

Mobile Network Softwarization & Service Customization

Edge Cloud Continuum: What Potential for B5G? Prof. Tarik Taleb

Director & Founder of MOSA!C LAB <u>www.mosaic-lab.org</u> Aalto University and Oulu University, Finland

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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



- 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 <u>capability target</u>, 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		Consur	ner Internet			Production Intern	net	AR/VR
Circuit switch, TDM eg: 64 Kbit/s constant bit rate (CBR) packet switch, eg: image, vio Best-effort			statistic multiplexing eo, search		Real-time Ethernet eg: event alarm Punctual, accurate			
	e (35e			Typical	# of	Tynical		E2E latency: ≤10ms reliability: 99.99% jitter: ~10 us
(high level)		Availability Cycl	Cycle time	payload size	devices service	service area		Industry Automation
Motion control	Printing machine	>99.9999%	< 2 ms	20 bytes	>100	100 m x 100 m x 30 m		Contraction of the second seco
	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		E2E latency: 25us-2ms reliability: 99.999% jitter: 1 us Automatic Driving
	Video-operated remote control	>99.9999%	10 – 100 ms	15 – 150 kbytes	100	< 1 km²		
Mobile control	Assembly robots or milling machines	>99.9999%	4-8 ms	40-250 bytes	4	10 m x 10 m		
safety functions	Mobile cranes	>99.9999%	12 ms	40-250 bytes	2	40 m x 60 m		
Process automation (process monitoring) >99.99%		>99.99%	> 50 ms	Varies	10000 devices per km ²			000 12112
White Paper. '	5G for Connected	Industries and	d Automation	," 5G Alliance f	or Connec	sted		E2E latency: ≤5ms reliability: 99.999%

jitter: 1 us

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

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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



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": Different Slice Mobility Patterns & Different Triggers



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



Deterministic Networking to Edge Cloud



Deterministic Networking to Edge Cloud



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.

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Extreme LLC - Deterministic Latency



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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



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, "Al-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.