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A Blockchain Based Approach for Optimal Energy Dispatch and Fault Reporting in P2P Microgrids

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Overview

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- Approaches for Energy Management
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Introduction

- A microgrid is a cluster of load and micro-resources operating as a single system [4].

- With these recent advancements in communication and the energy sector, it is possible to install and maintain microgrids with Distributed Energy Resources (DERs).

- Microgrid often operates in conjunction with the main grid connected at a common coupling; however, a microgrid can detach itself and operate as an isolated grid running on an island mode.

Approaches for Energy Management

- Centralised Approach
  - In the centralized approach, the surplus energy is transferred to the main grid, which in turn sells to the needful.

  - Advantage(s):
    - Easy to setup and manage.

  - Disadvantage(s):
    - Single point of failure.
    - Security breaches.
    - Issues with users privacy.

Approaches for Energy Management

- P2P Approach
  - The trade is performed between the buyer and the seller directly without any intervention of the main grid.

❖ Advantage(s):

➢ Limit the scope of being a single point of failure and provides a much robust ecosystem.

➢ Increases the incentives of the local prosumers.

Challenges in P2P based approach

- Because of lack of global transmission information, congestion might occur due to alleviated demands during peak hours.

- Uncontrolled congestion and energy overloads can have severe adverse effects on the transmission lines in the long run.

- Such issues may degrade performance of the microgrid depriving the prosumers from meeting their goals.

Contributions of the work

1. We model the P2P microgrid network as a graph and formulate the notion of optimal path for energy transmission.

2. We develop appropriate logic for transmission link capacity update, transmission link reservation and fault reporting; implement them as modules in the smart contract and deploy on the blockchain.

3. We perform experiments over our deployed blockchain and analyse the feasibility of the approach based upon payload sizes, transaction sizes, and energy consumption while maintaining the blockchain network.

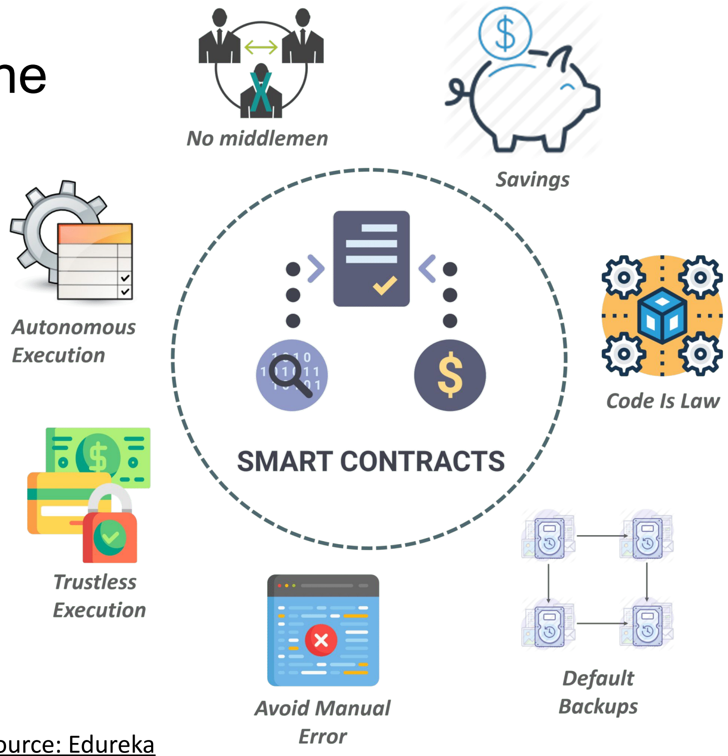
Background

Ethereum [1]:

- Public permissionless blockchain platform allows to setup a private and permissioned instance of the chain.
- Supports smart contracts (application specific code deployed on the blockchain).

Smart Contract [2]:

- A bunch of self-executable code sitting on top of a blockchain.
- Consists of well-defined conditions and their corresponding actions.
- Triggered by the Transactions.



Source: Edureka

Background

- Proof-of-Authority (PoA)[3]:

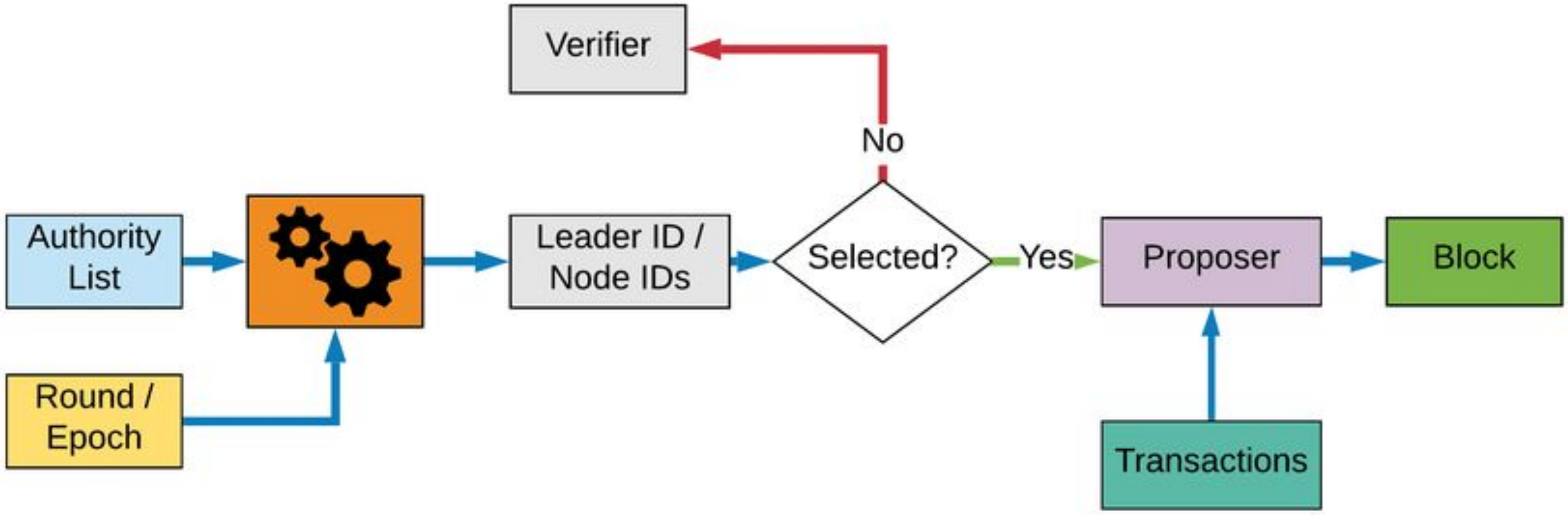
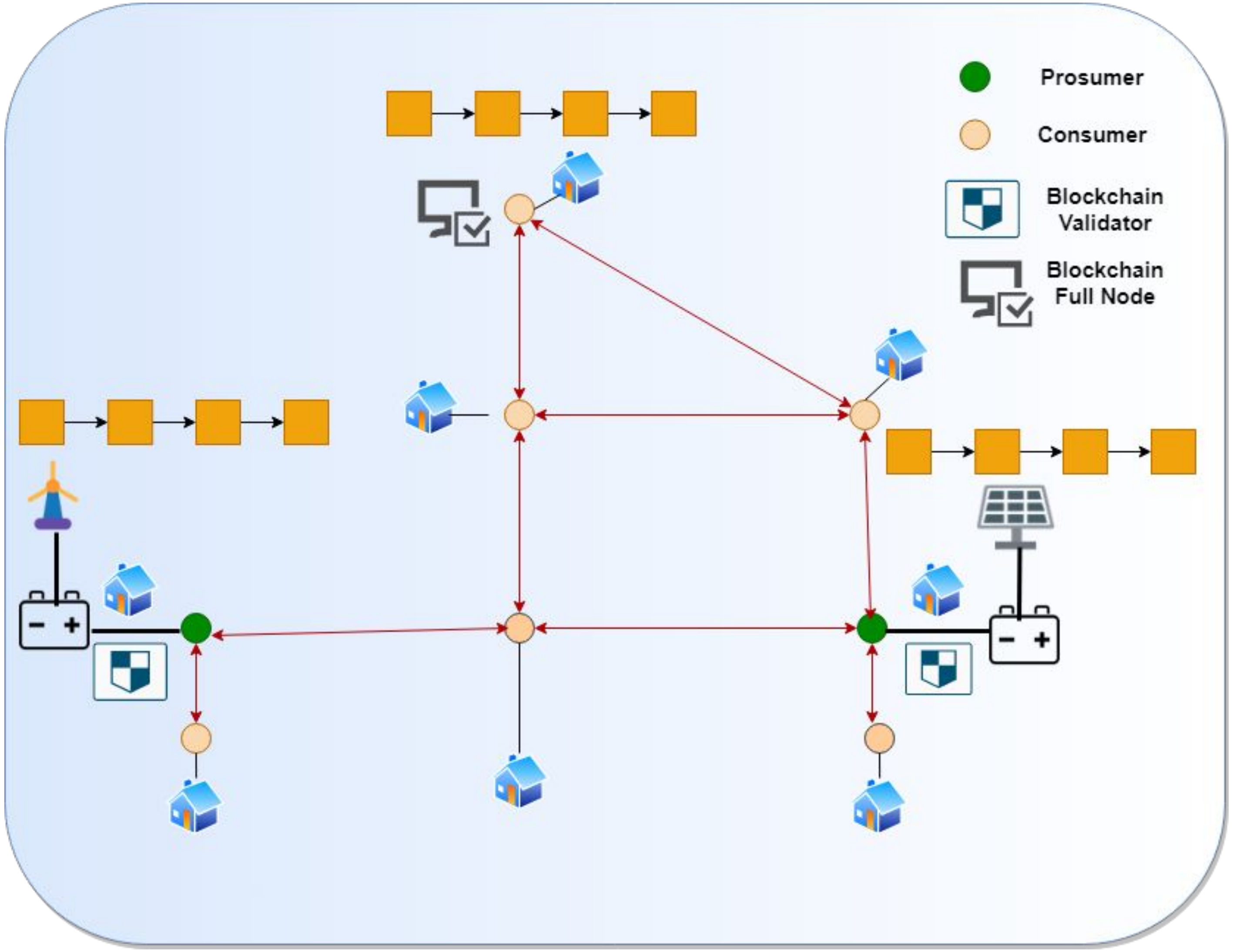
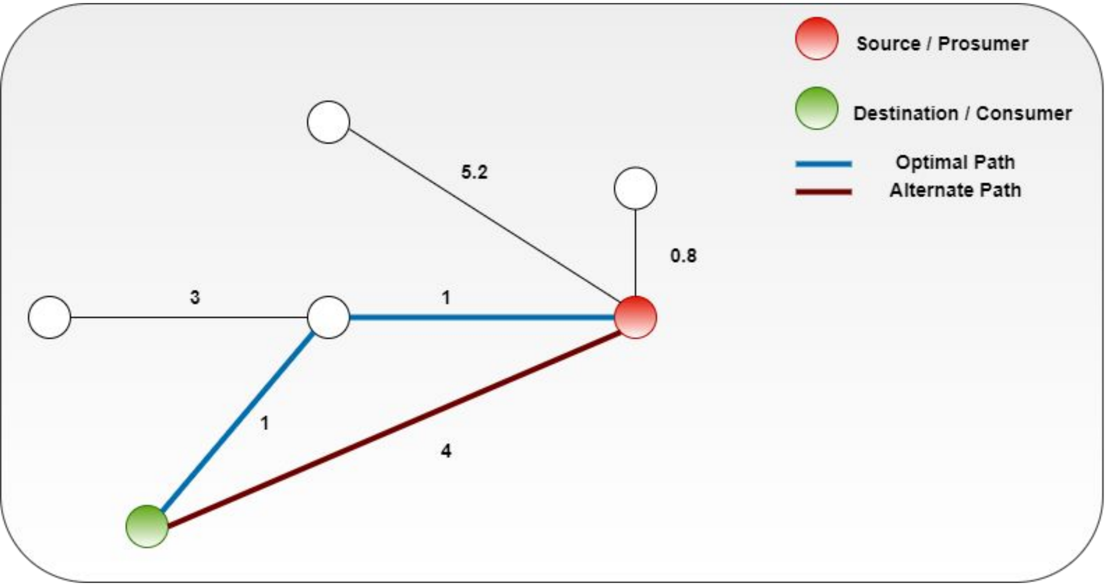


Image Source: [Researchgate Proof-of-Authority]

Proposed Approach : Architecture



Proposed Approach



$$W_{ij} = Min(C_{ij}^{available}, C_{ij}^{required}) * \frac{1}{dis(e_{ij})} \quad (1)$$

$$O_{xy} = Min\left(W_{xy}, \sum_{i=1,j=2}^{m,n} C_{ij}\right) \quad (2)$$

Proposed Approach : Psuedocode

Algorithm 1 Link Capacity Update

Input: None

Output: Link Capacity Updated

1: ***Require:*** msg.sender (*node*) is having a valid address. Ensuring a legitimate node in microgrid
2: $i \leftarrow msg.sender$
3: **for** each $node_j \in$ neighborhood(i $\in$ G) **do**
4: $availableCapacity[i][node_j] \leftarrow totalCapacity[i][node_j] - inUse[i][node_j]$
5: **end for**

Proposed Approach

- Link Reservation:
  - Objective is to reserve a transmission link for the timeframe in which transmission will happen.
  - Greedy Algorithms can be applied for finding the optimal path.
- Fault Reporting:
  - Each node keep track of inflow and outflow of energy passing through the link.
  - Any fluctuation above the threshold is reported.

Experiments and Results

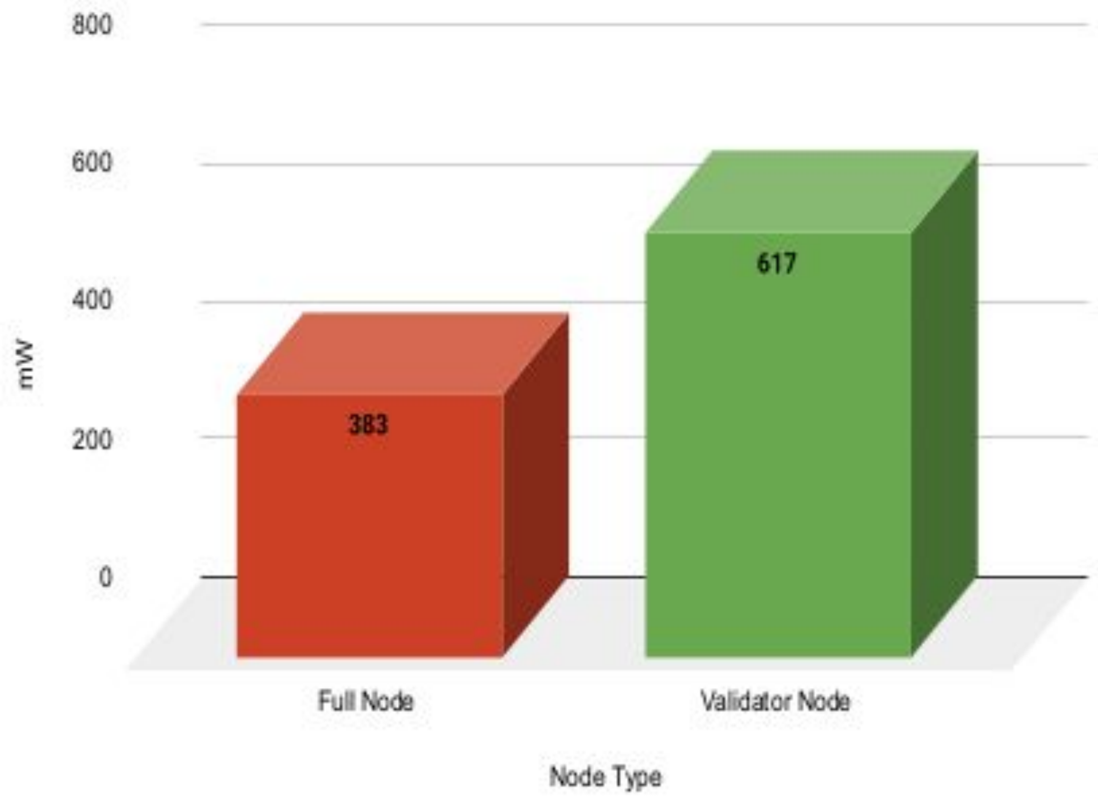
	Specification
Processor	Intel Core i5 @ 3.2 GHz
Memory	8 GB
Storage	1 TB
Operating System	Ubuntu 18.04.5 LTS
Ethereum Client	Geth 1.10.3-stable

TABLE I
SYSTEMS SPECIFICATION OF DESKTOP PC

	Transaction Size	Payload Size
Link Reservation	1008 B	522 B
Raise Alert	682 B	138 B
Link Capacity Update	615 B	74 B

B - Bytes

TABLE II
TRANSACTION AND PAYLOAD SIZES



Discussions

1. **Robust System :** Our proposed approach is much robust and provides higher tolerance against system faults.

2. **Improved Trust :** The notion of trustworthiness of data stored in the system is maintained by the virtue of digital signatures.

3. **Transparent :** As the data is stored on the blockchain, members of the community micro-grid can check the validity and authenticity of the data.

4. **Energy Efficient** : Use of lightweight Proof-of-Authority as the consensus mechanism for maintaining the system makes the approach energy efficient.

References

1. V. Buterin et al., “Ethereum white paper,” GitHub repository, pp. 22–23, 2013.
2. N. Szabo, “Formalizing and securing relationships on public networks,” First monday, 1997.
3. S. De Angelis, L. Aniello, R. Baldoni, F. Lombardi, A. Margheri, and V. Sassone, “Pbft vs proof-of-authority: Applying the cap theorem to permissioned blockchain,” 2018.
4. R. H. Lasseter, “Microgrids,” in 2002 IEEE Power Engineering Society Winter Meeting. Conference Proceedings (Cat. No. 02CH37309), vol. 1. IEEE, 2002, pp. 305–308.