Blockchain for Smart Grid Flexibility

Handling Settlements between the Aggregator and Prosumers

Fifteenth International Conference on the Digital Society
Nice, France, July 18th – 22nd, 2021

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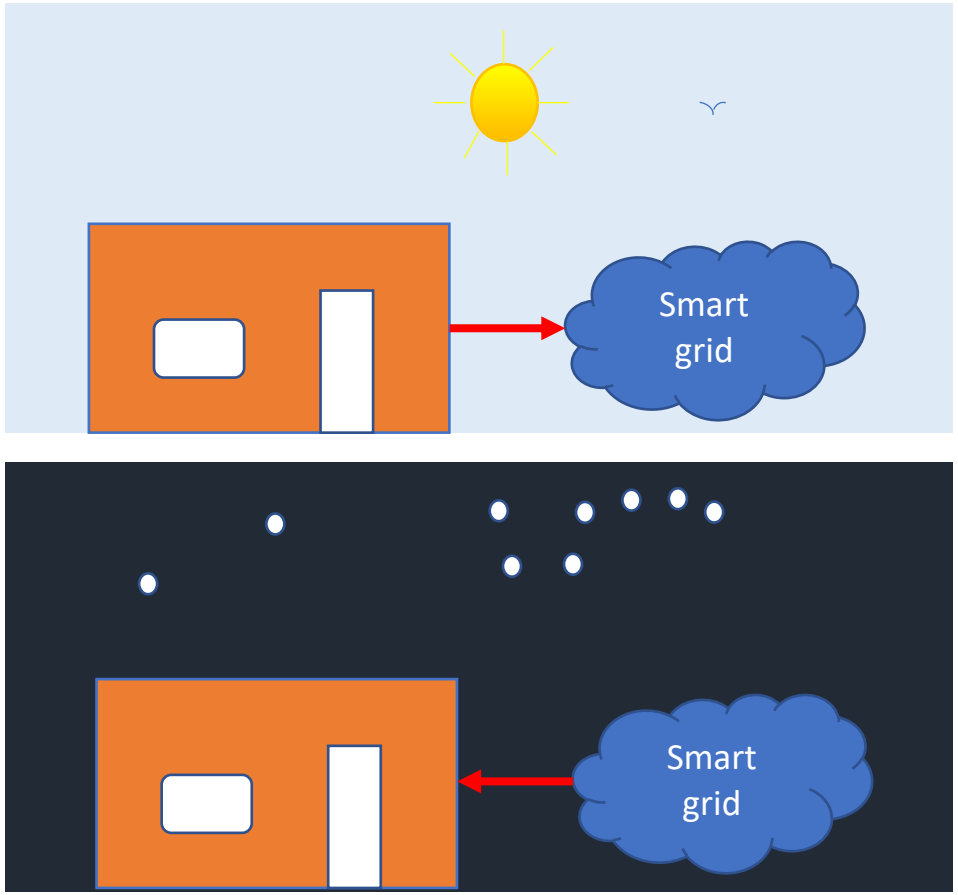
Introduction

- A smart grid is a power grid that keeps track of consumption and production.
- With new energy sources like solar panels, prosumers may sell and buy energy from the grid.
- A smart meter keeps track of the energy flow to and from the grid.
- Energy price varies throughout the day and is based on forecasts.
- The price intervals may down to ten minutes.



Flexibility occurs when a household can delay the use of electricity to a timeslot when the price is lower. A typical example is when to charge an electric vehicle.

Introduction

- Flexibility can be transferred to an aggregator.
- The customer can define some constraints:
  - The electric vehicle should be fully charged at 7 am
  - The temperature should not get below 16^{O}C
  - The water in the water heater should be above 70^{O}C

- The aggregator can then use algorithms to decide when to turn appliances on and off to fulfill the constraints, while getting the most beneficial rates from the energy market.
- The flexibility is essential for grid management since it can reduce the chances of overloading the grid and delay investments in upgraded electric power infrastructure.

The customer is rewarded for giving up control, either by favorable pricing or a discount on the electricity bill.

Introduction

Blockchain technology has the potential to have a significant impact on the energy sector.

The purpose of this paper is to present the Smart Multi-Layer Aggregator (Smart-MLA) project and how **blockchain technology** can handle settlements between the aggregator and its customers (prosumers).

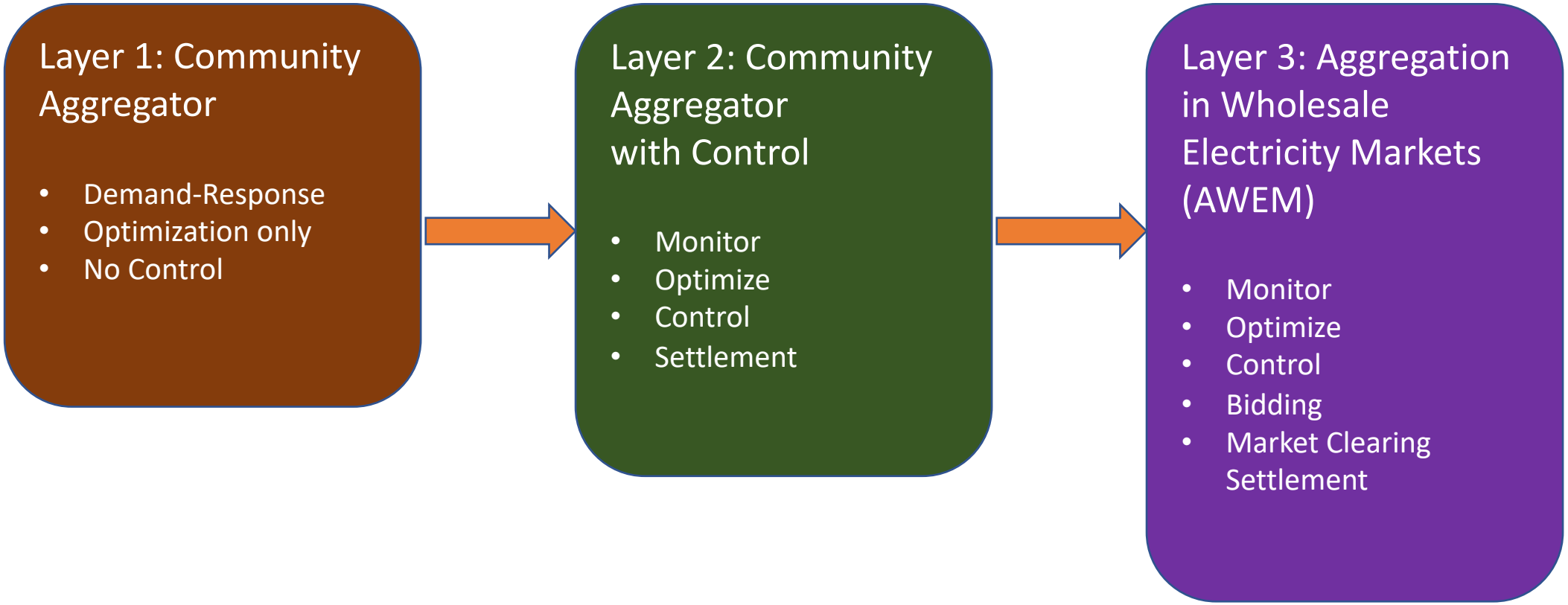
Smart Multi-Layer Aggregator

The Smart-MLA project is an ERA-Net Smartgrid Plus research project with academic and industrial partners from Denmark, Norway, Romania, Sweden, and Turkey.

The project web site can be found here: https://smart-mla.stimasoft.com

The aim is to develop and demonstrate a cloud-based multi-layer aggregator solution to facilitate optimum demand response and grid flexibility for energy systems to utilize up to 100% renewable energy. The project implements three layers of flexibility aggregation as shown on the next slide.

Smart Multi-Layer Aggregator Concept

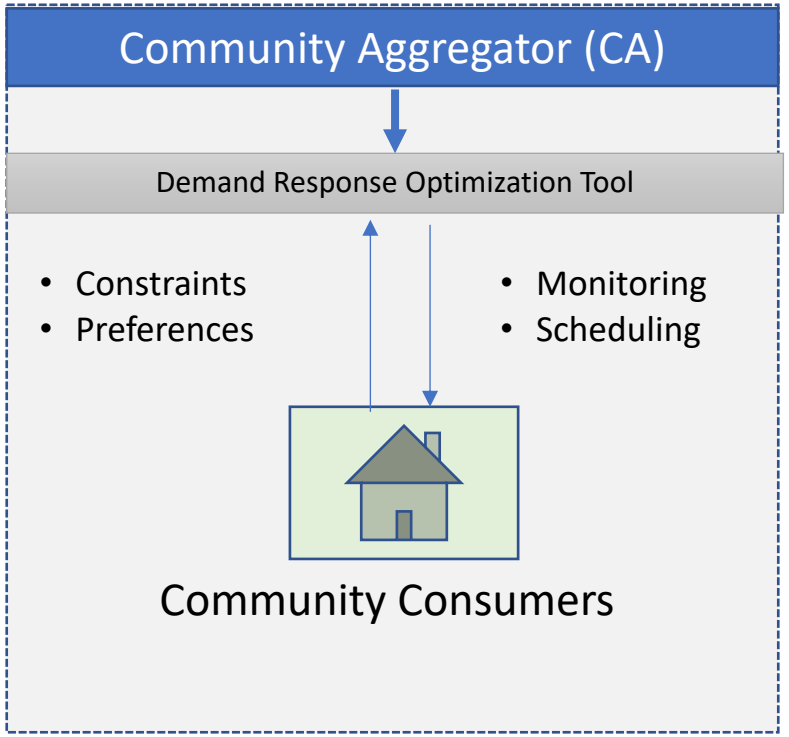


Smart Multi-Layer Aggregator Concept

On the lowest layer, flexibility occurs within a household or a building (no outside control of the flexibility).

- Customer sets constraints and preferred scheduling
- Algorithm optimizes operation of flexible appliances
- Customer is informed about savings.

Improves awareness on the merits of flexibility among customers/prosumers.

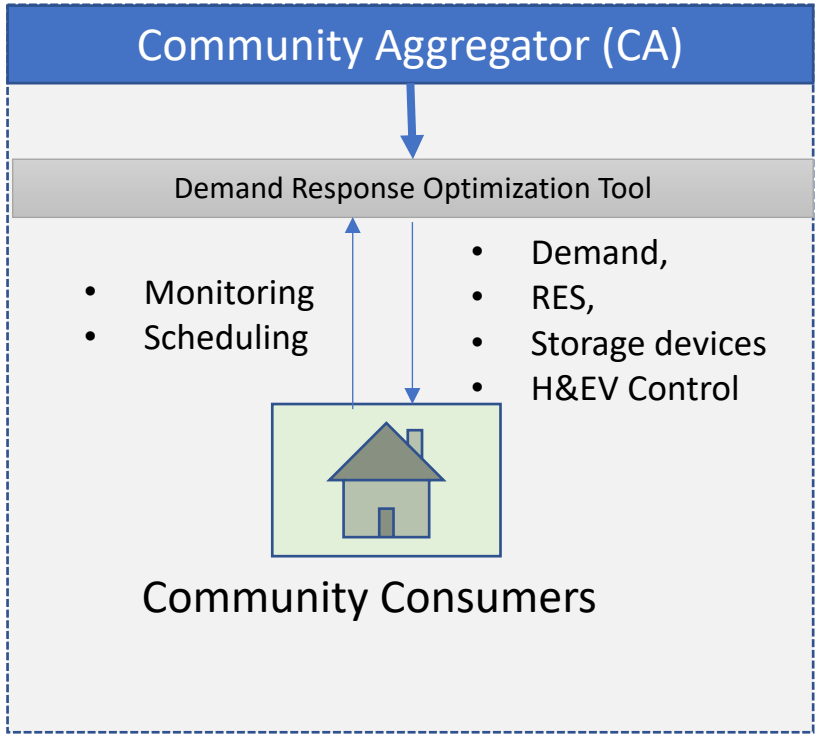


Smart Multi-Layer Aggregator Concept

Customer transfers control of flexibility to the aggregator.
Aggregator decides when to activate appliances:

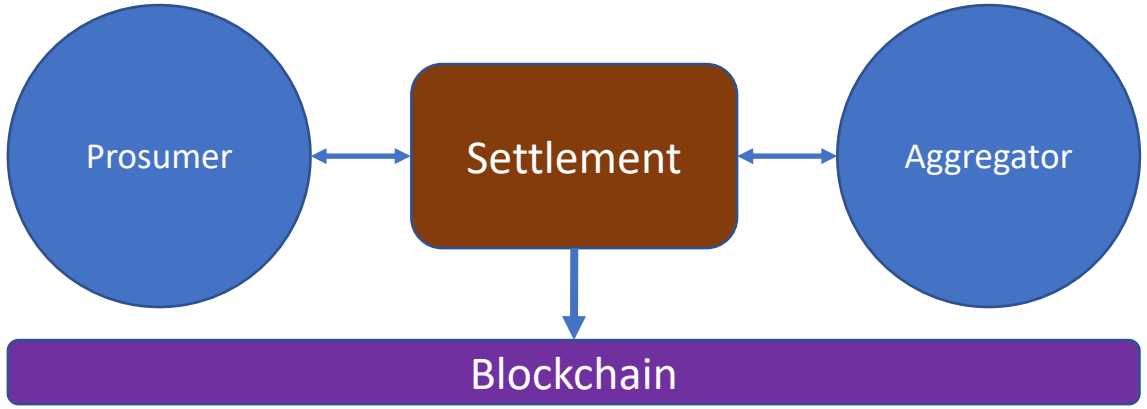
- Electric vehicle charger
- Heat pump
- Water heater

Constraints are set by customer/prosumer.



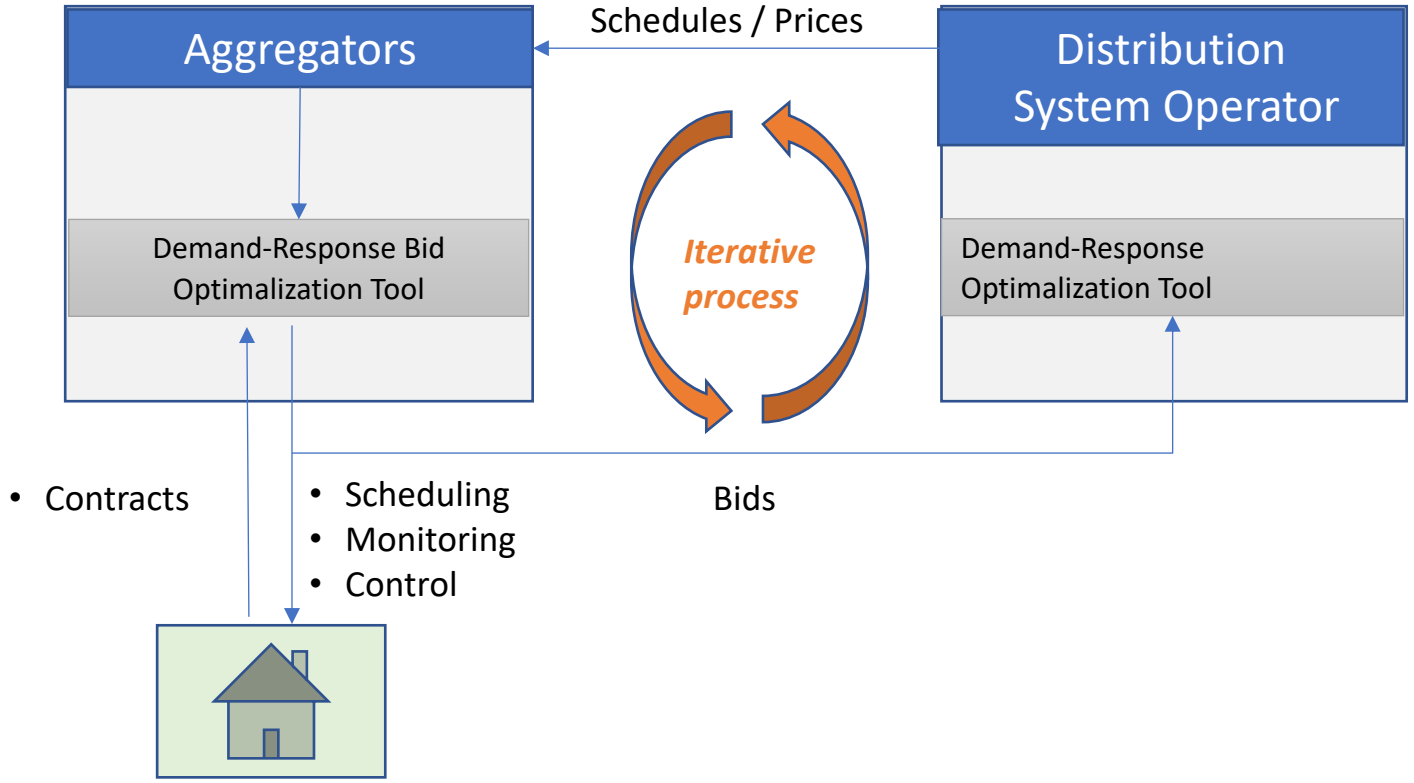
Smart Multi-Layer Aggregator Concept

- Layer 2 includes settlements between the aggregator and the prosumers.
- The grid is used as an on-demand delivery service that may also buy back excess energy
- The prosumers are rewarded for transferring flexibility.
- The settlements (including rewards) are registered on the blockchain.

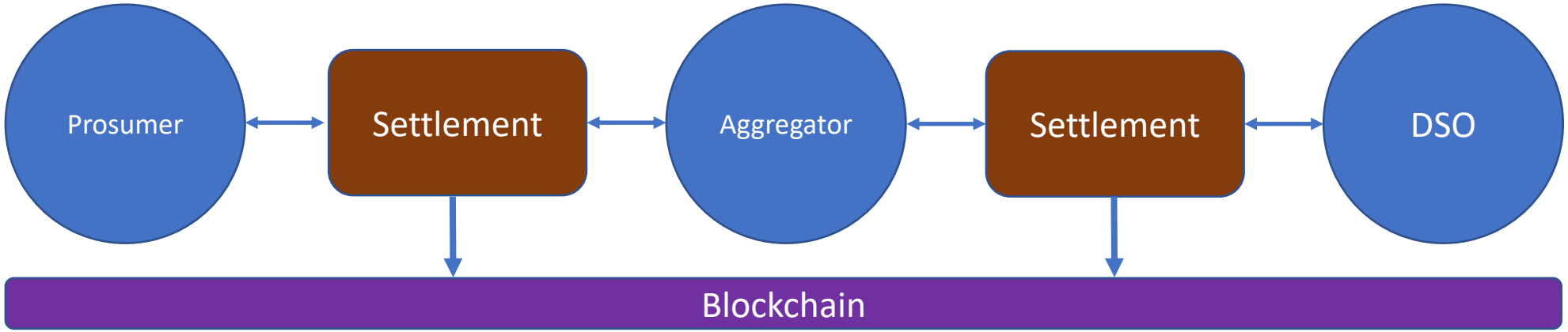


Smart Multi-Layer Aggregator Concept

- Layer 2 transfers flexibility from households to an aggregator.
- Layer 3 trades this flexibility in the local flexibility market in coordination with the Distribution System Operator (DSO)
- The aggregator uses an iterative process based on schedules, prices and bids.



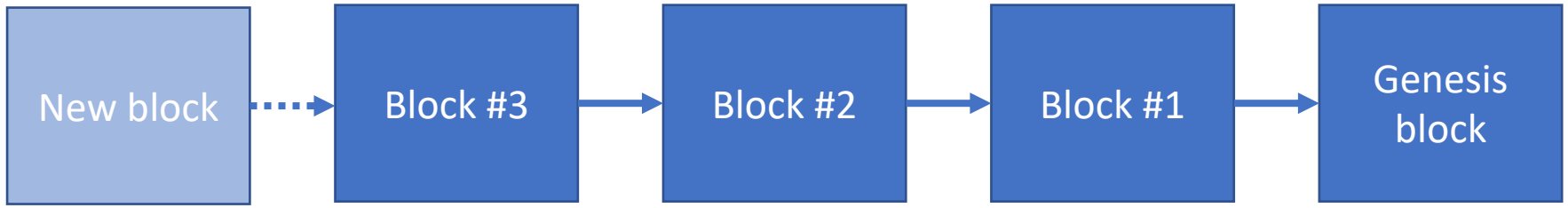
Smart Multi-layer Aggregator Concept



This figure shows the settlements between the prosumers and the aggregator, and the aggregator and the DSO. The transactions are written to the blockchain

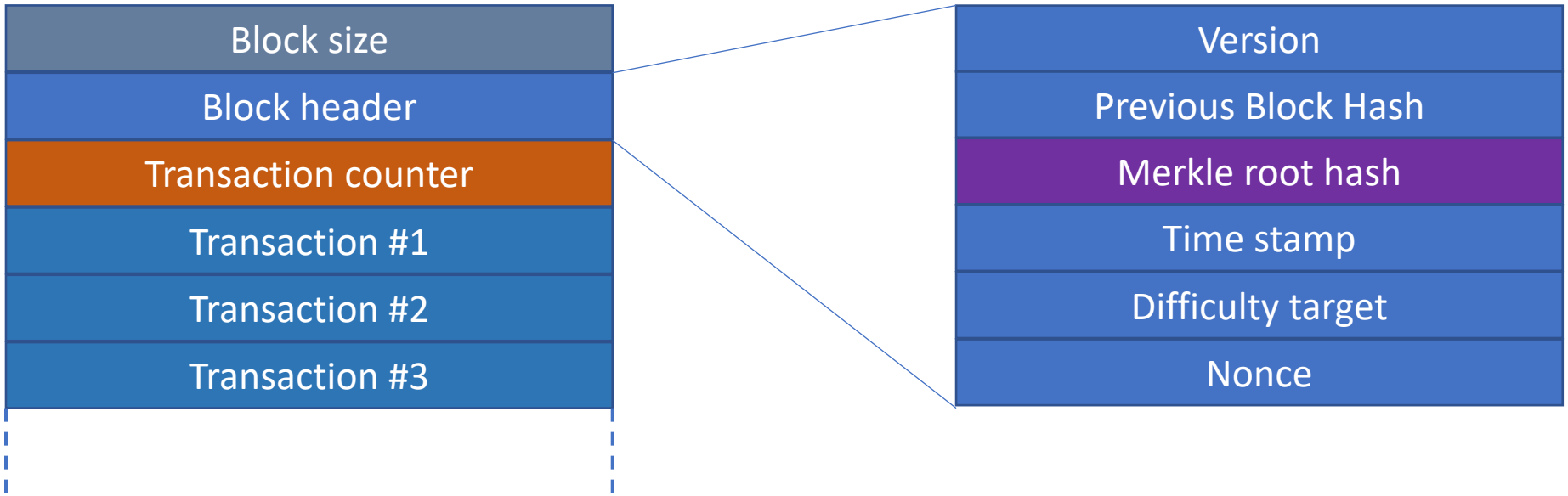
Blockchain Basics

- The blockchain can be seen as a decentralized, immutable ledger.
- Copies of the blockchain reside on a set of nodes



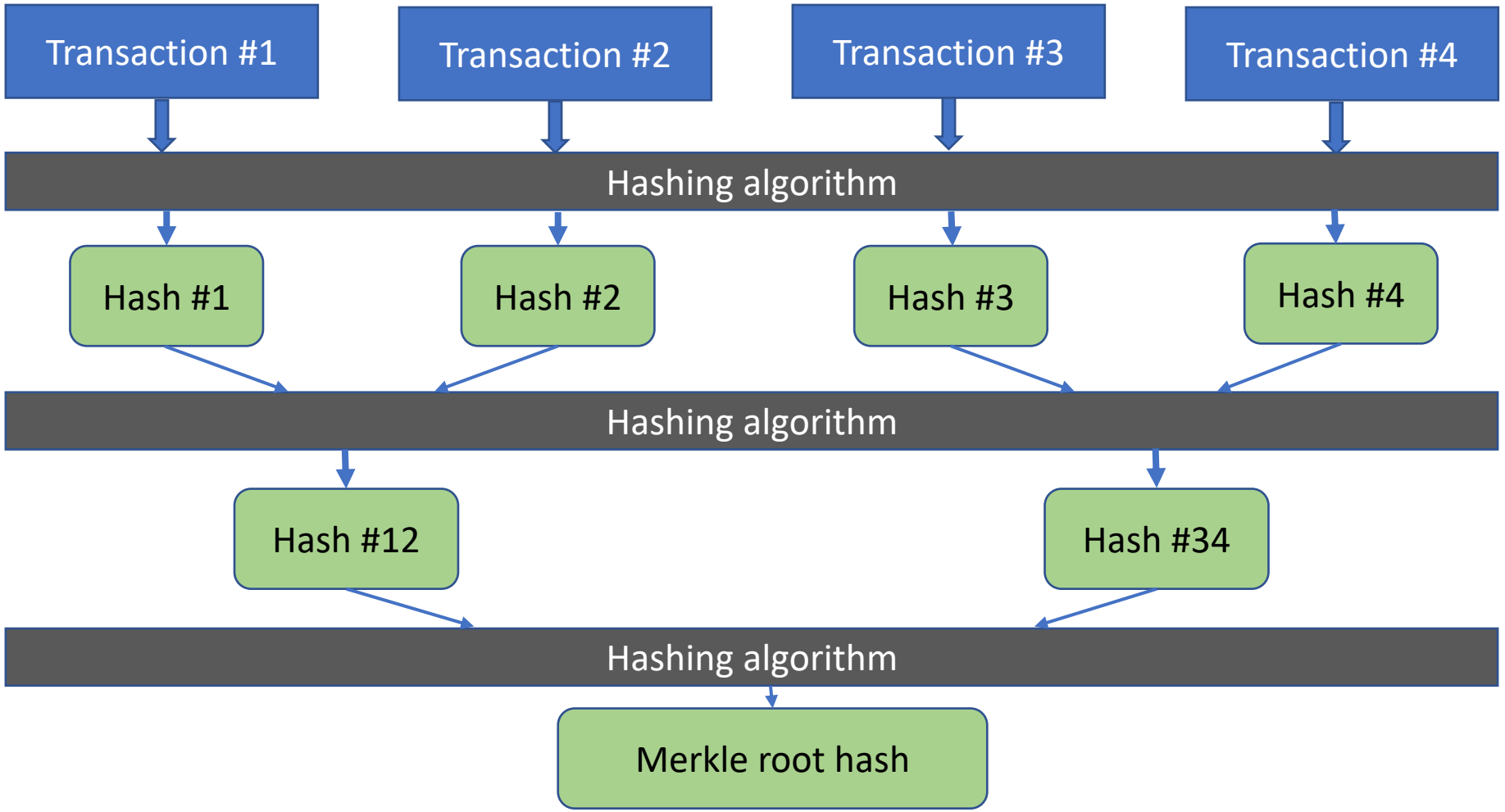
- Each block contains a link to the previous block
- Each block has a hash value of the previous block
- Each block is encrypted (including the hash value of the previous block)
- Changes to one block will make the whole blockchain invalid (for one node)
- The integrity is upheld by consensus among the set of nodes containing copies of the blockchain

Blockchain Blocks and Block Header



The Merkle tree (see next slide) ensures the integrity of each transaction added to a block

Computing the Merkle Root Hash



Public and Private Blockchain

A blockchain may be **public** or **private**.

Everyone has access to the public blockchain and can examine the transactions that have been made. Everyone can add to the blockchain (but a fee is required).

The blockchain is semi-anonymous; the user is identified with a binary address.

A private blockchain may require permission to add to and examine the content of the blockchain.

Blockchain in the Smart-MLA Project

What we have done as part of the Smart-MLA project:

- Setting up a local blockchain using **Ganache** and **Remix**
- Writing to and reading from the blockchain using **web3**
- Setting up a test blockchain using the **Ropsten** test network
- Using **Nethereum** to build applications using the .NET framework
- Making a test **API** for settlements

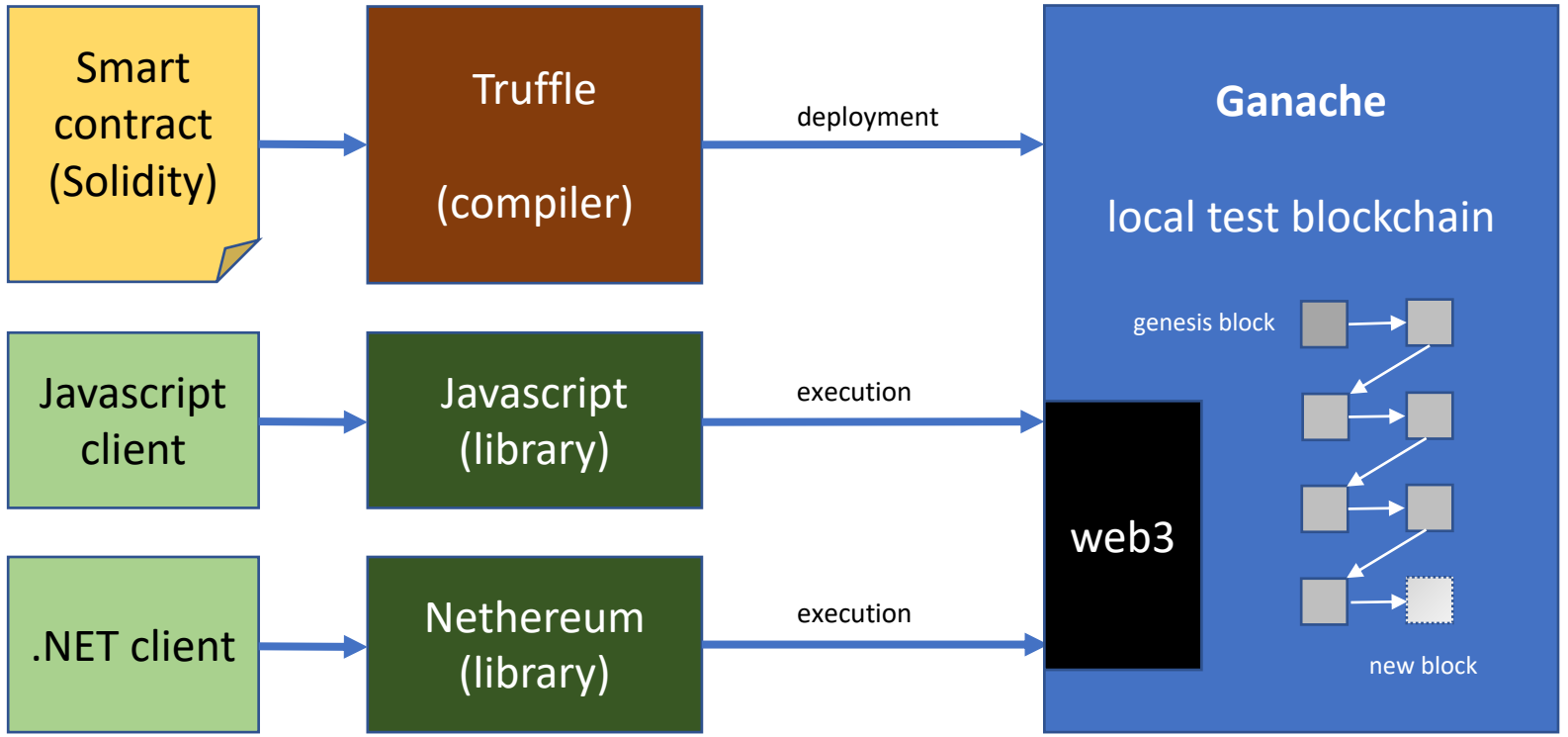
Setting Up the Local Blockchain

Local blockchain implemented by using Ganache.

Programs access the blockchain through web3.

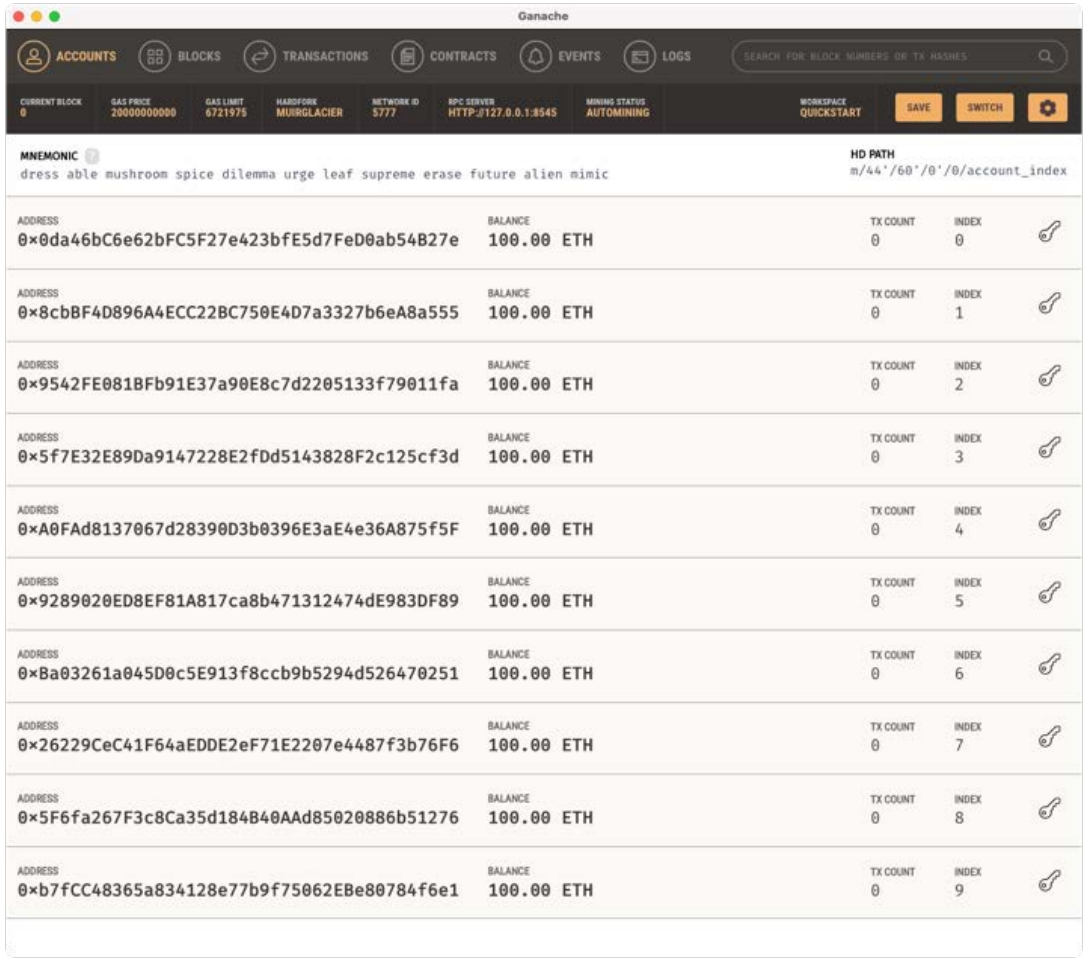
Nethereum provides access for .NET clients.

The Ropsten test network can also be accessed through web3.

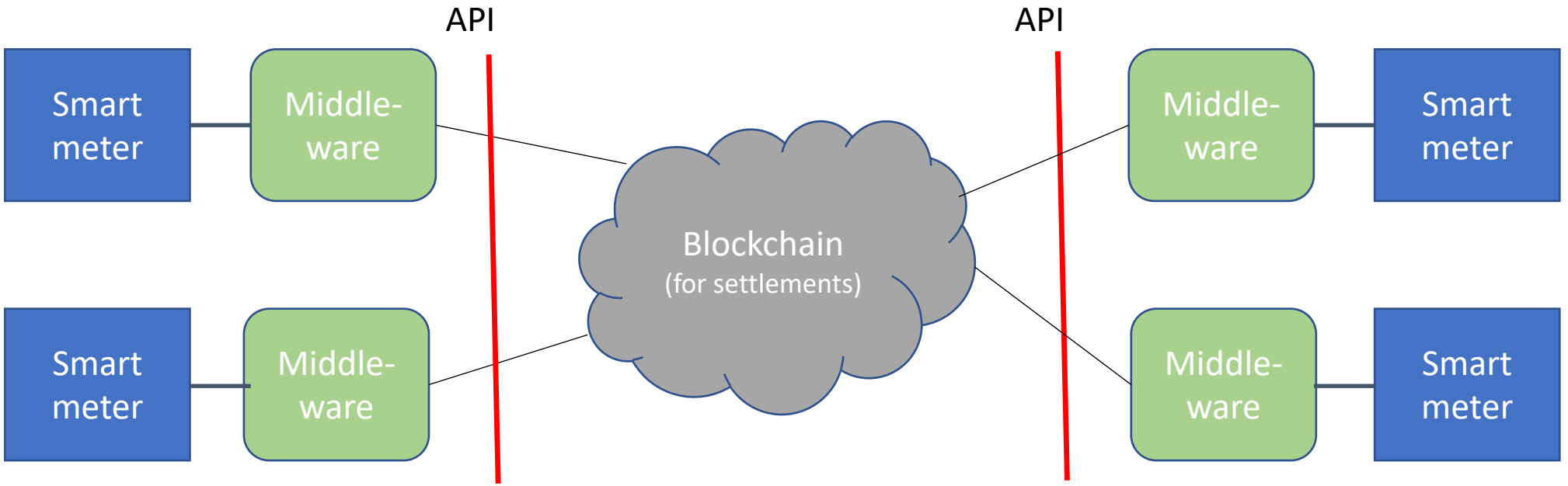


Ganache

- The figure shows the Ganache local blockchain with ten (defaults) test accounts.



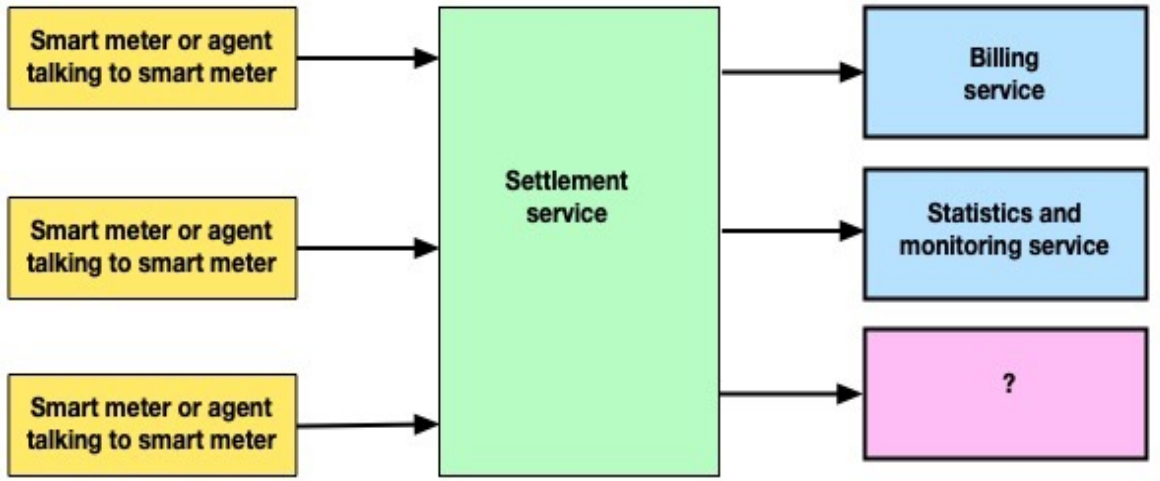
Blockchain for Settlements



The API is illustrated in the next slide

Application Programming Interface

- The settlement records contain the amount of energy, time, period, and the two entities involved in the transaction.
- The smart contract checks the validity of the sender and receiver; and if the sender has the necessary amount available.



Conclusions

- The Smart-MLA project has demonstrated the use of blockchain for a specific smart grid application – registering settlements between an aggregator and the prosumers connected to the smart grid.
- The demonstration showed some disadvantages of using blockchain for this purpose:
  - To register a transaction on the public Ethereum blockchain requires a transaction fee.
  - The current transaction fee on the Ethereum network is around USD 4.00 (June 2021).
  - Therefore, if blockchain is used to register car owner transfers, the transaction fee would be negligible compared to the transaction itself.
  - However, the settlements between the aggregator and prosumers will be tiny amounts. Even if aggregated for each hour or even each day, the transaction fee would create a considerable overhead for the transactions.
- Therefore, the public Ethereum blockchain should not be used for transactions involving minimal payments.
- Also, aggregation does not solve the problem since the whole idea of using blockchain was to achieve full transparency of all transactions.

Conclusions

- The alternative is to set up a private blockchain.
- In that case, the fees for registering will not have a real value.
- But the infrastructure itself, mainly servers, will have a price tag.
- Blockchain is supposed to have a large number of copies on a distributed network. For a private blockchain, the number of nodes will be limited, and the blockchain will be more vulnerable to security attacks.
- A traditional system of record (e.g., a relational database) could handle settlements in a much more efficient way. However, the problem with a database is the centralization of physical control combined with the ability to delete or modify records.
- The blockchain excels in being immutable and transparent.

Future Work

- The Smart-MLA project strives to demonstrate how aggregators may benefit from customer flexibility.
- The smart grid may be enhanced by letting prosumers trade with each other through a stock-market exchange.
- Prosumers with storage capacity may compete to buy energy from other prosumers for future sales. This will create an internal market within the smart grid.
- The aggregator will then have to compete for excess energy produced by prosumers, optimizing the revenues for the prosumers.
- Today, the aggregator decides the buying price in a monopolistic way. An internal market within the smart grid would remove the monopoly of the aggregator and make a sounder competitive environment.

Acknowledgements

This work was supported under the ERA-Net Smart Grids Plus scheme Grant number 89029 and funded through the Research Council of Norway grant number 295750 with the project title "Multi-layer aggregator solutions to facilitate optimum demand response and grid flexibility."

Thank you for your attention

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