CS 3551

# Is Blockchain a Better Solution for Managing Health Data?

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# Background Review: Issue

- Fragmented, slow access to medical data
  - Delayed maintenance by providers
- System interoperability
  - Barrier between different provider and hospital systems: lack of coordination
  - No universally recognized patient identifier (Director of CBMI, Shaun Grannis)
    - 1/5 of patient records are not accurately matched even within the same healthcare system
    - 1/2 of patient records are mismatched when data is transferred between healthcare systems
- Slow innovation: data quality and quantity for research

# Methodology

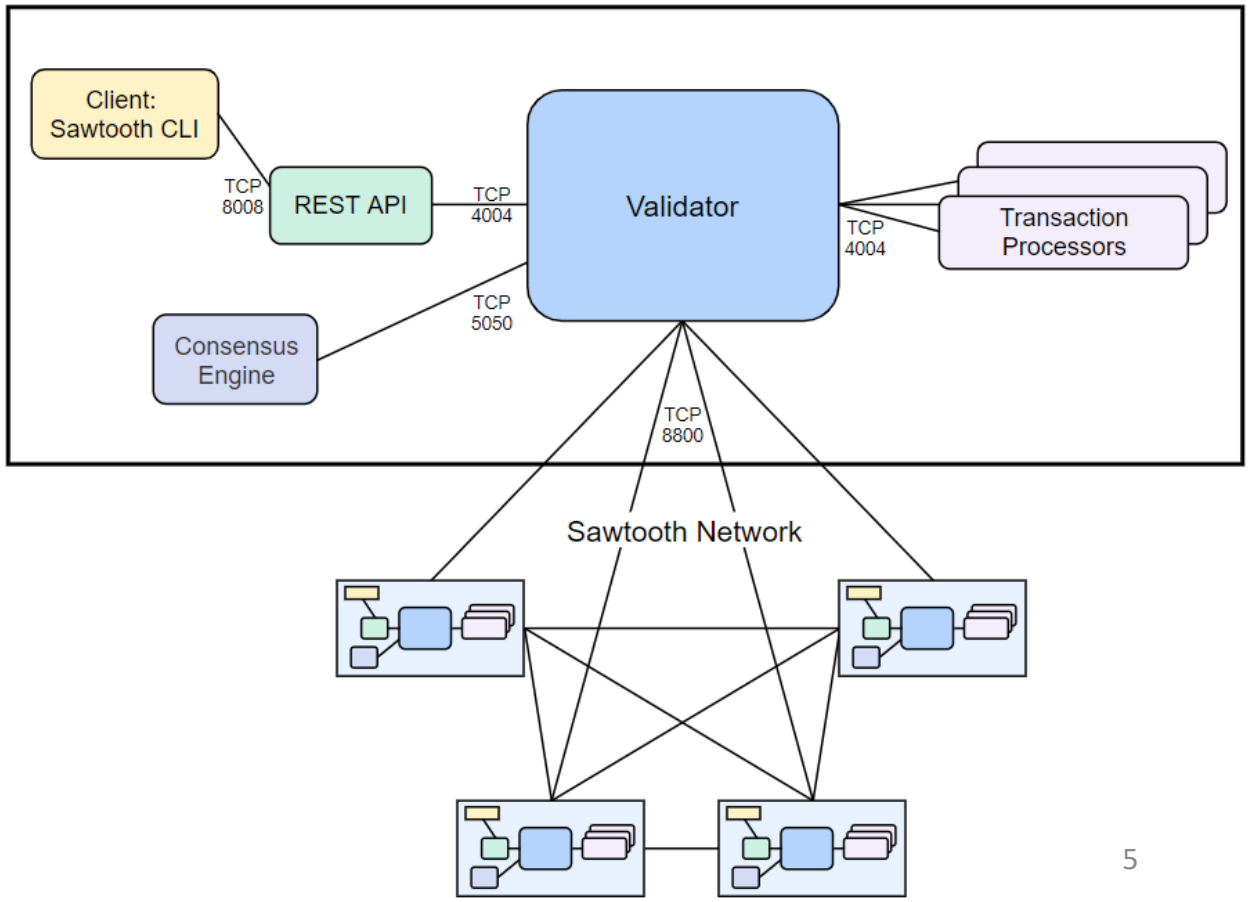
1. Background
   - ≈ Problems I want to solve
   - ≈ Overview of relevant healthcare applications: Hyperledger Sawtooth
2. Implementation
   - ≈ Sawtooth-Healthcare
3. Evaluation
   - ≈ How well does Sawtooth / Sawtooth-Healthcare work in general?
   - ≈ Comparison between Blockchain and centralized database
4. Conclusion
   - ≈ Decision Tree: Is Blockchain a better solution for managing health data?

# Sawtooth & Sawtooth-Healthcare

# Background Review: Sawtooth

- Especially for permissioned (private) and enterprise networks
- Parallel scheduling
- Highly modular
  - Transaction rules
  - Permissioning: roles, identities
  - Pluggable consensus algorithms
    - Sawtooth PBFT
    - Sawtooth Raft
    - **PoET: Proof of Elapsed Time**

→ **Scalable**



# Background Review: Sawtooth

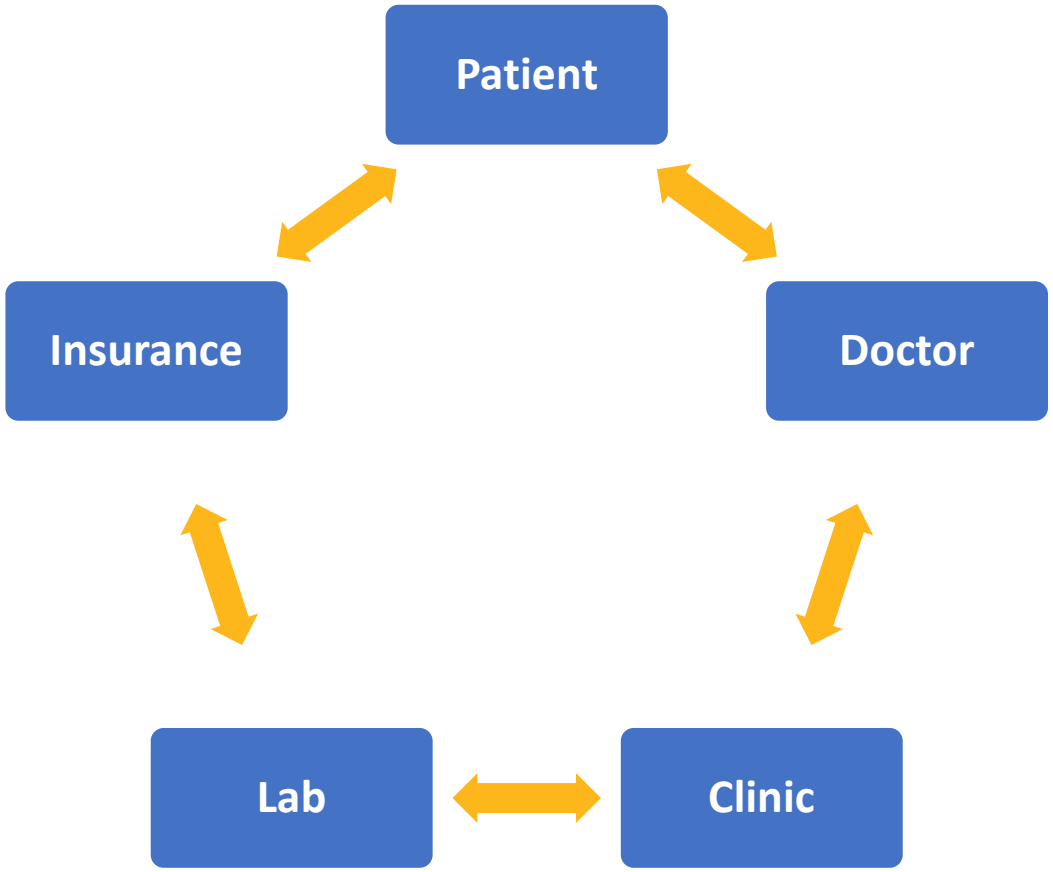
- **PoET: Proof of Elapsed Time**
  - Leader-election lottery

1) Each validator requests for a waiting time from the trusted module
2) Each validator is assigned with a random waiting time
3) The validator with the shortest time becomes the leader
4) Once waiting time has elapsed, the validator can claim the leadership

- Especially for large networks

# Implementation: Sawtooth-Healthcare

- Permissioned
- 3 nodes in 3 VMs
- Consensus: PoET



# Implementation: Sawtooth-Healthcare

- Functions
  - Register new users
  - Read lists: Clinics, Doctors, Patients, Labs, Insurance, Invoice
  - Read and Add records: Lab Test, Pulse, Contract, Claims
  - Patient allows/revokes consent to access his data by Clinic Desk/Doctor

# Implementation: Sawtooth-Healthcare

As Clinic|As Doctor|As Patient|As Lab|As Insurance

Client public key

037d4c53d0db9ea8f664e111cf6b484c68b3a2e11845b41061c19b753a1229b97d

- Clinics List
- Doctors List
- Patients List
- Labs List
- Insurance List
- Invoice List
- ---
- New Clinic
- ---
- Add Lab Test
- Lab Test List
- ---
- Add Pulse
- Pulse List
- ---
- Add Contract
- Contract List
- ---
- Register Claim
- Claims List

As Clinic|As Doctor|As Patient|As Lab|As Insurance

ID

ID

CLIENT PKEY

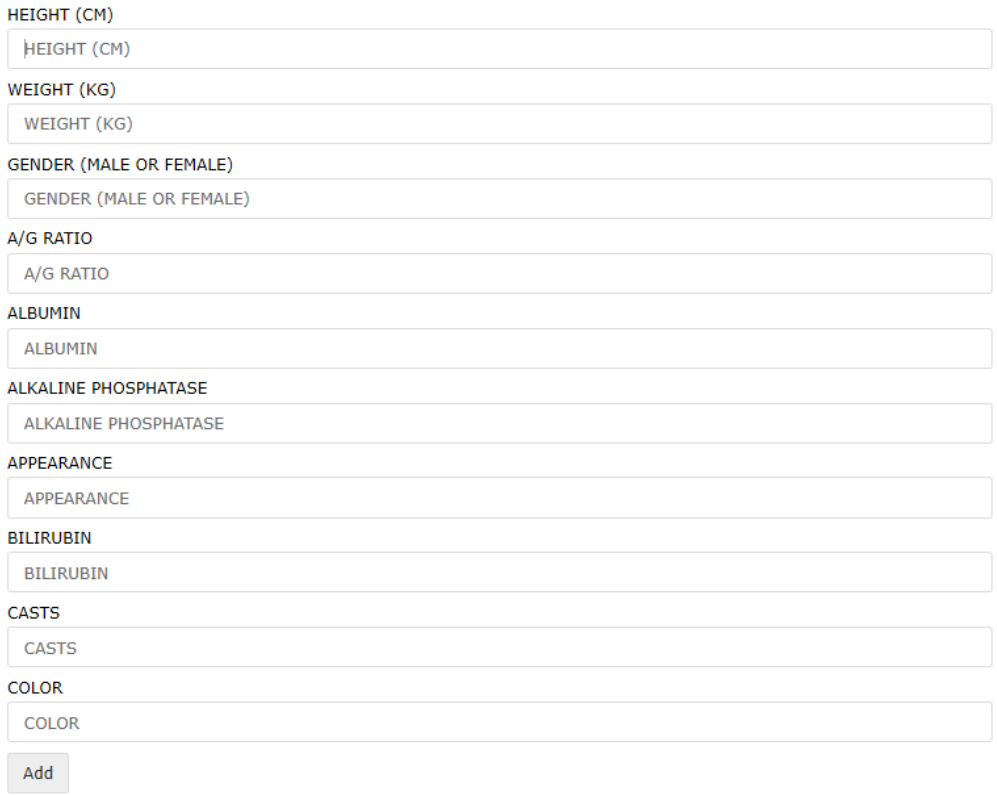
CLIENT PKEY

Add

```
DEBUG:rest_api.consent_common.transaction:client_pkey: 037d4c53d0db9ea8f664e111cf6b
DEBUG:rest_api.consent_common.transaction:inputs: 27177e029d030946748084e15e57c1282
DEBUG:rest_api.consent_common.transaction:payload: payload_type: ADD_CLIENT
create_client {
  public_key: "037d4c53d0db9ea8f664e111cf6b484c68b3a2e11845b41061c19b753a1229b97d"
  permissions {
    type: READ_CLINIC
  }
  permissions {
    type: WRITE_CLAIM
  }
  permissions {
    type: READ_CLAIM
  }
  permissions {
    type: CLOSE_CLAIM
  }
  permissions {
    type: WRITE_PAYMENT
  }
  permissions {
    type: READ_OWN_CLINIC
  }
  permissions {
    type: READ_PATIENT
  }
}
```

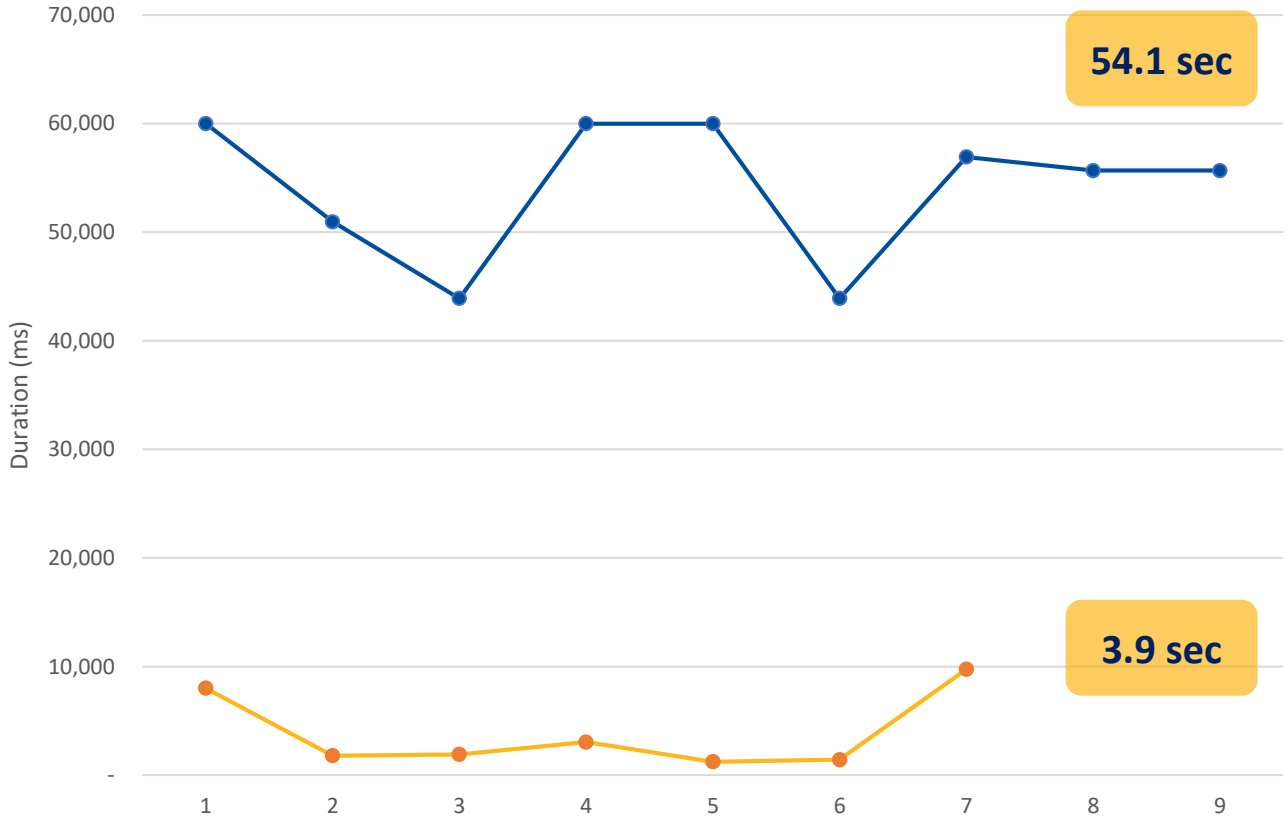
# Implementation: Sawtooth-Healthcare

- Add records: Lab Test, Pulse, Contract, Claims
- Patient allows/revokes consent to access his data by Clinic/Doctor



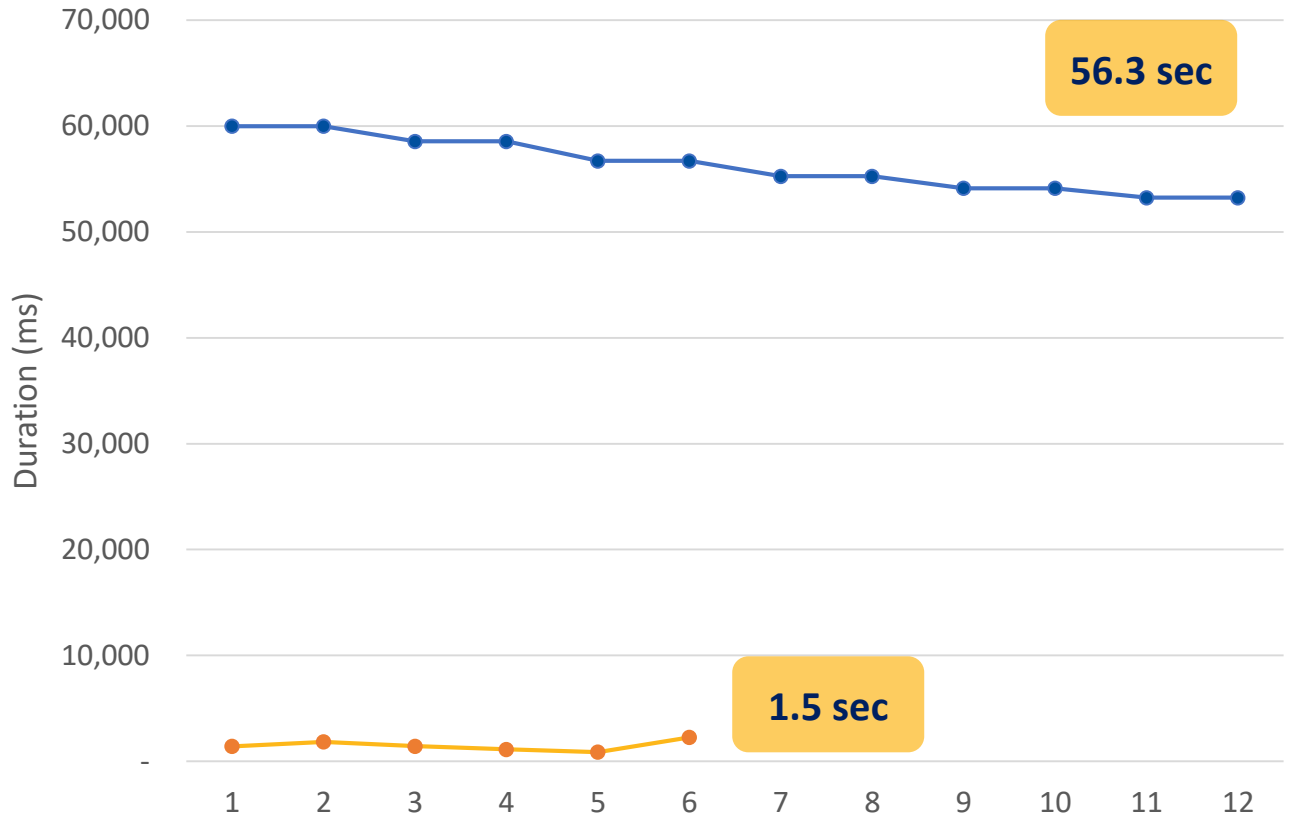

# Evaluation: Sawtooth-Healthcare

- Connection: 11.48 ms
- GET
  - Read list: 20 times
    - AVG: 28,997.14 ms (~30 sec)
    - 2 groups:
      - 3,883.15 ms
      - 54,111.13 ms
    - Outliers:
      - ~ 0.05 ms
      - > 3 min



# Evaluation: Sawtooth-Healthcare

- POST
  - Add record: 20 times
    - AVG: 28,901.26 ms (~30 sec)
    - 2 groups:
      - 1,491.37 ms
      - 56,311.15 ms
    - Outliers:
      - ~ 0.05 ms
  - Make payment
    - AVG: 34,516.39 (~35 sec)



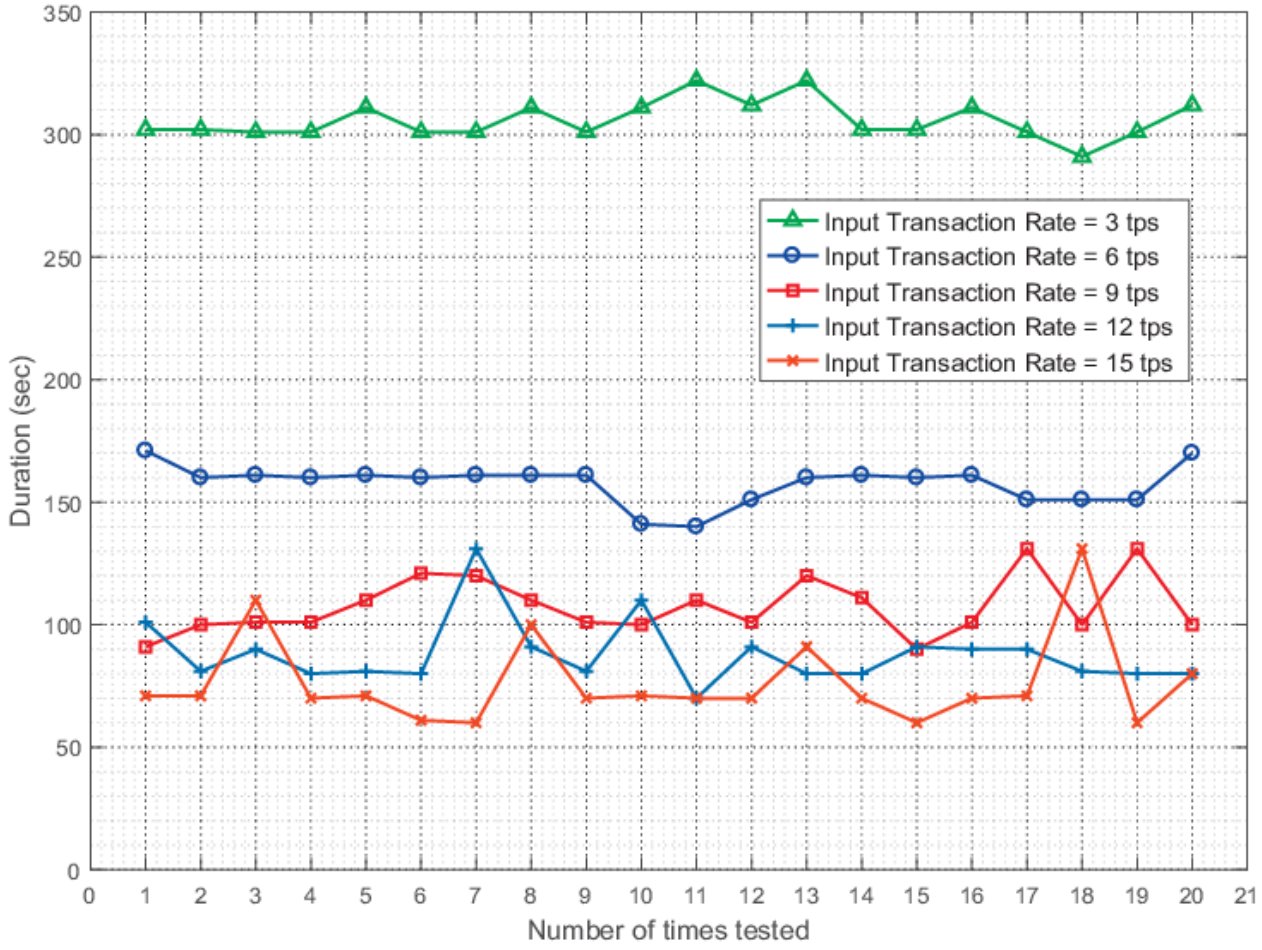
# Evaluation: Sawtooth-Healthcare

| Container | MEM (%) | CPU (%) | NET I (kB) | NET O (kB) |
|---|---|---|---|---|
| healthcare-web-app-0 | 4.20 | 0.01 | 1,290 | 1,380 |
| healthcare-web-app-1 | 4.12 | 0.01 | 1,290 | 1,360 |
| healthcare-web-app-2 | 4.14 | 0.01 | 1,300 | 1,360 |
| sawtooth-healthcare-poet-engine-0 | 1.46 | 0.03 | 77.65 | 67.3 |
| sawtooth-healthcare-poet-engine-1 | 1.39 | 0.03 | 72.20 | 62.33 |
| sawtooth-healthcare-poet-engine-2 | 1.37 | 0.03 | 77.83 | 67.59 |
| sawtooth-healthcare-poet-validator-0 | 1.02 | 0.02 | 78.63 | 67.53 |
| sawtooth-healthcare-poet-validator-1 | 1.01 | 0.02 | 76.55 | 67.10 |
| sawtooth-healthcare-poet-validator-2 | 1.03 | 0.02 | 80.80 | 70.78 |
| sawtooth-rest-api-0 | 1.43 | 0.03 | 123.50 | 111.90 |
| sawtooth-rest-api-1 | 1.32 | 0.02 | 121.60 | 111.30 |
| sawtooth-rest-api-2 | 1.31 | 0.02 | 124 | 113.48 |
| sawtooth-settings-tp-0 | 1.09 | 0.02 | 122.80 | 111.65 |
| sawtooth-settings-tp-1 | 1.03 | 0.01 | 121.95 | 112.03 |
| sawtooth-settings-tp-2 | 1.02 | 0.02 | 122.88 | 112.08 |

# Evaluation: Sawtooth Performance Consistency

- **Input Transaction Rate**
  - Low: stable but inefficient
  - High: fast but unstable (fork)

| Input Rate | Avg. Throughput | Avg. Duration |
|---|---|---|
| 3 tps | 2.93 tps | 305.90 sec |
| 6 tps | 5.67 tps | 157.65 sec |
| 9 tps | 8.36 tps | 107.50 sec |
| 12 tps | 10.24 tps | 87.95 sec |
| 15 tps | 12.03 tps | 76.40 sec |

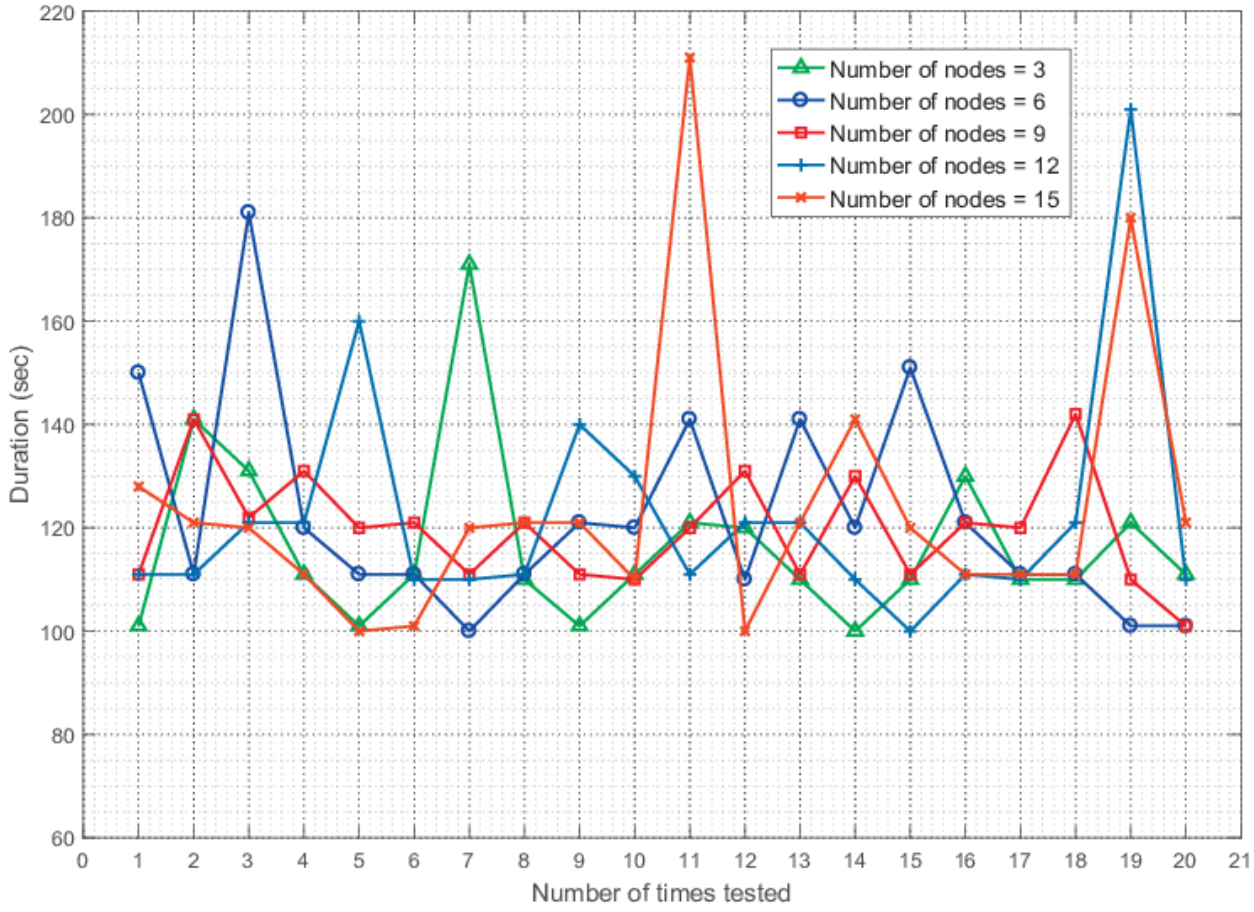



src: Shi, Z., Zhou, H., Hu, Y., Surbiryala, J., de Laat, C., & Zhao, Z. (2019). Operating permissioned blockchain in clouds: A performance study of Hyperledger Sawtooth. 2019 18th International Symposium on Parallel and Distributed Computing (ISPDC), pp. 50-57. http://doi.org/10.1109/ISPDC.2019.00010

# Evaluation: Sawtooth Performance Consistency

- Input Transaction Rate
- **# of VMs**
  - No obvious impact
  - Scalable

| # of VMs | Avg. Throughput | Avg. Duration |
|---|---|---|
| 3 | 7.75 tps | 116.60 sec |
| 6 | 7.43 tps | 122.20 sec |
| 9 | 7.47 tps | 119.80 sec |
| 12 | 7.46 tps | 122.05 sec |
| 15 | 7.40 tps | 124.00 sec |

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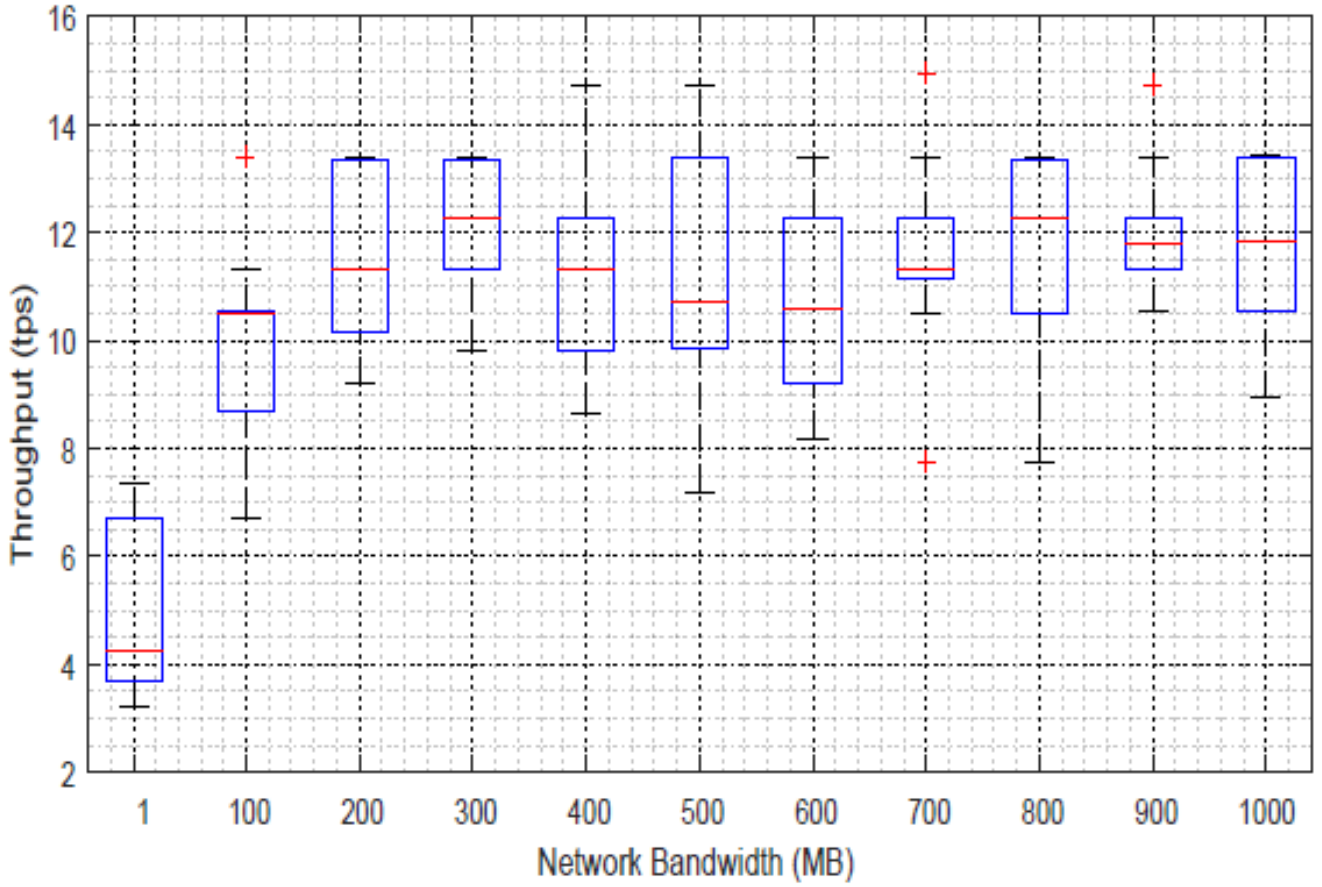
# Evaluation: Sawtooth Performance Stability

- **Network Bandwidth**
  - not sensitive
    till bandwidth is below 100MB

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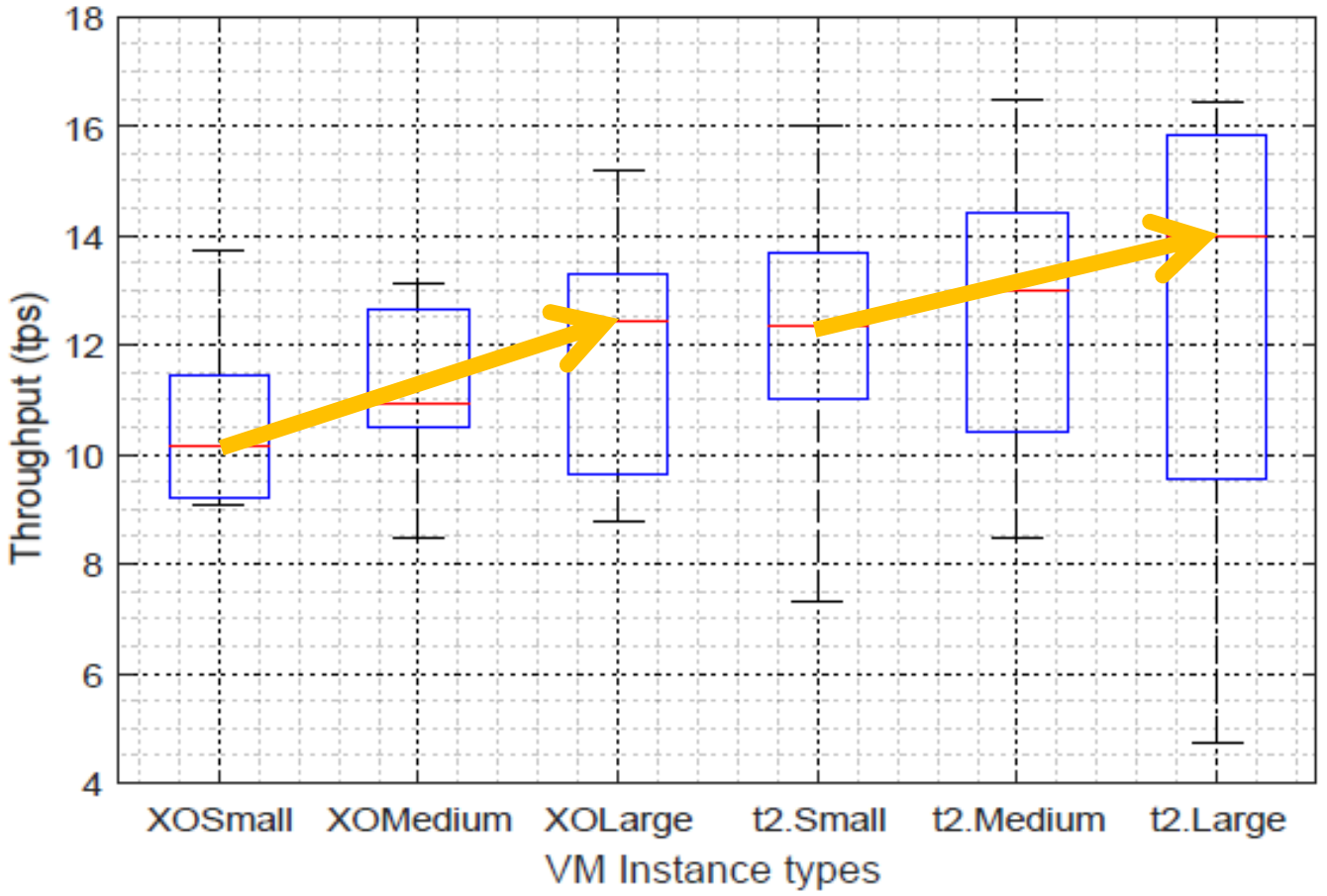
# Evaluation: Sawtooth Performance Stability

- Network Bandwidth
- **VM Specifications**
  - Significant improvement on throughput

| Cloud Provider | Resource Name | CPU Cores | Memory | DISK Size |
|---|---|---|---|---|
| ExoGENI | XOSmall | 1 | 1G | 10G |
| ExoGENI | XOMedium | 1 | 3G | 25G |
| ExoGENI | XOLarge | 2 | 6G | 50G |
| Amazon | t2.Small | 1 | 2G | 8G |
| Amazon | t2.Medium | 2 | 4G | 8G |
| Amazon | t2.Large | 2 | 8G | 8G |

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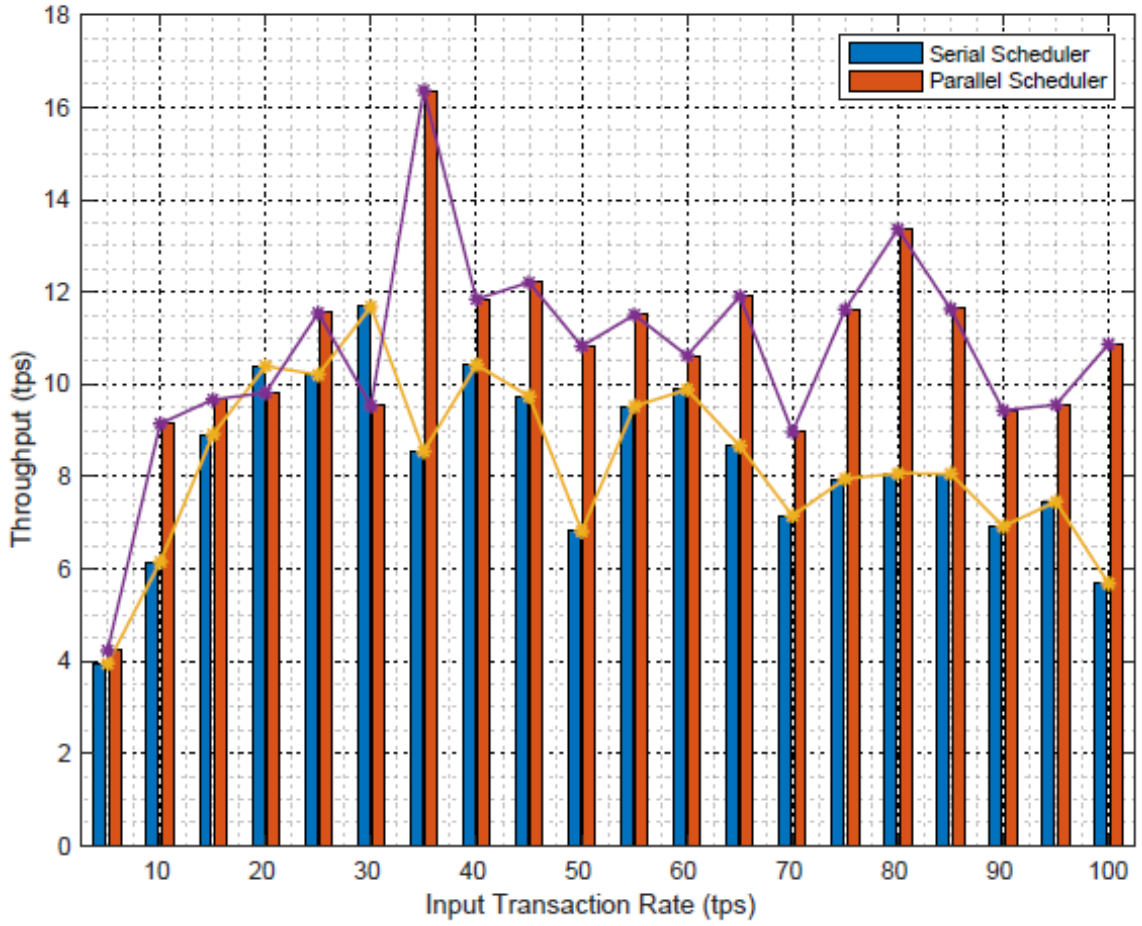
# Evaluation: Sawtooth Performance Scalability

- **Input Transaction Rate**
- **Scheduler Type**
  - Parallel Scheduling: BETTER
    - Larger input rate
    - Non-uniform duration
  - Serial Scheduling
    - Dependent transactions

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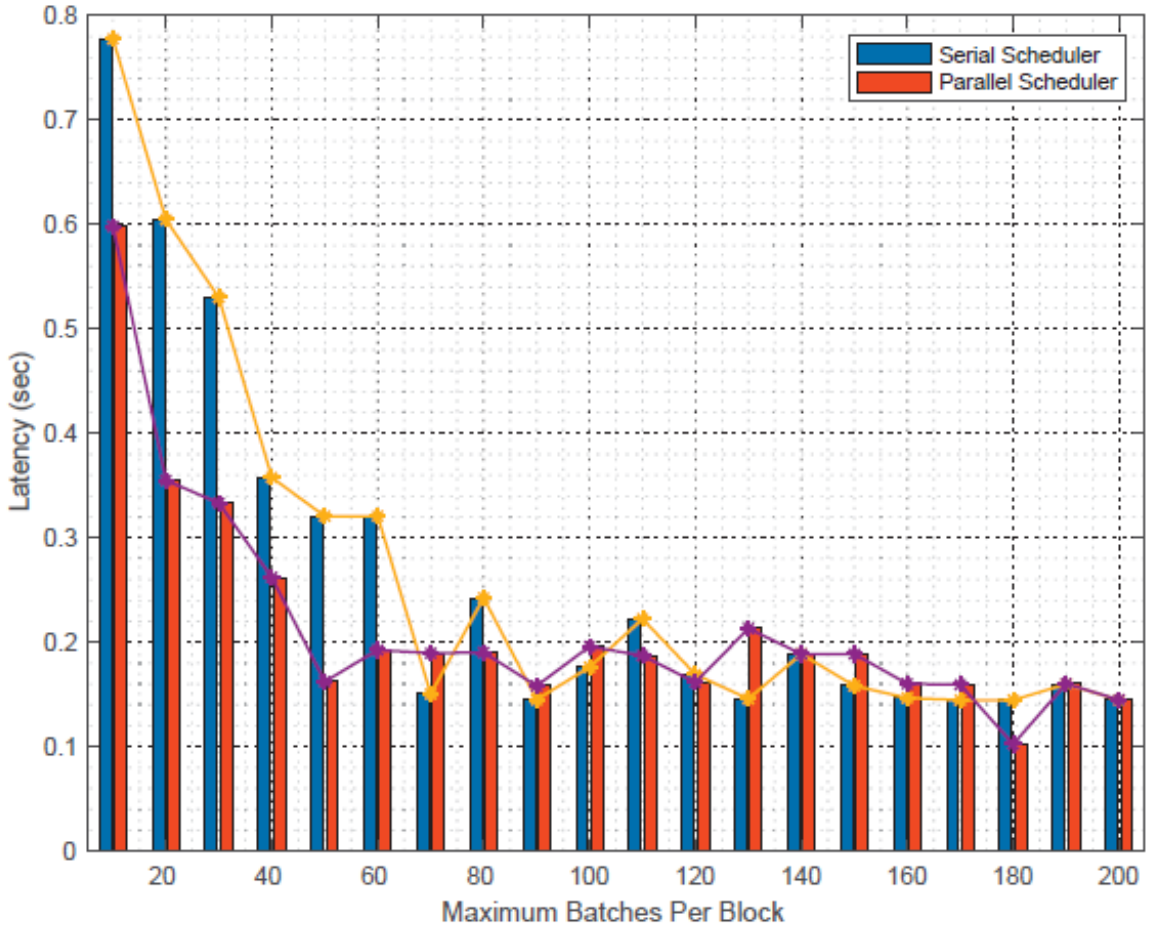
# Evaluation: Sawtooth Performance Scalability

- Input Transaction Rate
- Scheduler Type
- **Maximum Batches Per Block**
  - Parallel model is significantly better when MBPB is less than 60

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# Blockchain vs Centralized Database

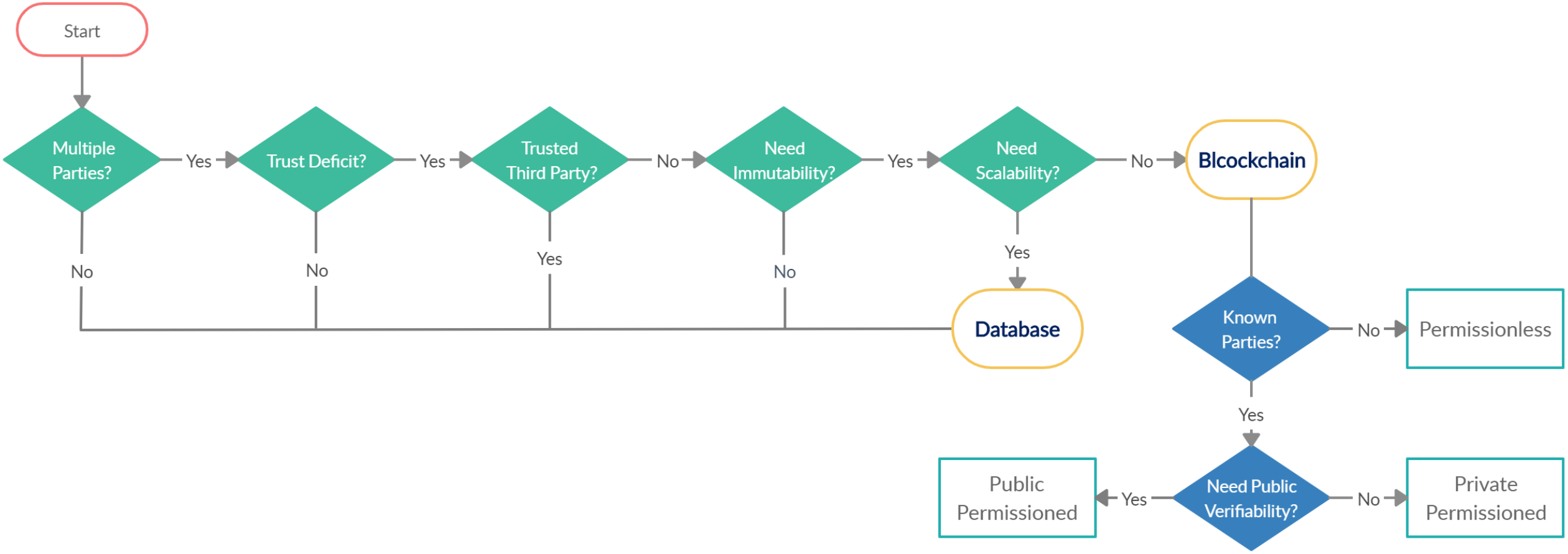
# Blockchain vs Centralized Database

| | Permissionless Blockchain | Permissioned Blockchain | Centralized Database |
|---|---|---|---|
| **Throughput** | Low | High  | High  |
| **Latency** | Long | Medium | Short  |
| **Fault Tolerance** | High | High  | Medium |
| **Data Integrity** | High | High  | Medium |
| **Security / Privacy** | Low | High  | High  |
| **Interoperability** | Low | Low | High  |

# When to use Blockchain?

- **Stakeholder**
  - # of Parties: consortium of independent companies
  - Do they trust each other?
  - Any trusted third-party they can rely on?
- **Data Requirement**
  - What type of data should be stored?
  - Should the record of transactions be immutable?
- **System Requirement**
  - How scalable should the system be?
    - Performance: throughput, latency

# Decision Tree

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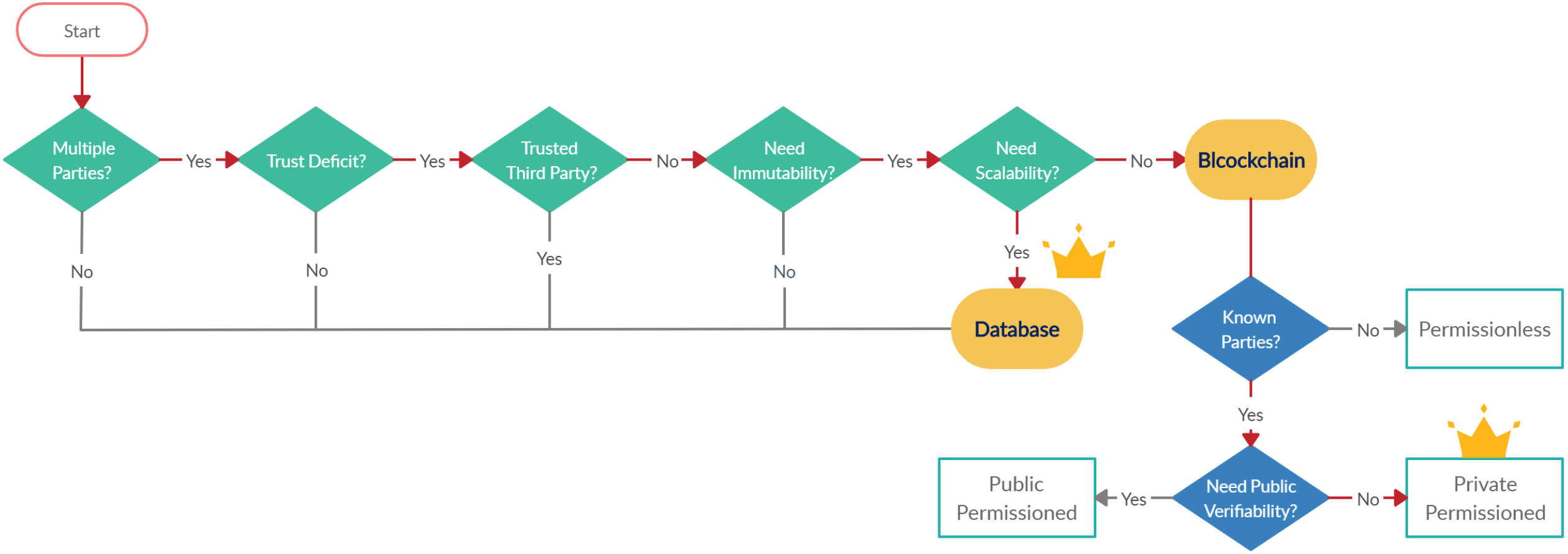
# Is Blockchain a Better Solution for Managing EHR?

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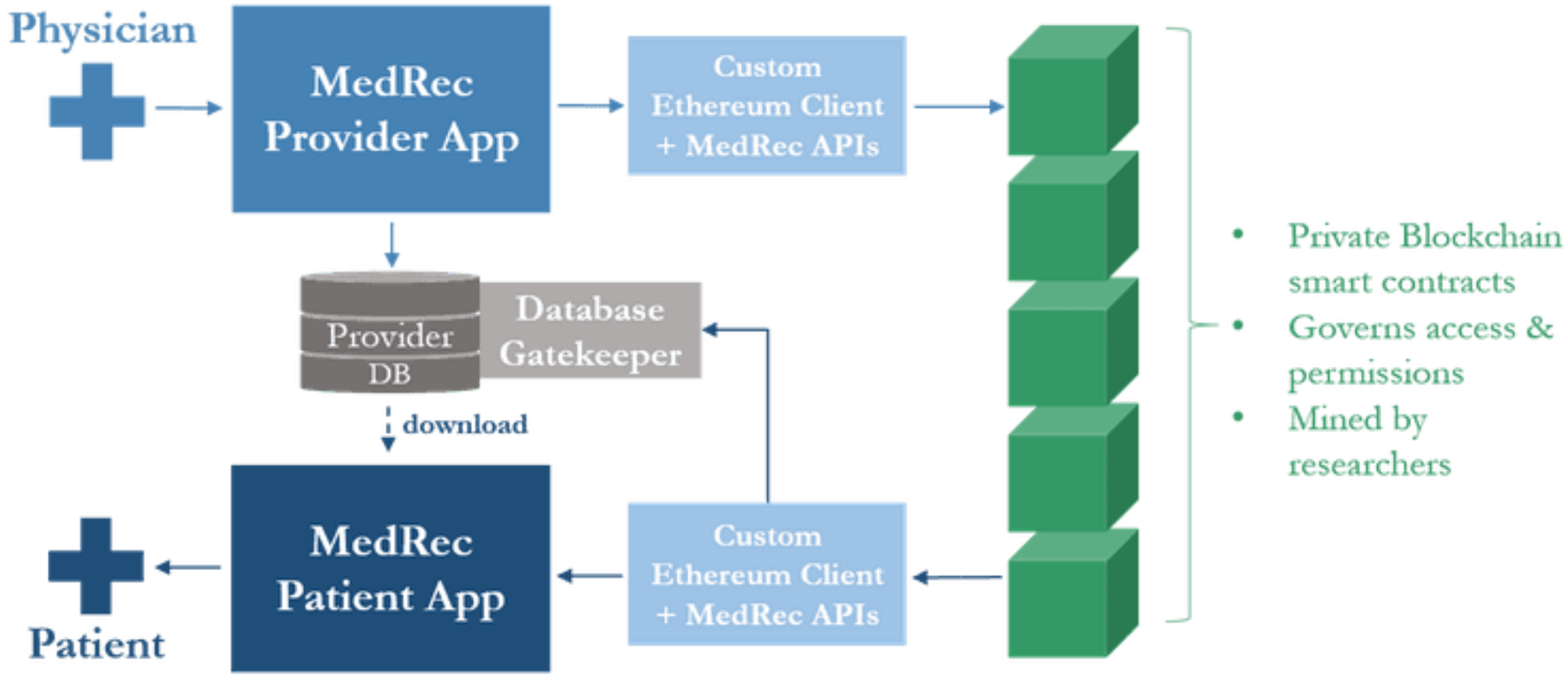
# Future: Is Blockchain a Better Solution for Managing EHR?

- Permissioned Blockchain + Database: e.g. MedRec



# Conclusion

**Blockchain for:**

- More than 1 admin authority
  - Trust Building
- Fault Tolerance
- Data Confidentiality

**Centralized Database for:**

- Performance
  - Throughput
  - Low Latency

Try it yourself here: http://doyouneedablockchain.com

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