Reliability enhancements for mmW communication using IEEE 802.1CB

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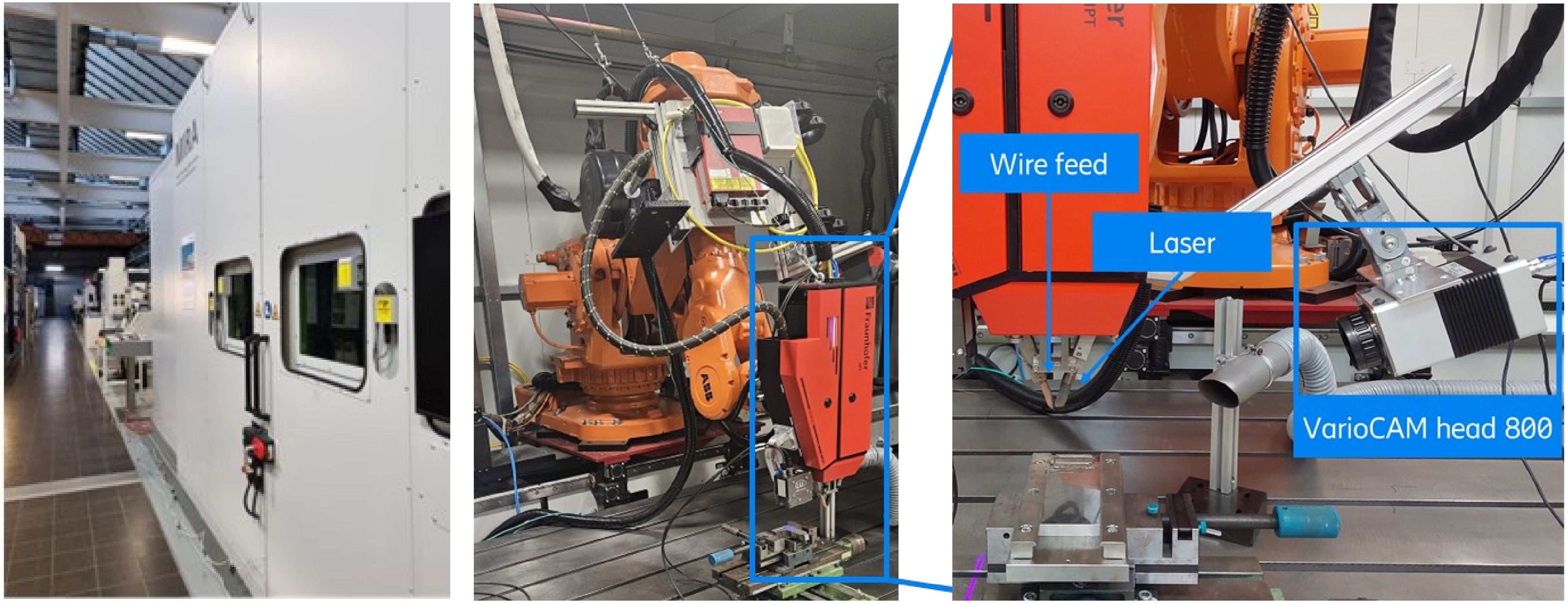
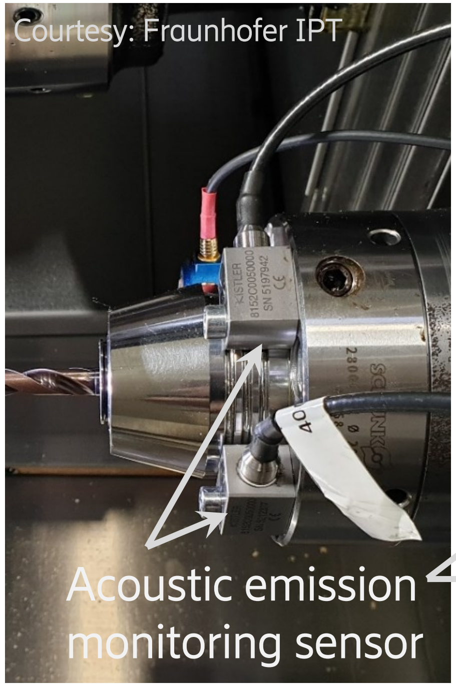
5G mmW enabled industrial use-case 1

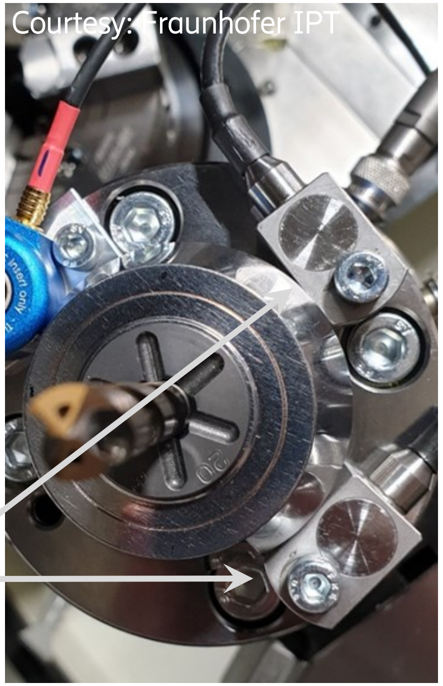


https://www.mdpi.com/2079-9292/14/3/607

Robot laser structuring based on runtime analysis of high-resolution imaging data

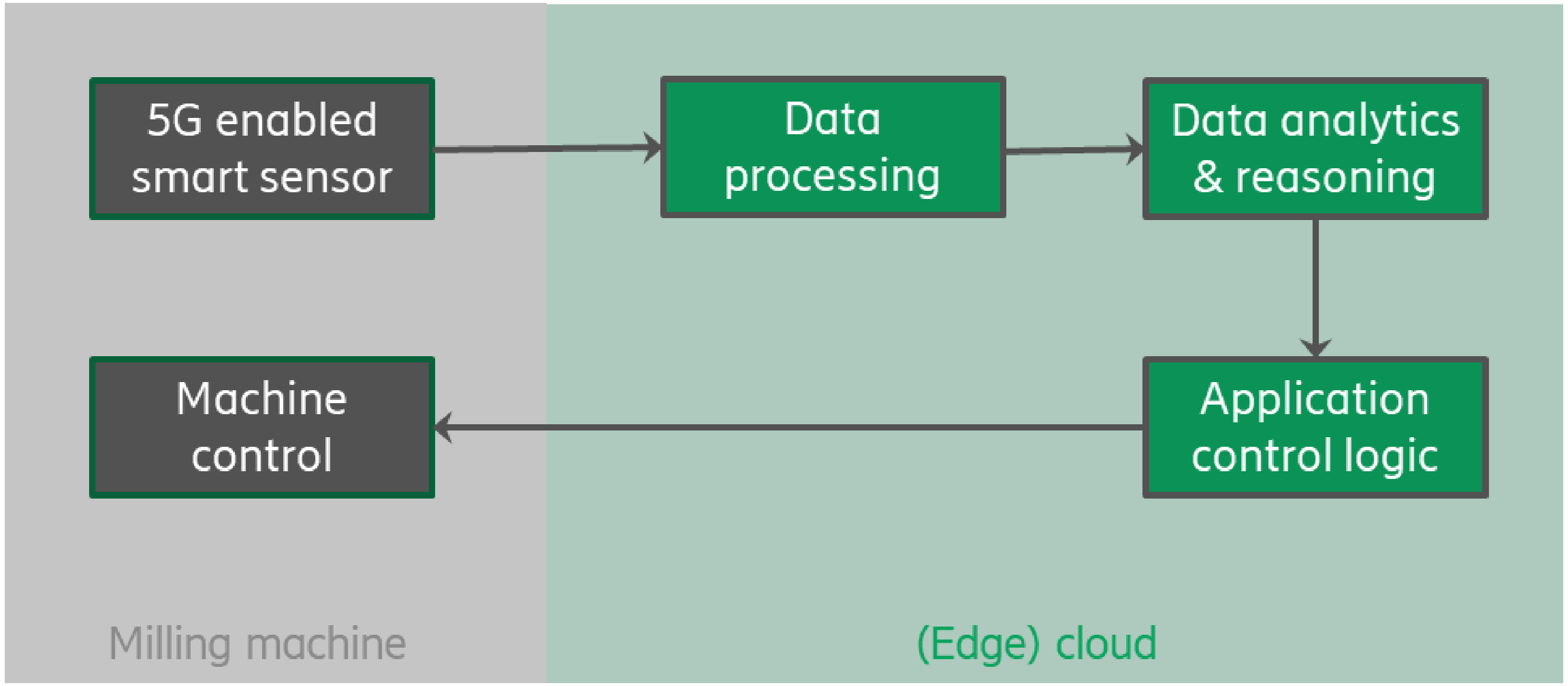
5G mmW enabled industrial use-case 2





Tool condition monitoring and breakage prevention using acoustic emission data

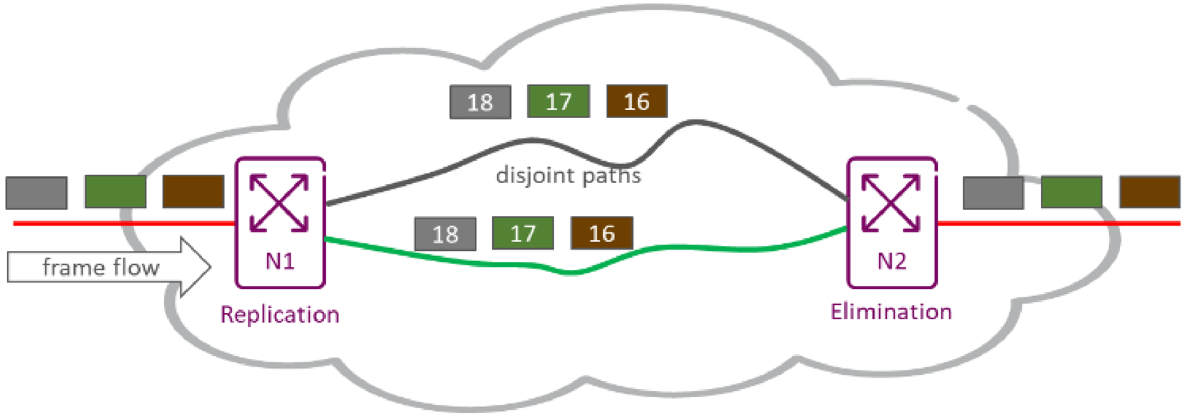
5G mmW enabled industrial use-case 2

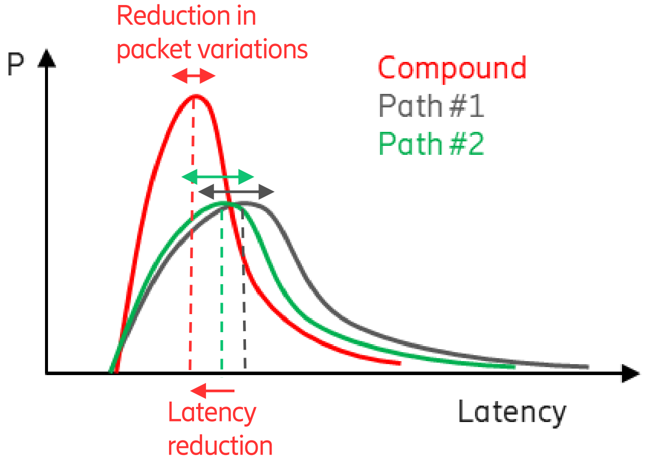


Tool condition monitoring and breakage prevention using acoustic emission data

Why 5G and IEEE 802.1CB?

- 5G communication shows packet delay variations: retransmissions due to unsuccessful decoding, variable delays due to processing, protocol stack signaling, alignment with transmit opportunity, etc.
- IEEE 802.1CB may help reduce packet delay variations in 5G



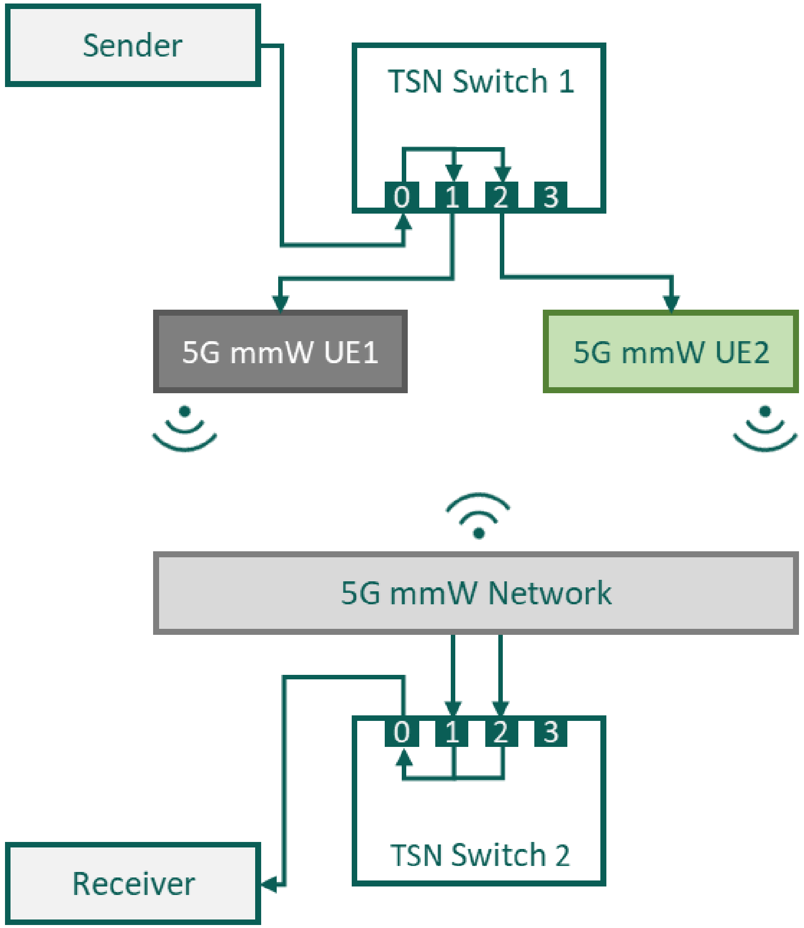


Experimental setup – commercial equipment

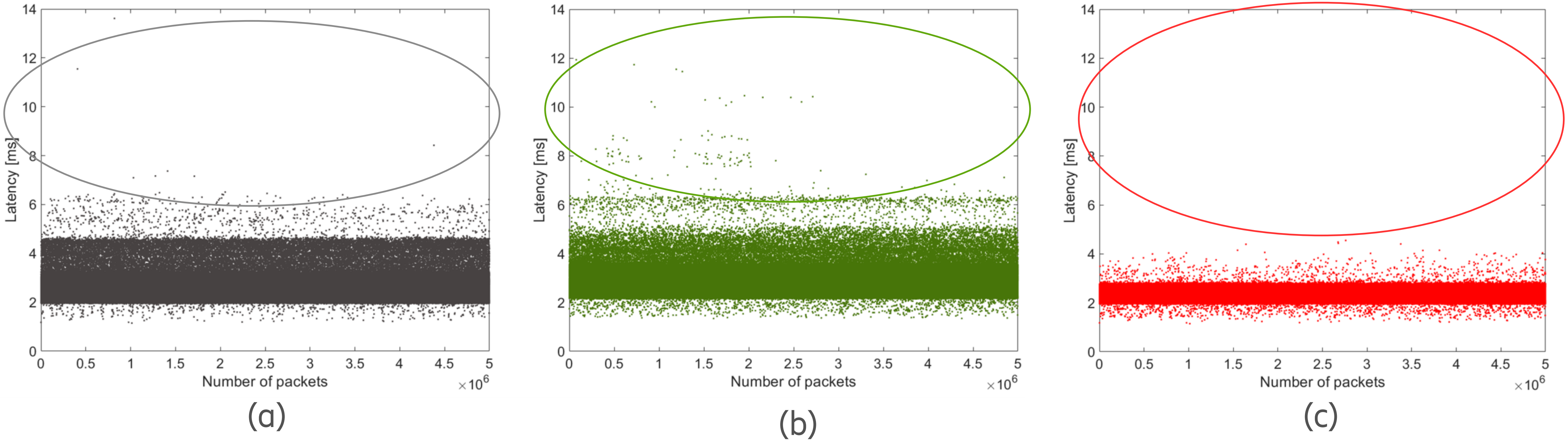
- Real production environment – Fraunhofer IPT shopfloor with area of 3000 m^2
- Over-the-air 5G mmW transmissions
  - 5G mmW non-public network (Ericsson) in the frequency range: 26.7 GHz to 27.5 GHz
  - Terminal devices with Qualcomm SDX65 modem chipsets
  - Separation of Radio Unit and UEs: ~ 70 m
- TSN switches with IEEE 802.1CB implementation (Moxa G5008 series)
- Embedded PCs for L2 tunnels

Schematics – measurement setup

- Emulation of industrial traffic profiles
- TSN Switch 1: Replication operation
- TSN Switch 2: Elimination operation
- Redundant paths using two mmW UEs
  - UE1: Power Class 4 – min EIRP: 31.0 dBm
  - UE2: Power Class 3 – min EIRP: 20.6 dBm
- All packets are accurately time-stamped to determine the end-to-end latency of the compound and individual paths
- Large number of experimental samples are obtained for high statistical significance

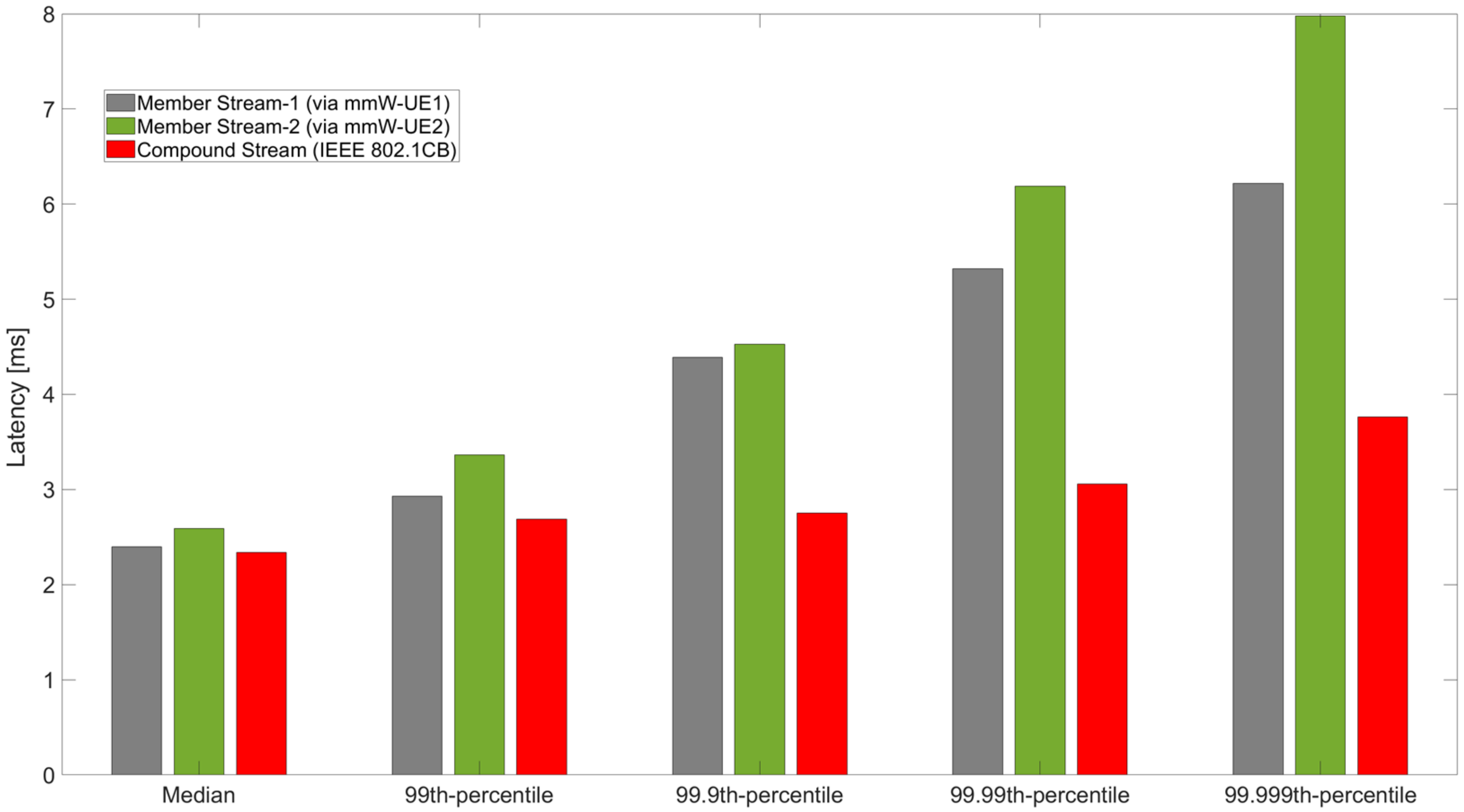


End-to-end latency



Latency of each transmitted packet (a) Member Stream-1 via UE1, (b) Member Stream-2 via UE2 and (c) Compound Stream using the IEEE 802.1CB scheme.

End-to-end latency percentiles



Latency percentiles for individual paths and the combined effect on using IEEE 802.1CB protocol.

Summary and key takeaways

- 5G communication shows packet delay variations due to unsuccessful decoding, packet processing, protocol stack signaling, alignment with transmit opportunity, etc.
- Use of IEEE 802.1CB can improve reliability of 5G communication as the likelihood of redundant paths undergoing outage etc. is significantly low.
- Picking the first packet from redundant active paths leads to reduction in latency and packet delay variations
- Redundancy in 5G communication comes with a cost of additional radio resource consumption
- Currently, investigating ML methods for introducing on-demand redundancy in order to optimize radio resource consumption

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