Discrete-Time Analysis of Wireless Blockchain Networks

Centre Tecnològic de Telecomunicacions de Catalunya

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Outline

Towards Blockchain-enabled Communications

Network sharing in 5G/6G

- Economic sustainability
- Need for automation to exchange network resources
- Need for trust

Blockchain

- Immutability, transparency, and security
- Exchange resources in 5G/6G
- Important challenges (computation, energy, delay, scalability)

Need for understanding the impact of BC over wireless networks

Main contributions

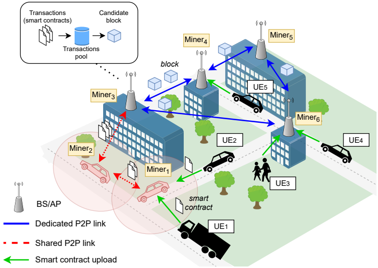

Figure 1: Envisioned BC-enabled RAN ecosystem

1. Open, flexible BC RAN ecosystem
2. Batch-service queue model for BC
3. Model validation
4. Insights on Wireless BC Networks

All the source code used in this project is of open access and completely available:

- BC batch-service queue simulator: `https://github.com/fwilhelmi/batch_service_queue_simulator`
- Model implementation: `https://bitbucket.org/francesc_wilhelmi/model_blockchain_delay`

Important references

Blockchain characterization

- Simulation, analytical model, traces
- Broad survey: [FGKM20]

Markov processes and batch service queuing

- Packets leave the queue in batches, rather than individually
- Baseline works: [KK17, Y. 18, LMC18, GPL$^+$19, LMC$^+$19]

Our contribution

- We model queue states at departure instants
- We incorporate the key effects of timers and forks

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Blockchain-enabled RAN delays

Transaction **confirmation** latency:

1. Smart contract upload (T_{up})
2. Queuing (T_{q})
3. Block generation (T_{bg})
4. Block propagation (T_{bp})

$$T_{\mathrm{BC}} = T_{\mathrm{up}} + \frac{(T_{\mathrm{q}} + T_{\mathrm{bg}} + T_{\mathrm{bp}})}{1 - p_{\mathrm{fork}}}$$

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Queue behavior

Overview

- Finite-length $M/M^s/1/K$ queue
- Departures conditioned to arrivals (λ), block size (S^B), mining timeout (T_w), and mining rate (μ)
- Goal: find expected queue occupancy

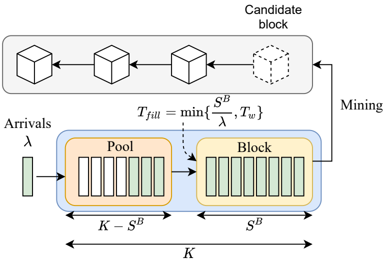

Figure 2: Blockchain queue

Markov model

Steps

1. Find departures distribution ($\boldsymbol{\pi}^d$)
2. Get steady-state distribution ($\boldsymbol{\pi}^s$)
3. Compute expected queue occupancy and delay

Forks

1. Concurrent miners affect to the mining rate ($\mathrm{E}[X_{(1)}] = \frac{1}{n\mu}$)
2. Transactions involved in forks are re-added to the queue

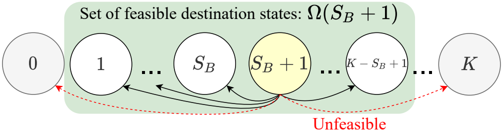

Figure 3: Inter-departure states

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Simulation scenario

Scenario

- Random cellular deployment
  - 19 BS acting as miners
- BC links
  - IEEE 802.11ax (UE-BS)
  - 5G NR X2/Xn (P2P)
- Characterize the delay for different BC parameters

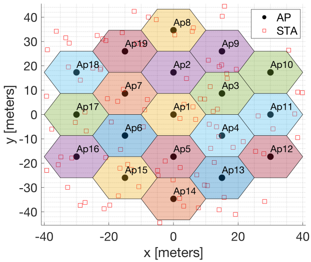

Figure 4: Simulation scenario

Validation of the queuing delay

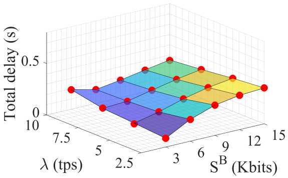

Figure 5: $T_w = 0.5$ s, forks disabled

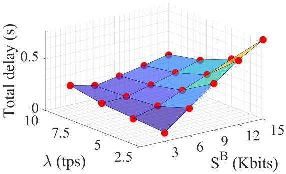

Figure 6: $T_w = 2$ s, forks disabled

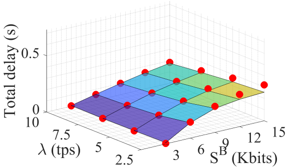

Figure 7: $T_w = 0.5$ s, forks enabled

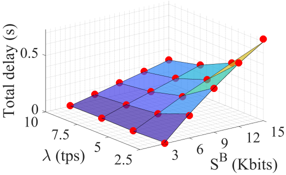

Figure 8: $T_w = 2$ s, forks enabled

Analysis of the queuing delay

- Impact of λ, S^B and T_w
- Closed-form results
- Averaged results for $\lambda = \{2.5, 5, 7.5, 10, 12.5, 15\}$

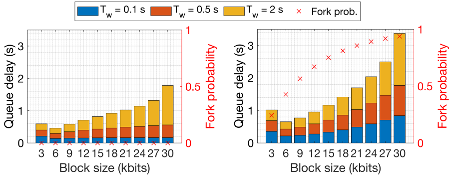

Figure 9: Queuing delay

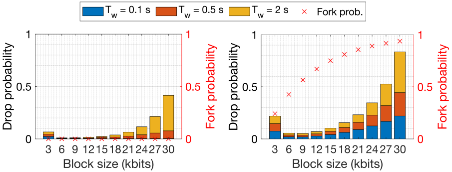

Figure 10: Drop probability

Transaction confirmation latency

- 5-30 concurrent STAs
- Full-buffer UDP-like traffic
- Block size (S^B) fixed to 6 Kbits
- Arrivals rate (λ) fixed to 7.5
- 10 random deployments

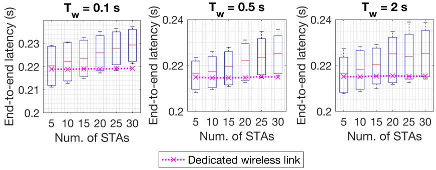

Figure 11: Forks disabled

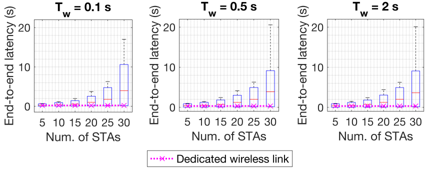

Figure 12: Forks enabled

Outline

Some conclusions

- Future communications enabled by BC
- Novel queue model for the BC delay, including timers and forks
- Analysis on the performance of the wireless BC network
- Future work:
  - Model packet losses
  - Model re-transmissions
  - Model burst arrivals
  - Model different types of transactions

Questions

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