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

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# 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

1. Introduction

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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

(1) Make an offer to OP1

(2) Receive offer from OP2

(3) Generate SC

(4) Receive SC

(5) OP2 controls virtual resources allocated in O-RU1,1

UE1

Cell A (OP1)

Cell B (OP2)

O-RU2

O-RU1,1

O-RU1,2

O-Cloud (OP1)

O-Cloud (OP2)

RIC

BC adapter

SMO1

O-CU1

O-DU1

O-CU2

O-DU2

Distributed ledger

Mined blocks

Unconfirmed transactions

Smart Contract

O-RAN centralized unit (O-CU):
RRC, SDAP, PDCP

System management and orchestration (SMO):
O&M, FCAPS, RIC

O-RAN decentralized unit (O-DU):
RLC, MAC, PHY-high layers of gNB

RAN intelligent controller (RIC):
Non-RT + Near-RT operations

O-RAN radio unit (O-RU):
PHY-low layers of gNB (RF processing)
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
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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 (\(E\))
    \[
    S_n(t) = 1 - \exp (-K \cdot b_n^\psi \cdot p_n^\xi)
    \]
    - \(K\): normalizing constant
    - \(b_n\): resources allocated to user \(n\)
    - \(p_n\): price paid by \(n\)
    - \(\psi\) \& \(\xi\): sensitivity to service/price (user profile)
  - **Blockchain**: delay, overhead

\(^1\) Custom Matlab implementation of the network and sharing mechanisms: [https://github.com/fwilhelmi/blockchain_enabled_ran_architecture](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/](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](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
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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**
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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
- **Auditability**: 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?

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