Integration of blockchain and O-RAN to enable the Network-as-a-Service paradigm in Beyond 5G[1]

Lorenza Giupponi & **Francesc Wilhelmi**

fwilhelmi@cttc.cat

Hyperledger Telecom SIG

[1] [1] Giupponi, L., & Wilhelmi, F. (2021). Blockchain-enabled Network Sharing for O-RAN. IEEE Network Magazine.

Table of contents

Outline

Network sharing sustainability

Current situation

1. Unclear ARPU increment for 5G deployments
2. Concentration of costs in the RAN
3. Need for cutting CAPEX/OPEX costs

RAN sharing as a promising solution

1. Increase competitiveness
2. Attract new players (OTT SP, verticals, private networks...)
3. Virtualization + Open market & interfaces (O-RAN)

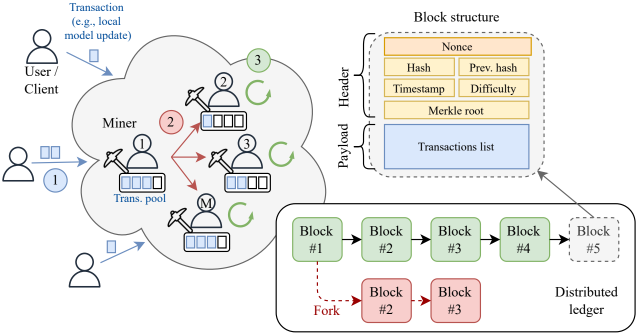
Challenges

1. Sharing resources with ‘untrusted’ parties
2. Monitoring and reliability of measurements

How blockchain can help?

Blockchain for autonomous network management

1. Key properties: Immutability, decentralization, transparency
2. Removes the need for costly intermediaries
3. Automation of the network management and operation



Outline

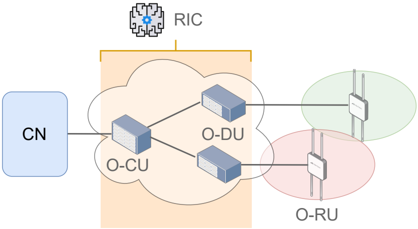
O-RAN basics

O-RAN characteristics

1. Disaggregation of the gNB (similar to what 3GPP proposes)
2. Openness (open interfaces)
3. Intelligence (xApps/rApps)

O-RAN components [2]

- SMO (manag. & orch.)
- O-CU (centralized unit)
- O-DU (distributed unit)
- O-RU (radio unit)
- RIC (intelligent controller)



Blockchain for O-RAN

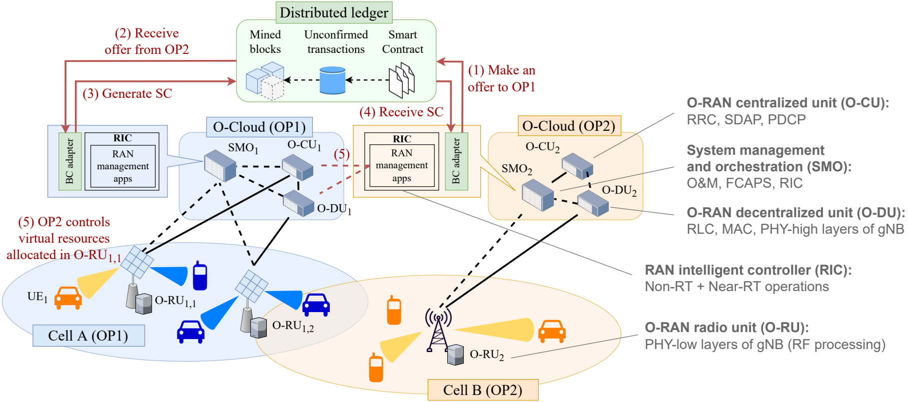
Existing literature

- O-RAN-based architecture to conduct zero-trust mutual authentication with specialized hardware [3]
    - Currently being discussed in O-RAN's Security Focus Group (SFG)
- Blockchain-enabled resource sharing in 5G/6G [4, 5]
- Slice brokering [6, 7]

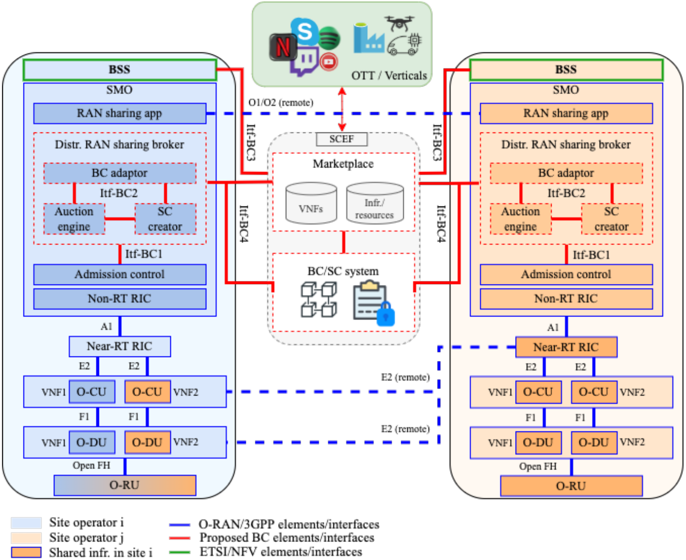
Our work

- We focus on RAN sharing and apply blockchain to automate, accelerate, and secure the trade of resources
- We extend O-RAN arch. to automate the RAN sharing use case
- We focus on network's performance

Blockchain-enabled O-RAN scenario



Blockchain-enabled O-RAN Architecture



RAN sharing mechanisms

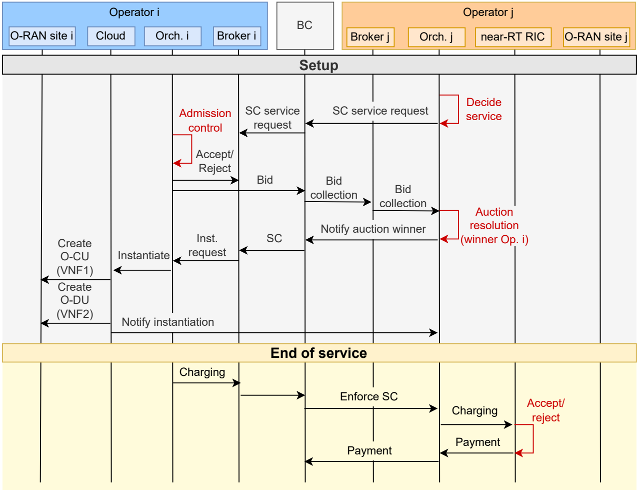
Marketplace-oriented

- Published offers
- Low flexibility
- High efficiency
- Low overhead

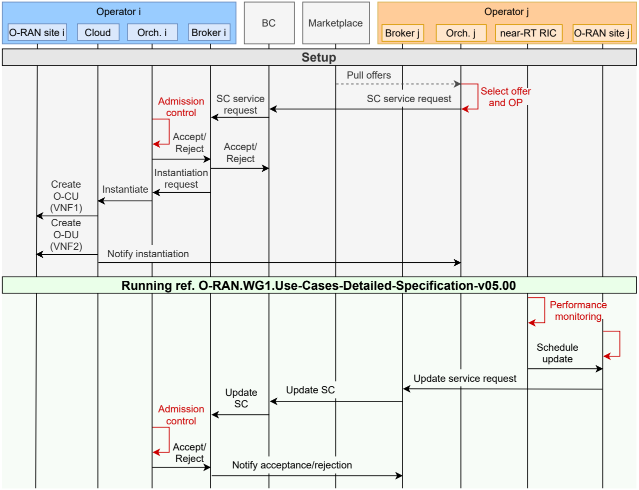
Auction-based

- Bidding system
- High flexibility
- Poor scalability
- High overhead

Flow diagram - Auction



Flow diagram - Marketplace



Outline

Simulation scenario

- Random cellular deployment:[2]
  - 19 APs / 200 users
  - 200 users
- M = [2, 4, 8] MNOs/MVNOs
- Generic PoW-based blockchain
- Legacy vs Auction & Marketplace
- Metrics:
  - **Network:** capacity utilization (C), user satisfaction (S), efficiency (E)

$$S_n(t) = 1 - \exp\left(-K \cdot b_n^{\psi} \cdot p_n^{\xi}\right)$$

    - K: normalizing constant
    - b_n: resources allocated to user n
    - p_n: price paid by n
    - ψ & ξ: sensitivity to service/price (user profile)
  - **Blockchain:** delay, overhead

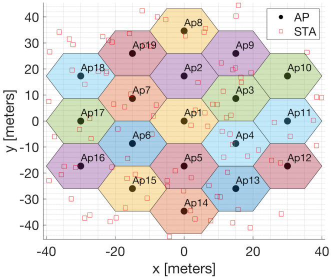


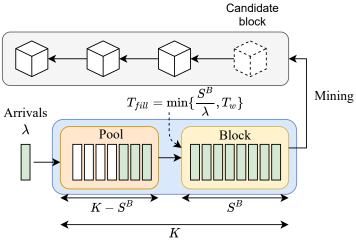
Figure 1: Random deployment

[1] Custom Matlab implementation of the network and sharing mechanisms: `https://github.com/fwilhelmi/blockchain_enabled_ran_architecture` (open access)

Results

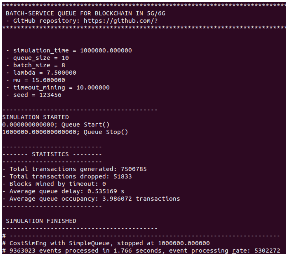
Queue model

- Proposed in [8]
- Complete framework in [8] and [9]
- Matlab implementation: https://bitbucket.org/francesc_wilhelmi/model_blockchain_delay/src/master/



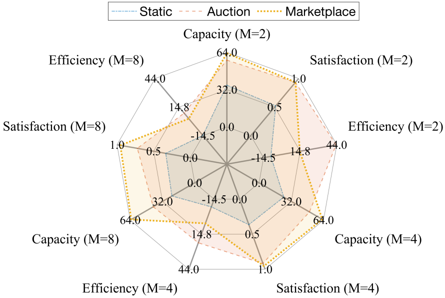
Queue simulator

- Written in C/C++
- Introduced in [8] for validation purposes
- Fast and reliable queue execution
- Source code: https://github.com/fwilhelmi/batch_service_queue_simulator



Blockchain delay characterization

- **Performance improvements**
- Blockchain overheads
- A use case: MNO vs MVNO [10]



- Blockchain-based methods allow leveraging network resources
  - New business opportunities
  - Economic sustainability
- **Auction:** higher efficiency (more flexibility)
- **Marketplace:** higher capacity
  - Limited offers (e.g., 10 MHz/h per site)
  - Faster response to new UE requests

Blockchain delay characterization

- Performance improvements
- **Blockchain overheads**
- A use case: MNO vs MVNO [10]

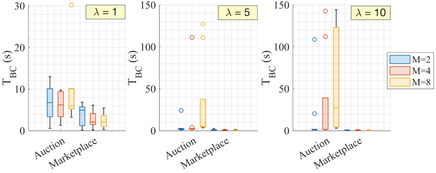


Figure 2: Extra delay (s)

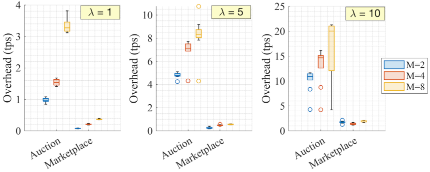
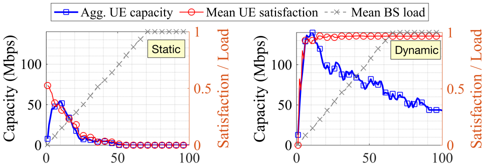


Figure 3: Overhead (tps)

Blockchain delay characterization

- Performance improvements
- Blockchain overheads
- **A use case: MNO vs MVNO [10]**

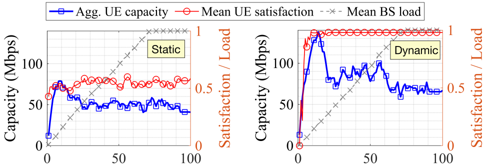


Two settings:

- **Ownership: 100-0**
- Ownership: 50-50

Blockchain delay characterization

- Performance improvements
- Blockchain overheads
- **A use case: MNO vs MVNO [10]**



Two settings:

- Ownership: 100-0
- **Ownership: 50-50**

Outline

Challenges & Opportunities

Opportunities

- **Automated management:** remove long interactions with third parties
- **Resources efficiency:** higher network capacity, more coverage, and improved users' satisfaction
- **Competitiveness:** attract more investments in the network
- **Auditablity:** improved trust and transparency in RAN sharing

Challenges

- **Communication overhead:** accurate short-term requests vs long-term fixed contracts
- **Transaction confirmation latency:** the distribution of information across the blockchain adds delay for instantiating RAN functions
- **Stability:** the stability of a blockchain is strongly tied to the network consensus and game-theoretical aspects may motivate selfish behaviors
- **Scalability:** an increase in the number of blockchain users and transactions can represent both a communication and a storage issue

Any questions?

?

Francesc Wilhelmi, Ph.D.
fwilhelmi@cttc.cat
Centre Tecnològic de Telecomunicacions de Catalunya (CTTC)

Giupponi, L., & Wilhelmi, F. (2021). Blockchain-enabled Network Sharing for O-RAN. *arXiv preprint arXiv:2107.02005.*

O-RAN Alliance, "O-RAN Architecture Description 3.0," `https://www.o-ran.org/resources`, [Accessed on 31 August 2021].

Xu, H., Zhang, L., & Sun, E. (2021). "BE-RAN: Blockchain-enabled RAN with Decentralized Identity Management and Privacy-Preserving Communication". *arXiv e-prints, arXiv-2101.*

"Maksymyuk, T., Gazda, J., Volosin, M., Bugar, G., Horvath, D., Klymash, M., & Dohler, M. (2020). Blockchain-empowered framework for decentralized network management in 6G". *IEEE Communications Magazine, 58(9), 86-92.*

"Togou, M. A., Bi, T., Dev, K., McDonnell, K., Milenovic, A., Tewari, H., & Muntean, G. M. (2020). DBNS: A distributed blockchain-enabled network slicing framework for 5G networks". *IEEE Communications Magazine, 58(11), 90-96.*

Afraz, N., & Ruffini, M. (2020, June). 5g network slice brokering: A distributed blockchain-based market. In 2020 European Conference on Networks and Communications (EuCNC) (pp. 23-27). IEEE.

Togou, M. A., Bi, T., Dev, K., McDonnell, K., Milenovic, A., Tewari, H., & Muntean, G. M. (2020, June). A distributed blockchain-based broker for efficient resource provisioning in 5g networks. In 2020 International Wireless Communications and Mobile Computing (IWCMC) (pp. 1485-1490). IEEE.

Wilhelmi, F., & Giupponi, L. (2021, September). Discrete-time analysis of wireless blockchain networks. In 2021 IEEE 32nd Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC) (pp. 1011-1017). IEEE.

Wilhelmi, F., Barrachina-Muñoz, S., & Dini, P. (2022). End-to-End Latency Analysis and Optimal Block Size of Proof-of-Work Blockchain Applications. arXiv preprint arXiv:2202.01497.

Wilhelmi, F., & Giupponi, L. (2021). On the Performance of Blockchain-enabled RAN-as-a-service in Beyond 5G Networks. In 2021 IEEE Globecom. IEEE.