On the Performance of Blockchain-enabled RAN-as-a-service in Beyond 5G Networks

Centre Tecnològic de Telecomunicacions de Catalunya

Francesc Wilhelmi and Lorenza Giupponi

Globecom 2021

7-11 December 2021

Table of contents

1. Introduction and Related Work
2. BC-enabled dynamic RAN sharing
3. System model
4. Numerical results
5. Conclusions

Outline

1. Introduction and Related Work
2. BC-enabled dynamic RAN sharing
3. System model
4. Numerical results
5. Conclusions

Towards Blockchain-enabled Communications

RAN sharing in 5G/6G

- Need for fostering economic sustainability
- Push towards decentralized solutions
- Exchanging resources among untrusted parties

Towards Blockchain-enabled Communications

RAN sharing in 5G/6G

- Need for fostering economic sustainability
- Push towards decentralized solutions
- Exchanging resources among untrusted parties

Blockchain

- Open telecom market without centralized management
- Immutability, transparency, and security
- Automation of definition and enforcement of SLAs

Towards Blockchain-enabled Communications

RAN sharing in 5G/6G

- Need for fostering economic sustainability
- Push towards decentralized solutions
- Exchanging resources among untrusted parties

Blockchain

- Open telecom market without centralized management
- Immutability, transparency, and security
- Automation of definition and enforcement of SLAs

Need for understanding the impact of BC over wireless networks

Main contributions

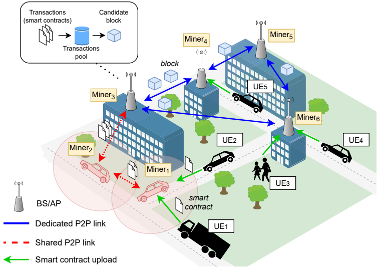

Figure 1: Envisioned BC-enabled RAN ecosystem

1. We foresee a BC-enabled RANaaS scenario for sharing resources
2. We study the performance of BC (wired vs wireless)

Important references

Blockchain & RAN

- Ecosystem: [MGV+20, XKO+20]
- Architectural integration: [XZS+21]

Important references

Blockchain & RAN

- Ecosystem: [MGV+20, XKO+20]
- Architectural integration: [XZS+21]

Slice broker

- Enabler for dynamic resource leasing
- Previous work: [BYVM17, NKH+19]

Important references

Blockchain & RAN

- Ecosystem: [MGV+20, XKO+20]
- Architectural integration: [XZS+21]

Slice broker

- Enabler for dynamic resource leasing
- Previous work: [BYVM17, NKH+19]

Our contribution

- Broader view on RAN ecosystem (operators + UEs)
- Hybrid BC system ([FZZC20])

Outline

1 Introduction and Related Work

2 BC-enabled dynamic RAN sharing

3 System model

4 Numerical results

5 Conclusions

Basics on Blockchain technology

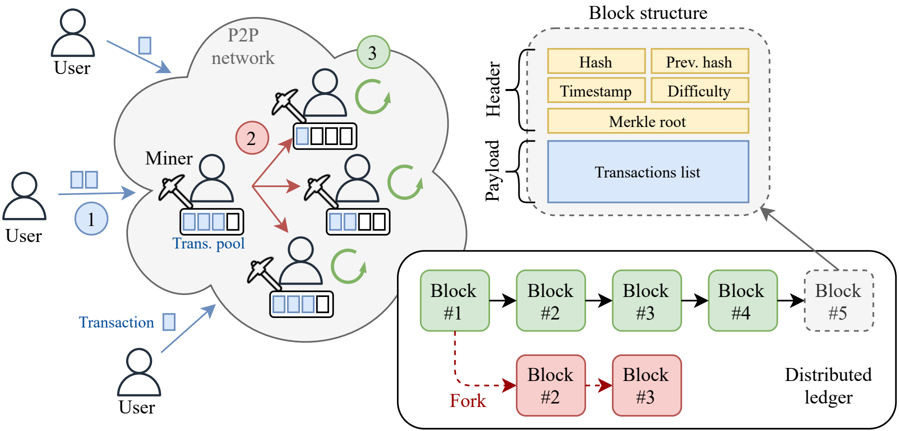

Figure 2: Blockchain (BC) overview

RAN-as-a-Service (RANaaS) ecosystem

UEs

1. Not tied to a single operator
2. On-demand service requests
3. Subscribe based on e.g., offered price, QoS, reputation

RAN-as-a-Service (RANaaS) ecosystem

UEs

1. Not tied to a single operator
2. On-demand service requests
3. Subscribe based on e.g., offered price, QoS, reputation

Operators, providers

1. Exchange radio & infrastructure resources
2. Based on dynamic demand
3. Set prices based on expenses, e.g., equipment, site build-out, licenses

Blockchain for RA automation and auditability

Blockchain types

1. Service blockchain (public)
2. RAN blockchain (private)

Blockchain for RA automation and auditability

Blockchain types

1. Service blockchain (public)
2. RAN blockchain (private)

Functionalities

1. Record transactions
2. Enable auctions
3. Payment by enforcing SCs

Blockchain for RA automation and auditability

Blockchain types

1. Service blockchain (public)
2. RAN blockchain (private)

Functionalities

1. Record transactions
2. Enable auctions
3. Payment by enforcing SCs

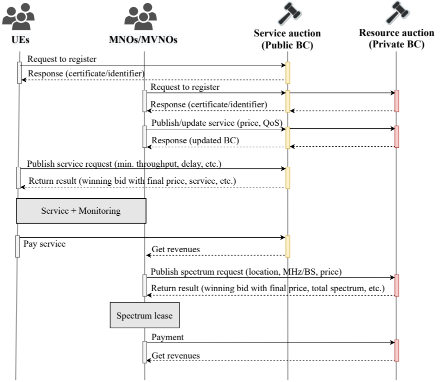

Figure 3: BC-enabled RA procedures

Outline

1 Introduction and Related Work

2 BC-enabled dynamic RAN sharing

3 System model

4 Numerical results

5 Conclusions

Blockchain transaction confirmation delay

Steps

1. Users submit transactions to peer nodes (T_{up})
2. Collect transactions to fill a candidate block (T_{queue})[a]
3. Miners run consensus (T_{mine})
4. The winning miner propagates the mined block (T_{prop})

[a] More details in [WG21]

$$T_{\text{c}} = T_{\text{up}} + \frac{(T_{\text{queue}} + T_{\text{mine}} + T_{\text{prop}})}{1 - p_{\text{fork}}}$$

Other performance metrics

UE performance:

$$C_n = b_n \log_2(1 + \mathrm{SINR}_n)$$

UE service acceptance:

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

Outline

1. Introduction and Related Work
2. BC-enabled dynamic RAN sharing
3. System model
4. Numerical results
5. Conclusions

Simulation scenario

Scenario

- Random cellular deployment
  - 19 BSs acting as miners
- BC links
  - Public (UEs): IEEE 802.11ax
  - Private (operators): 5G NR X2/Xn
- Simulation-driven analysis

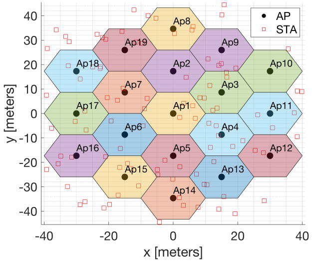

Figure 4: Simulation scenario

Note: The code used in this paper is of open access, available at `https://github.com/fwilhelmi/blockchain_ran_sharing_simulator`

Analysis of the confirmation delay

- Arrivals (λ)
- Block size (S^B)
- Max. waiting time (T_w)
- 802.11ax or X2/Xn

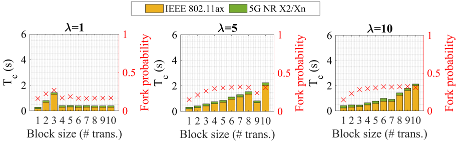

Figure 5: $T_{\text{wait}} = 0.1\text{s}$

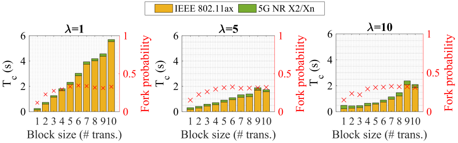

Figure 6: $T_{\text{wait}} = 5\text{s}$

UE performance

- RAN sharing type:
  1. **Static:** no exchange
  2. **Dynamic:** BC-based auction
- User traffic profiles:
  1. Low
  2. Average
  3. High
- M sharing operators

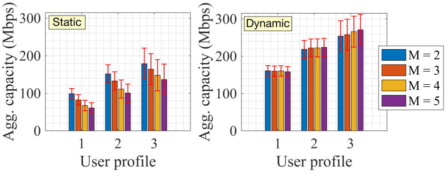

Figure 7: Capacity

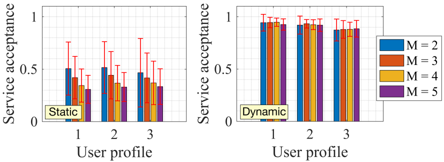

Figure 8: Service acceptance

Use case: MNO & MVNO

- Static vs dynamic sharing:
  1. The MNO owns all the resources
  2. Split resources equally on before-hand

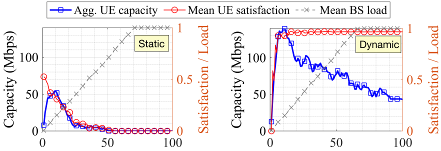

Figure 9: {1,0} RAN ownership ratio

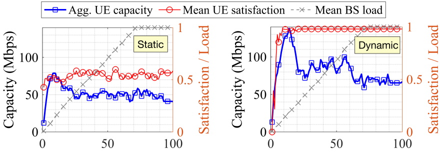

Figure 10: {0.5,0.5} RAN ownership ratio

Outline

1. Introduction and Related Work
2. BC-enabled dynamic RAN sharing
3. System model
4. Numerical results
5. Conclusions

Conclusions

Summary

- Proposal to adopt BC technology for RANaaS
- Simulation-driven performance evaluation

Conclusions

Summary

- Proposal to adopt BC technology for RANaaS
- Simulation-driven performance evaluation

Some conclusions

- Fostering competitiveness is useful to reduce O&M costs
- BC performance can be drastically compromised
- Links with constant delays (e.g., X2/Xn) favor BCs operation
- Contention-based links (e.g., 802.11ax) generate high instability

Conclusions

Summary

- Proposal to adopt BC technology for RANaaS
- Simulation-driven performance evaluation

Some conclusions

- Fostering competitiveness is useful to reduce O&M costs
- BC performance can be drastically compromised
- Links with constant delays (e.g., X2/Xn) favor BCs operation
- Contention-based links (e.g., 802.11ax) generate high instability

Ways forward

- Architectural & implementation aspects for BC integration
- Operators pricing and strategies

Questions

?

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

References I

Jere Backman, Seppo Yrjölä, Kristiina Valtanen, and Olli Mämmelä, *Blockchain network slice broker in 5G: Slice leasing in factory of the future use case*, 2017 Internet of Things Business Models, Users, and Networks, IEEE, 2017, pp. 1–8.

Sizheng Fan, Hongbo Zhang, Yuchen Zeng, and Wei Cai, *Hybrid Blockchain-Based Resource Trading System for Federated Learning in Edge Computing*, IEEE Internet of Things Journal (2020).

Taras Maksymyuk, Juraj Gazda, Marcel Volosin, Gabriel Bugar, Denis Horvath, Mykhailo Klymash, and Mischa Dohler, *Blockchain-Empowered Framework for Decentralized Network Management in 6G*, IEEE Communications Magazine **58** (2020), no. 9, 86–92.

Boubakr Nour, Adlen Ksentini, Nicolas Herbaut, Pantelis A Frangoudis, and Hassine Moungla, *A blockchain-based network slice broker for 5G services*, IEEE Networking Letters **1** (2019), no. 3, 99–102.

Francesc Wilhelmi and Lorenza Giupponi, *Discrete-Time Analysis of Wireless Blockchain Networks*, arXiv e-prints (2021), arXiv–2104.05586.

References II

Hao Xu, Paulo Valente Klaine, Oluwakayode Onireti, Bin Cao, Muhammad Imran, and Lei Zhang, *Blockchain-enabled resource management and sharing for 6G communications*, Digital Communications and Networks **6** (2020), no. 3, 261–269.

Hao Xu, Lei Zhang, Elaine Sun, et al., *BE-RAN: Blockchain-enabled Open-RAN with Decentralized Identity Management and Privacy-Preserving Communication*, arXiv preprint arXiv:2101.10856 (2021).