portugal, Jun. 2021.