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Bretagne-Pays de la Loire
École Mines-Télécom

A fuzzy reputation system for Radio Access Network sharing

NCA, Bertinoro, 24/10/2024

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Special thanks to Hélène Le Bouder [1,3]

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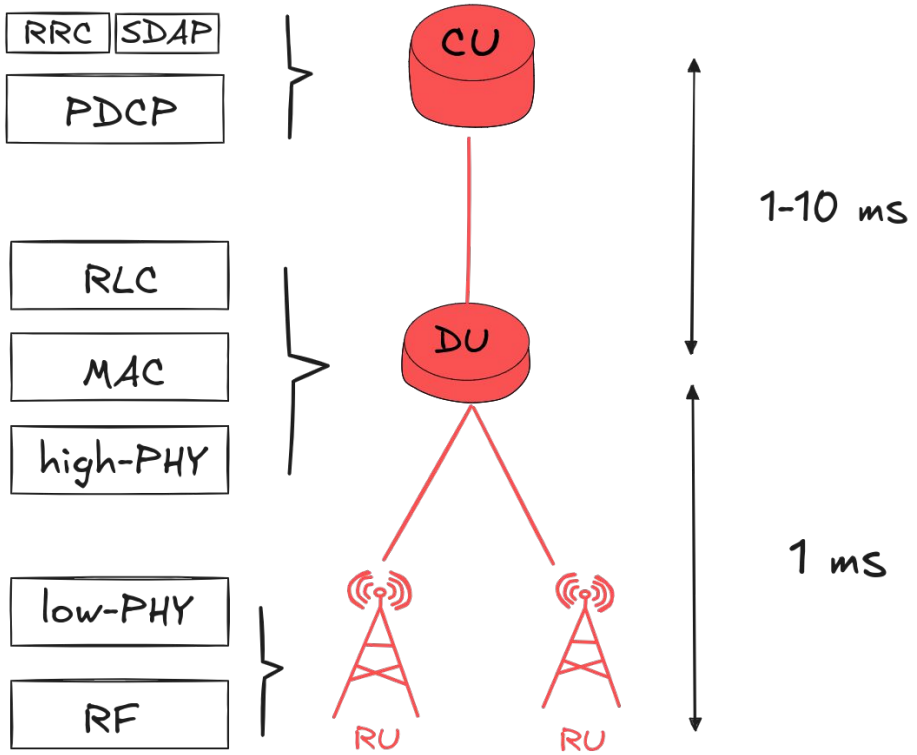
[3] IRISA

O-RAN primer



O-RAN functional split 7.2

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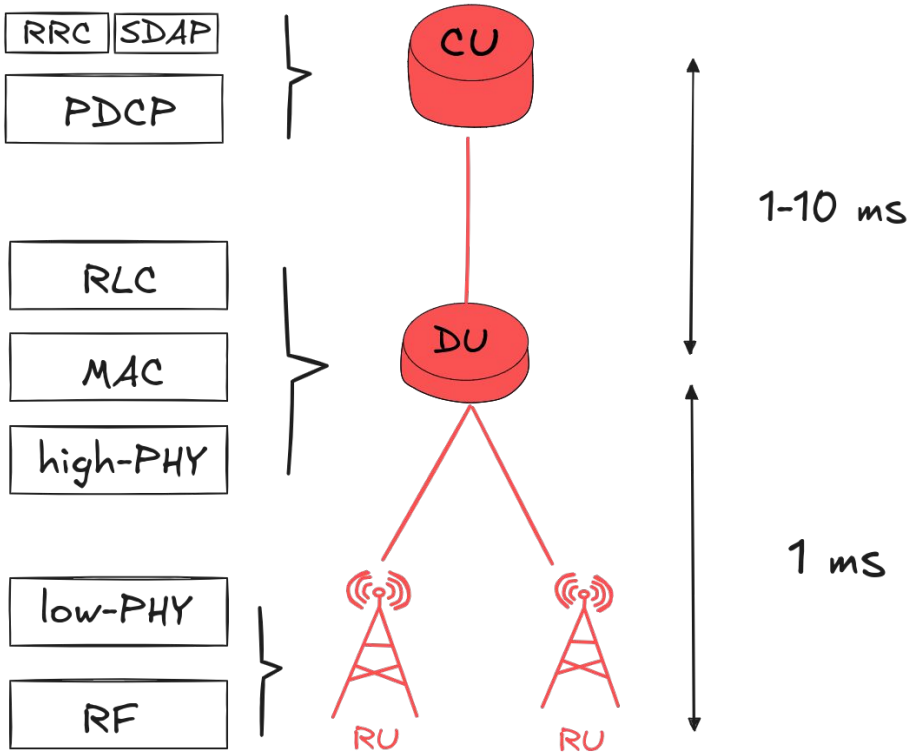
O-RAN primer

Benefits

➔ Better interoperability.

➔ Standardization: easier infrastructure sharing.



O-RAN functional split 7.2

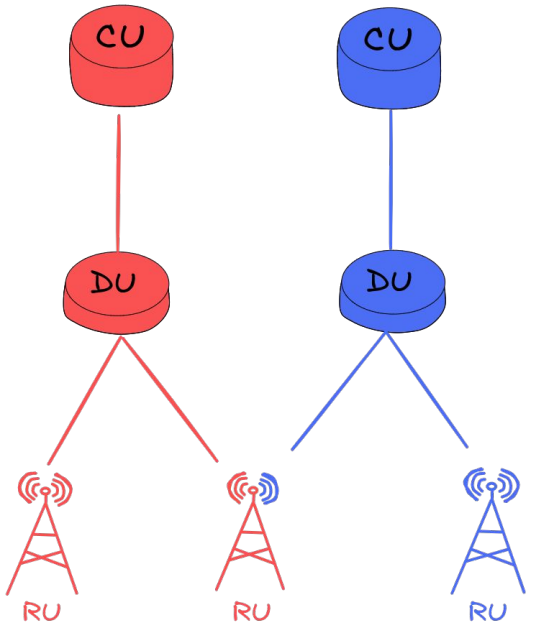
RAN sharing

Motivations for sharing

- ➔ Share infrastructure cost.
- ➔ Extend geographical coverage.
- ➔ Access frequency band.
- ➔ Adjust infrastructure to load.

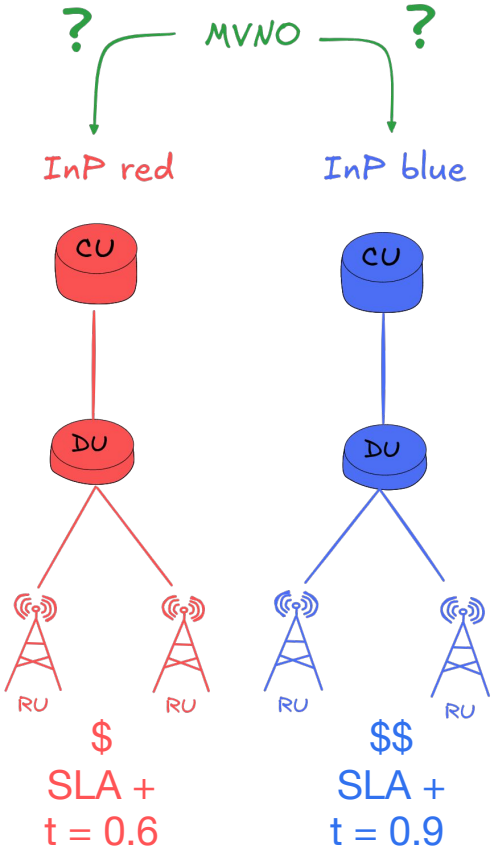
Terminology

- ➔ **Infrastructure provider (InP):** Supply the infrastructure and/or frequency bands.
- ➔ **Mobile virtual network operator (MVNO) :** Lease infrastructure and/or frequency bands.



Multi operator RAN

RAN sharing - MVNO choosing an InP



Selection criteria

➔ Cost.

➔ Service level agreements.

SLA pitfalls

➔ Compensate failure only after they occur.

Proposed solution

➔ Build a trust overlay.

Trust and reputation

***Trust definition** [1]:* Subjective probability that assess whether a particular action will be performed before this action can be monitored.

Reputation necessary conditions [2]

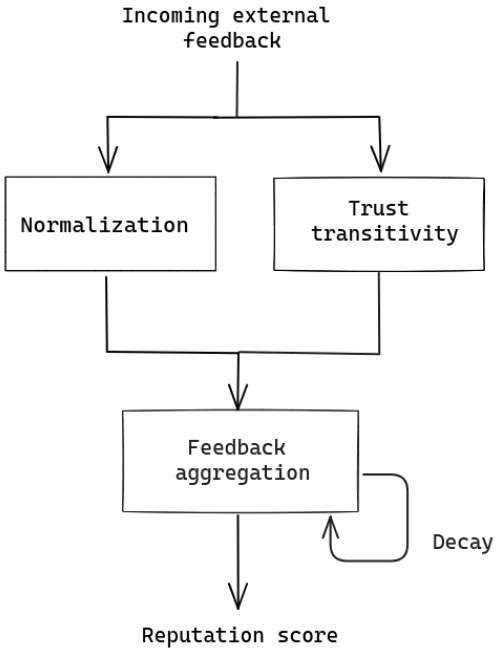
- ➔ **Long-lived entities** that inspire an expectation of **future interaction**;
- ➔ **Capture and distribution of feedback** about current interactions (such information must **be visible** in the future); and
- ➔ Use of feedback to guide trust decisions.

[1] Gambetta, D. (1988). Can we trust trust? In Gambetta, D. (Ed.) Trust: Making and breaking cooperative relations (Chapter 13, pp. 213–237).
[2] Resnick, et al. "Reputation systems." Communications of the ACM 43.12 (2000): 45-48.

5G specificities and existing trust approaches

5G constraints

- ➔ c1: 5G support multiple use cases (URLLC, eMBB, mMTC): reputation should be subjective to each MVNO use case.
- ➔ c2: reputation should adjust quickly to network failure.
- ➔ c3: forgiveness should be possible after a failure recovery should be possible.



Reputation system architecture

5G specificities and existing trust approaches

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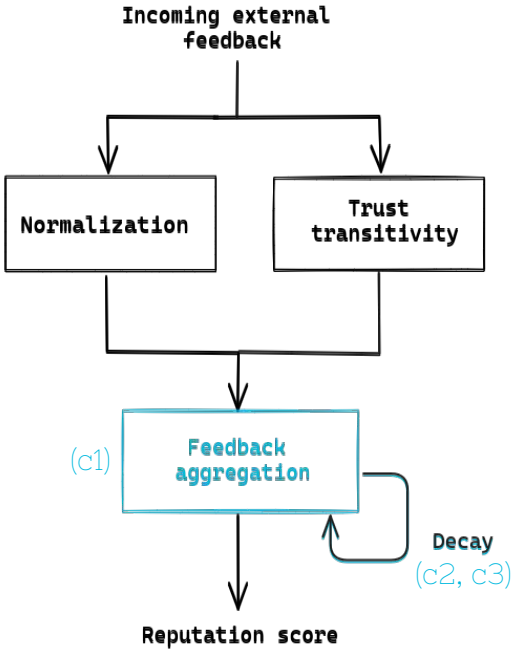


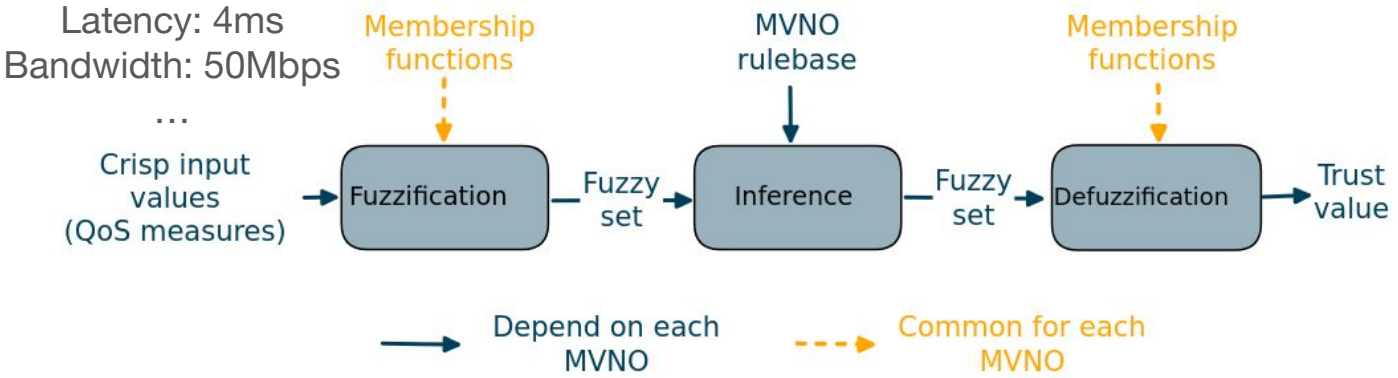
Reputation system architecture

Archi - aggregation

Few trust and reputation systems for resource sharing in 5G [3,4]

➔ Most are based on blockchains and enforce SLAs.

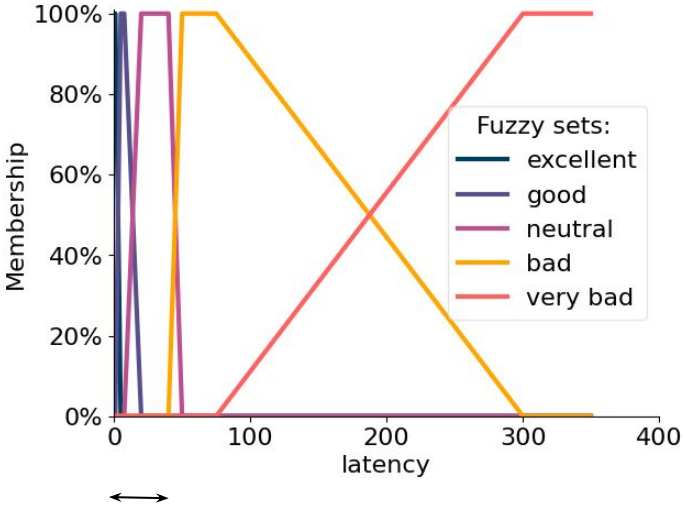
➔ None address use case diversity (constraint c1).

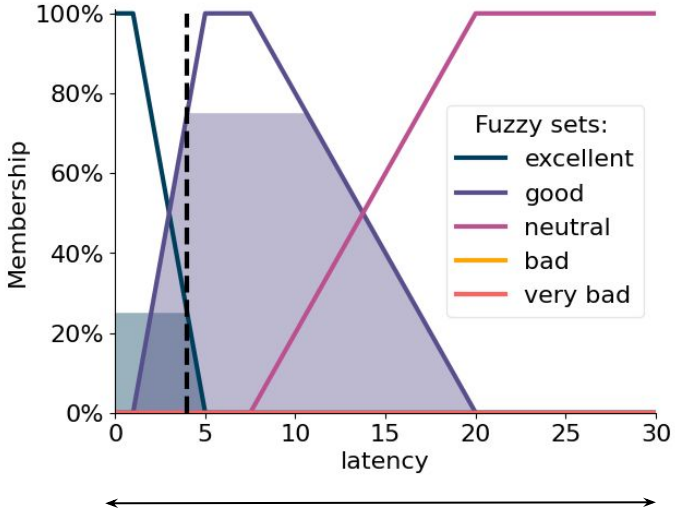


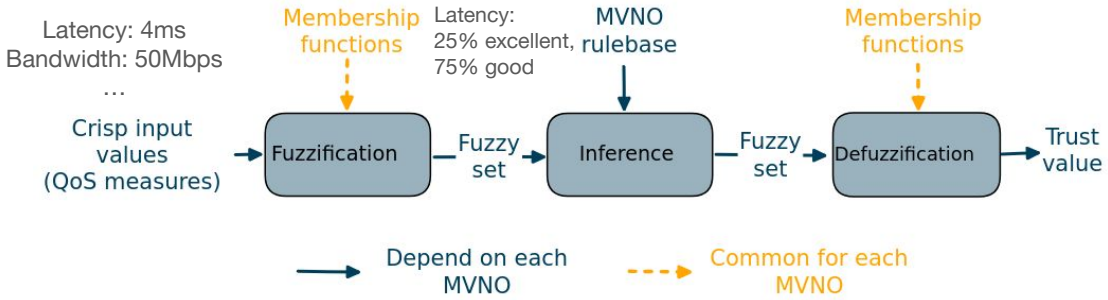
[3] JMJ. Valero, et al. "SLA-Driven Trust and Reputation Management Framework for 5G Distributed Service Marketplaces." IEEE Transactions on Dependable and Secure Computing, 2023

[4] GO. Boateng, et al. "Blockchain-Enabled Resource Trading and Deep Reinforcement Learning-Based Autonomous RAN Slicing in 5G." IEEE Transactions on Network and Service Management, 2022

Archi - aggregation - membership functions illustrated







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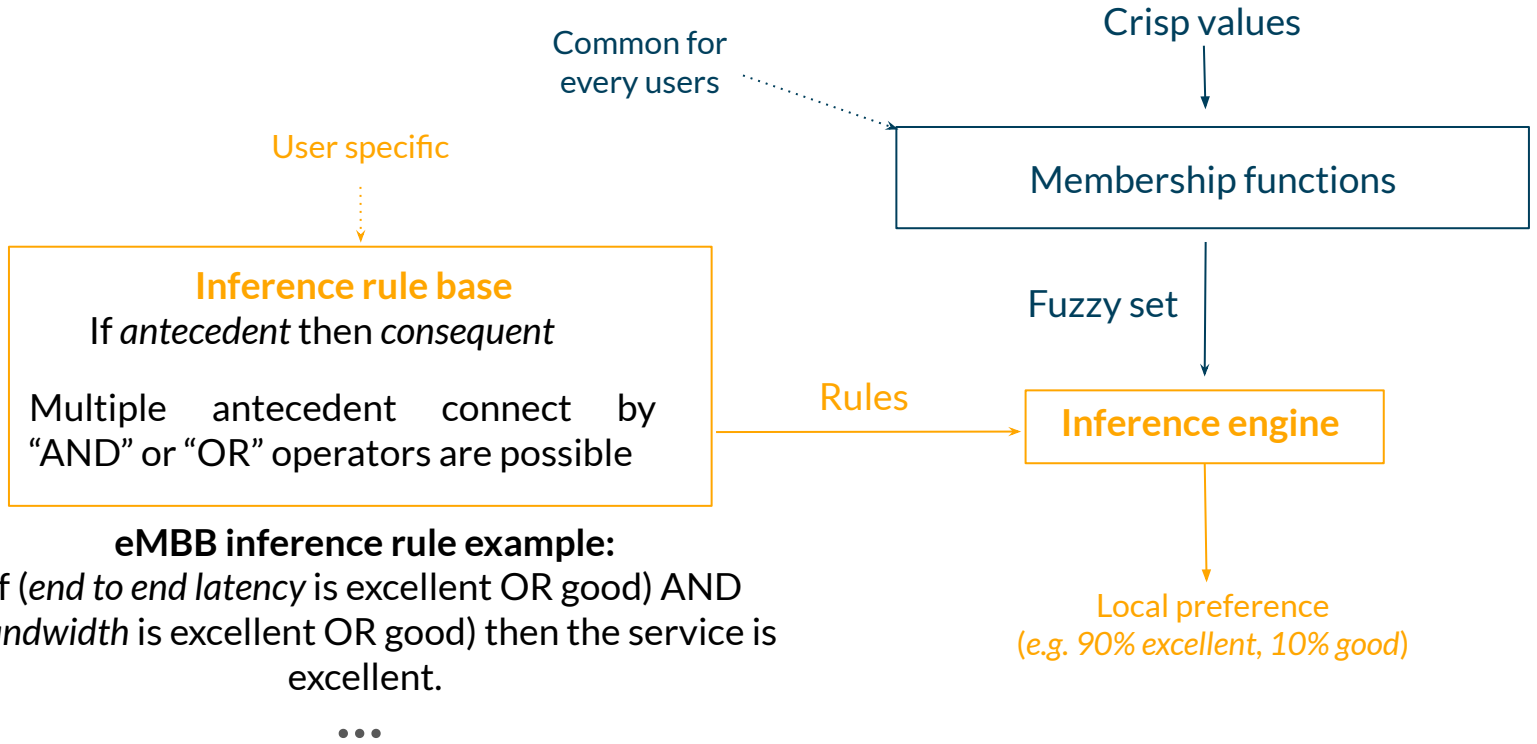
Archi - aggregation - inference engine



eMBB inference rule example:
if (*end to end latency* is excellent OR good) AND (*bandwidth* is excellent OR good) then the service is excellent.

...

Archi - Decay

Constraints

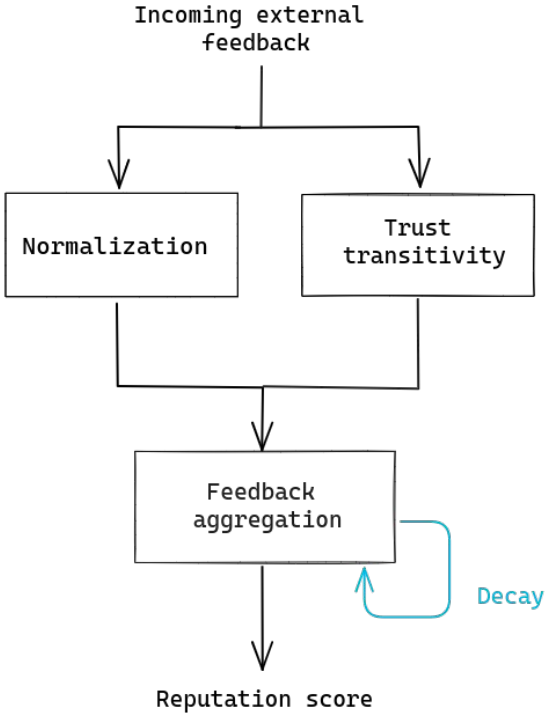
- ➔ c2: reputation should adjust quickly to network failure.
- ➔ c3: failure recovery should be possible.

Exponential decay [5]

- ➔ Gradually decrease the importance of older transactions.
- ➔ Tradeoff between memory and freshness adjusted with a λ parameter.

Adaptive window [6]

- ➔ Consider a big and short sliding window.
- ➔ Reputation is computed on the worst window.



[5] A. Jøsang, et al. "The Beta Reputation System." Conference on Electronic Commerce, 2002.
[6] L. Xiong, et al. "PeerTrust: Supporting Reputation-Based Trust for Peer-to-Peer Electronic Communities." IEEE Transactions on Knowledge and Data Engineering, 2004

Evaluation - setup

Geographical split [7]:

➔ 10 geographical zones,

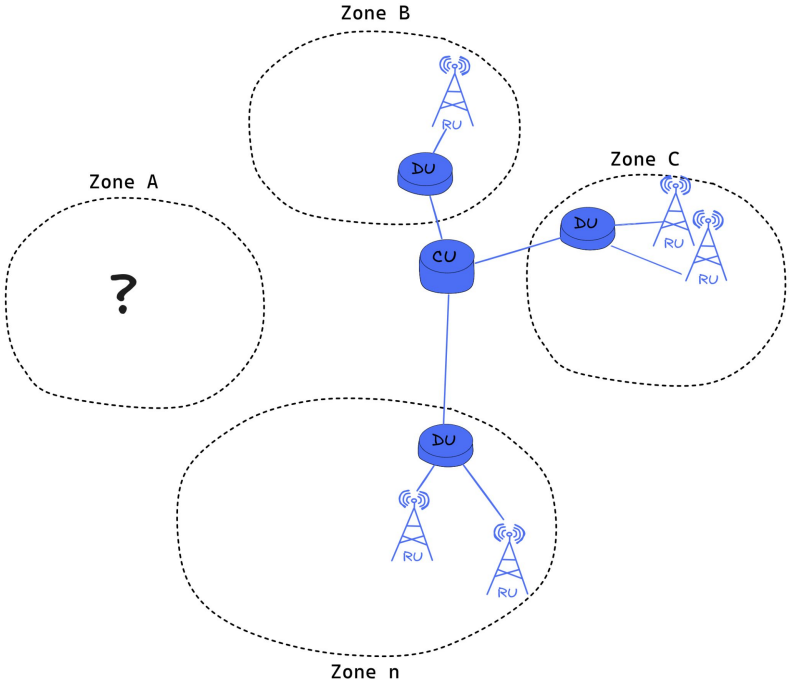
➔ all participants only have a partial geographical coverage.

Logical split [8]:

➔ Each participant specialized in a single use case, *e.g. eMBB, URLLC, mMTC.*

Split level:

➔ 15 participants that own their CU but rent DU + RU.
CU hosts SDAP / PDCP which include QoS flow handling + ciphering.

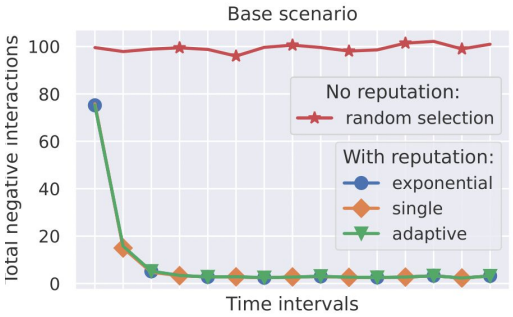


[7] Zeydan, *et al.* "Exploring Blockchain Architectures for Network Sharing: Advantages, Limitations, and Suitability." IEEE Transactions on Network and Service Management, 2023

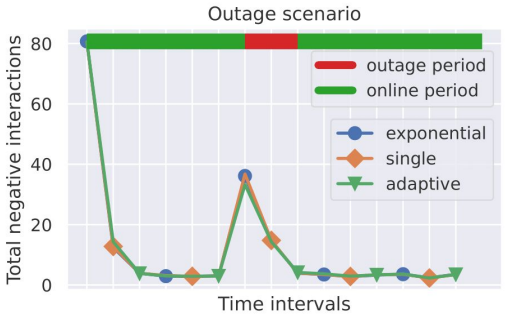
[8] L. Giupponi, *et al.* "Blockchain-Enabled Network Sharing for O-RAN in 5G and Beyond." IEEE Network,, 2022.

Evaluation

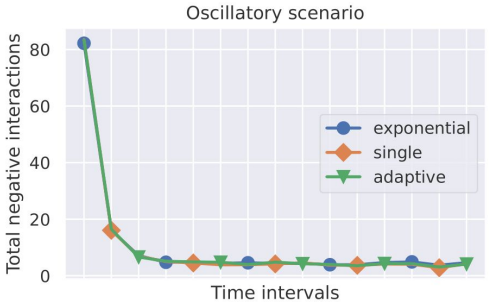
Q: Can the reputation system limit negative interactions ?



Absolute number of negative interactions in the system with no failure on participants.

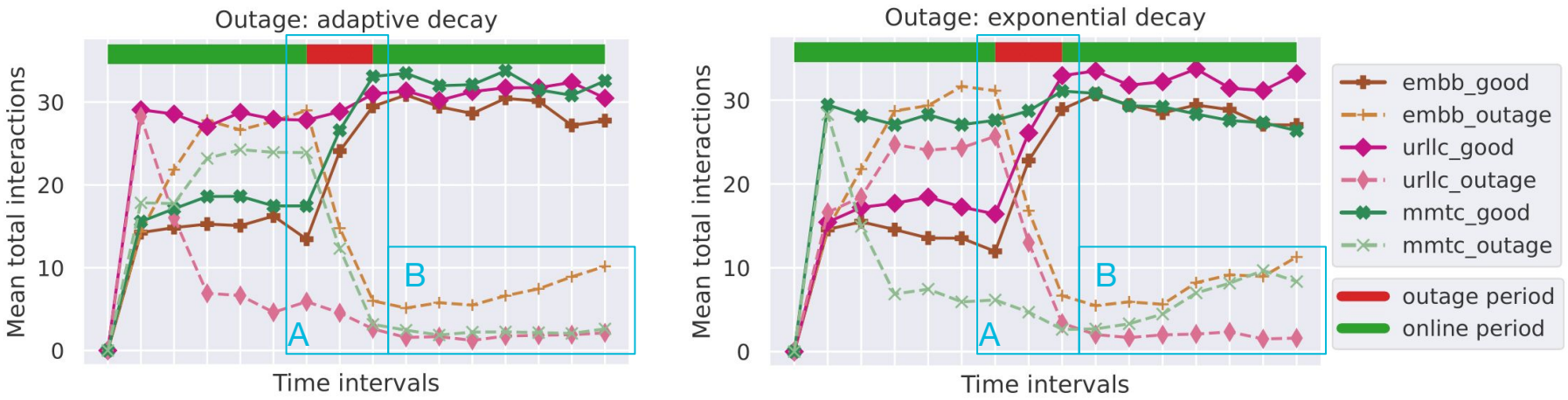


Same but some participants have an outage period.



Same but some participants have a slightly higher failure rate.

Evaluation - outage, zooming on participants



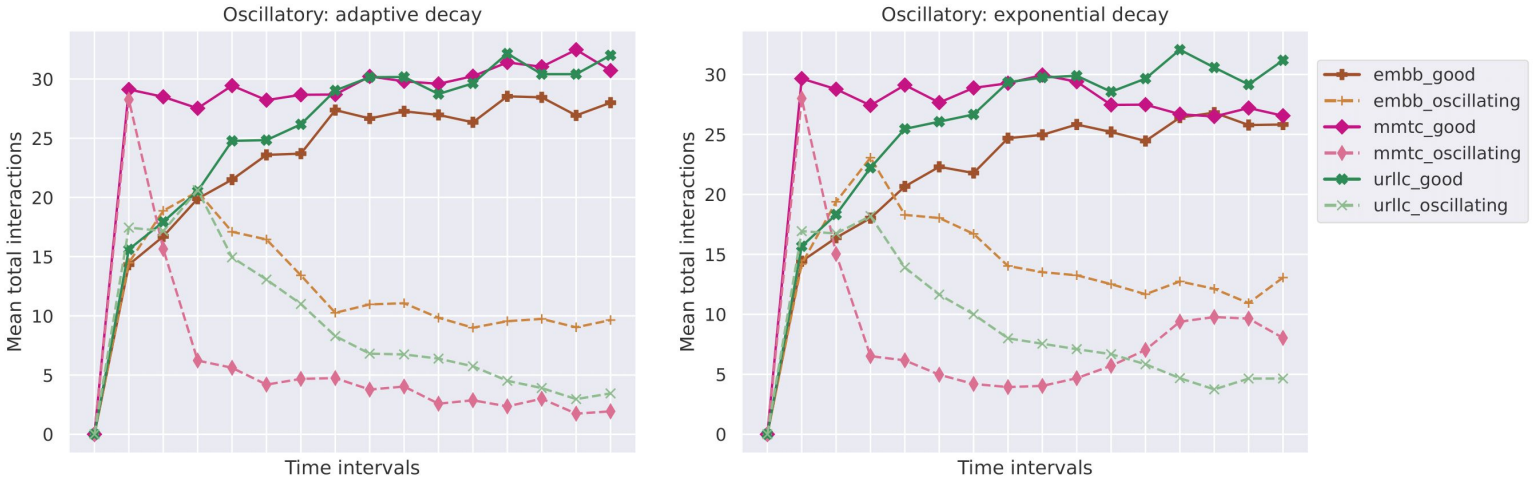
Number of interaction per participant depending on their category. Left chart is adaptive decay, right chart is exponential decay.

Takeaways :

A) Both decay strategies quickly limit the outage impact.

B) Both decay strategies durably penalize outage participants.

Evaluation - oscillatory, zooming on participants



Number of interaction per participant depending on their category. Left chart is adaptive decay, right chart is exponential decay.

Takeaways

- ➔ Adaptive window is slightly better than exponential decay at penalizing oscillatory behaviors.
- ➔ In some case exponential decay “forgot” bad behavior (pink dashed line).

Conclusion

The proposed reputation system:

- ➔ address participants specific requirements using fuzzy logic,
- ➔ handle failure and oscillatory behavior,
- ➔ tested on a RAN scenario but can be generalized elsewhere.

We also highlighted:

- ➔ limits of existing decay strategies for 5G systems.

Short term future works:

- ➔ propose a novel decay strategy,
- ➔ stress test direct attacks on the reputation system (*e.g.* badmouthing).

Mid/long-term future works:

- ➔ include the proposed reputation system in a multi-criterion decision process.

Thank you for your attention !

A fuzzy reputation system for Radio Access Network sharing

- ➔ A novel fuzzy reputation system for RAN sharing in an heterogeneous context.
- ➔ An evaluation validating the proposed architecture and assessing existing decay strategies.

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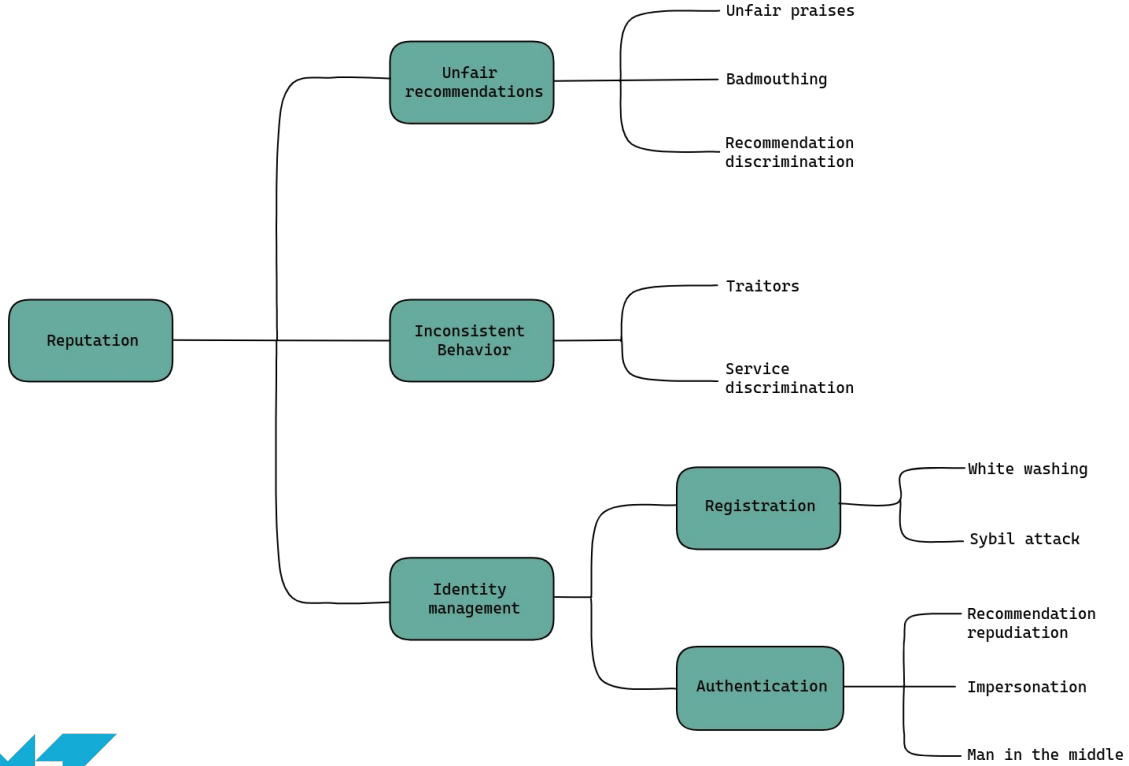
Backup slides - attacks on reputation



[B1] Koutrouli, et al. "Taxonomy of Attacks and Defense Mechanisms in P2P Reputation Systems—Lessons for Reputation System Designers." Computer Science Review. May, 2012.

Addressed in this contribution

Addressed using access control

Addressed using existing cryptographic primitive

Attack on reputation systems taxonomy (adapted from [B1])