Digitalisering och ny teknik inom elnätet

Blockchain based smart contract for smart grids

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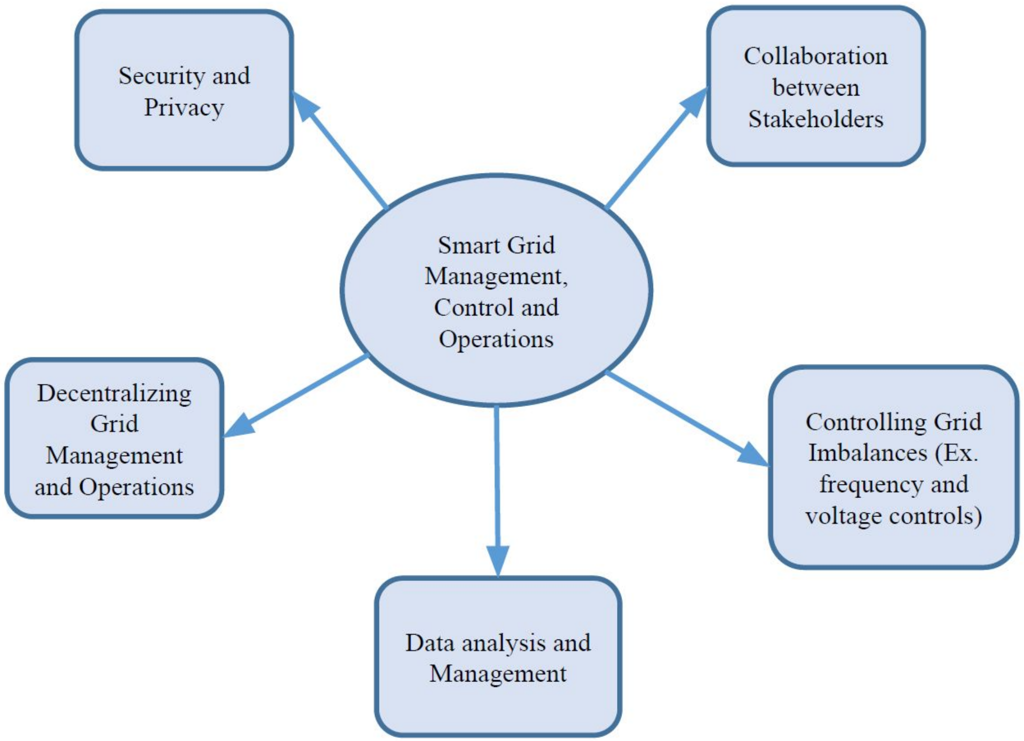
Challenges for management, control, and operation of smart grid



1. Collaboration between stakeholders
2. Controlling grid imbalance
3. Data analysis and management
4. Decentralizing grid Management and operation
5. Security and privacy

Collaboration between stakeholders

- New technologies, high investments, lack of accurate information, etc. complicate the coordination between actors in the energy sector.
- The current smart grid system faces the problem of energy balancing.
- Energy suppliers and traders typically request an estimated amount of energy from generators and consumers.
- Important to establish close collaboration between relevant players such as generators, distributors, retailers, consumers and regulators to facilitate grid management.

Controlling Grid imbalance

- Both physical and technical problems can contribute to imbalances in power generation and consumption.
- The failure of some network components, interference from third parties, damages, and natural causes can contribute to imbalances in power supply.
- Technical problems such as malicious attacks, frequency deviations, overloads, synchronization losses, and voltage dips can also contribute to power imbalances.
- It is essential to control and monitor the power supply in each period.
- However, this becomes a challenge due to the number and diversity of power generation methods and regulatory requirements.

Data Analysis and Management

- A large amount of data is generated and transferred between different entities, and multiple smart grid domains are involved in the process.
- Emerging problems with data aggregation quality, security, compliance control, common scope, and efficiency of the management mechanism.
- Accurate and consistent incoming data streams are important to avoid sudden and unexpected power supply disruptions.
- There is a regulatory requirement to provide accurate data as frequently as possible.

Decentralizing Grid Management and Operation

- Distributed automation devices are used to decentralize the operation of the grid, such as phasor management units (PMUs), remote terminal units (RTUs), supervisory control and data acquisition (SCADA), and smart meters that are used to collect and monitor data.
- Decentralizing grid operations allows stakeholders to control and manage their data locally.
- This management and operation of distributed energy resources is complicated.
- It is needed to facilitate coordination between decentralized and centralized stakeholders.

Security and Privacy

- The operation and management of the smart grid brings security and privacy challenges.
- The SCADA module in modern power systems collects data at remote terminals, transmits, and stores it in plain text to the main control center.
- This centralized data collection and storage is highly vulnerable to cyberattacks.
- Over the years, more and more cyberattacks have taken place on the smart grid.
- Security and privacy is one of the biggest and most difficult challenges facing the current smart grid.

Challenges of renewable energy

- Management, control and coordination between the participants of the renewable energy system.
- Power quality, voltage and frequency fluctuations in the interconnected system.
- Harmonics associated with DG systems.
- Inadequate planning leads to unstable voltage distribution
- Rapid response to demand.
- Decentralized operation
- Acceleration of the energy supply chain.
- Security in the commercial chain from generation to consumption.
- Stability.
- Imbalance between generation and load.
- Energy trading.

Swedish Energy Marketing

- Increasing electricity production and consumption:
- Layered architecture:backbone network (transmission network), regional network, and local area network (distribution network).
- Lots of energy sectors: approximately 170 electricity grid operators
- Free trading
- High digitalization
- Separated energy sectors

What is Blockchain

- Blockchain is a collection of technologies, including peer-to-peer networks, cryptography, fault-tolerant consensus algorithms, smart contracts, and database management technologies. Thus Blockchain builds a cost-effective, secure, and efficient operations management system, and potentially offers a new systematic solution to the above challenges to smart grids.
- It minimizes data management, fair incentive mechanisms, regulatory costs and technical issues, transaction fees between distributed nodes, speed of resources, and price adjustment issues.
- It increases transparency among stakeholders, ensure data security and privacy, simplify the energy demand and supply chain, and minimize distribution losses.
- Countries around the world are recognizing the potential applications of blockchain in the energy sector.

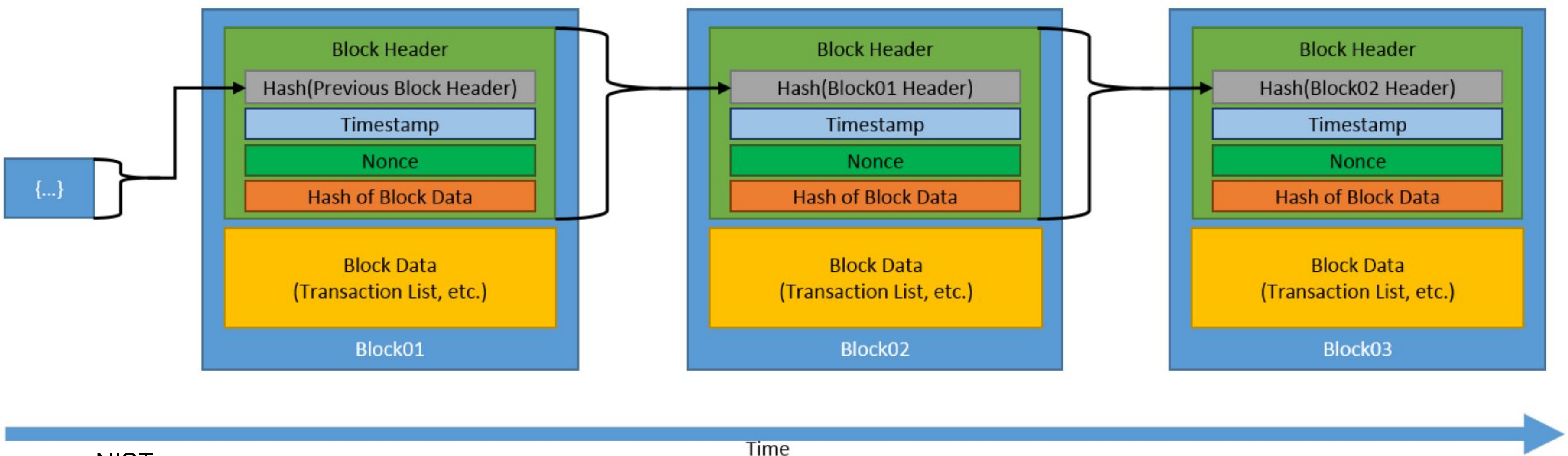
Characteristics of a blockchain

- programmable
- decentralization
- immutable
- time-stamped
- consensus
- anonymous
- secure

BLOCKCHAIN ARCHITECTURE AND KEY ELEMENTS

Key elements of Blockchain:

- Block: contains the head and the body (data, transactions).
- Chain: connects blocks, creates trust among them, connected by hash.
- Network: a collection, or a group of computers commonly known as a node. The decentralized network becomes more secure if it is scaled up.



source: NIST

Main technologies for Blockchain

Append-only system of record shared across business network

Shared Ledger

Cryptography

Ensuring secure, authenticated & verifiable transactions

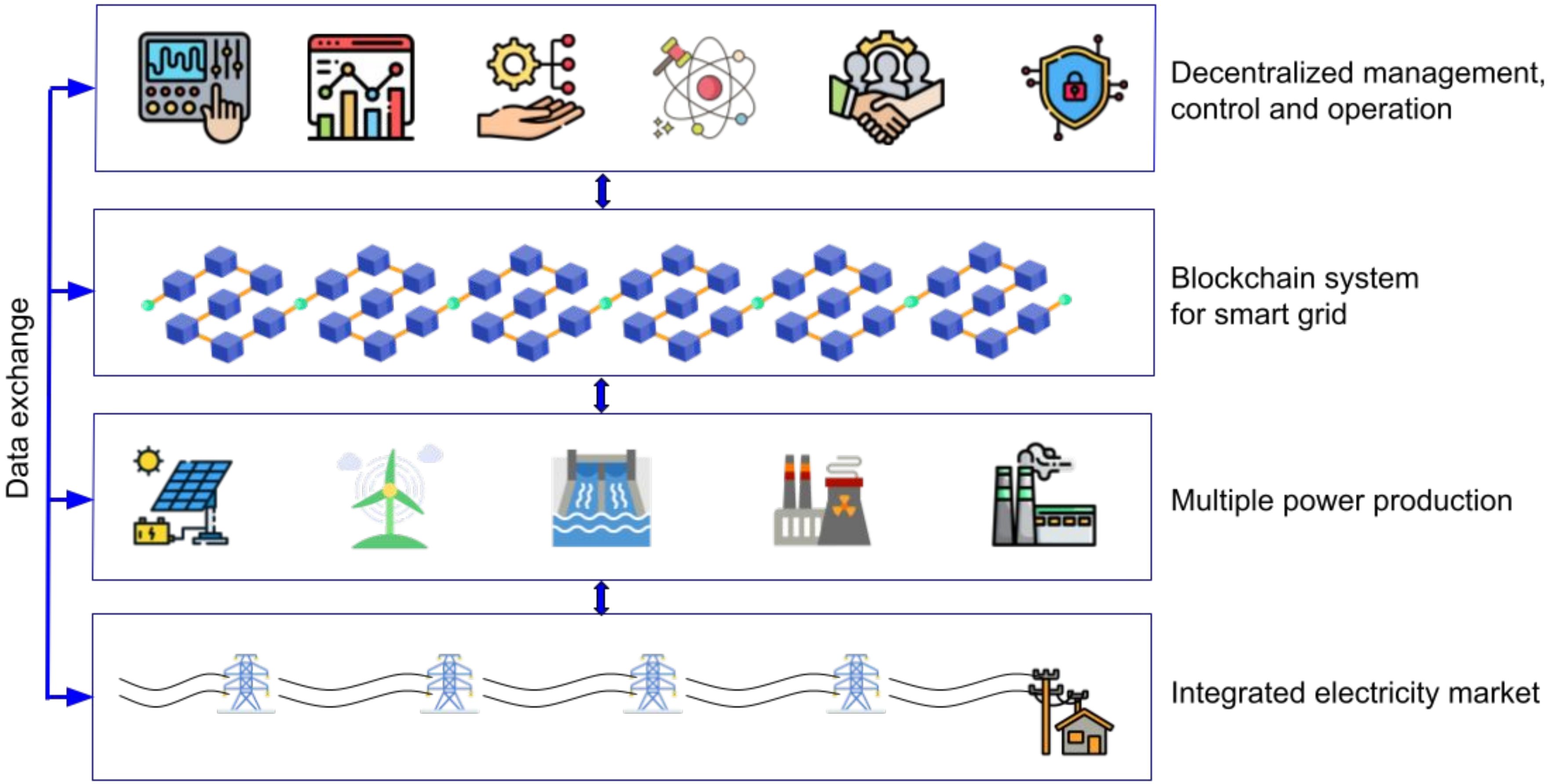
All parties agree to network verified transaction

Consensus

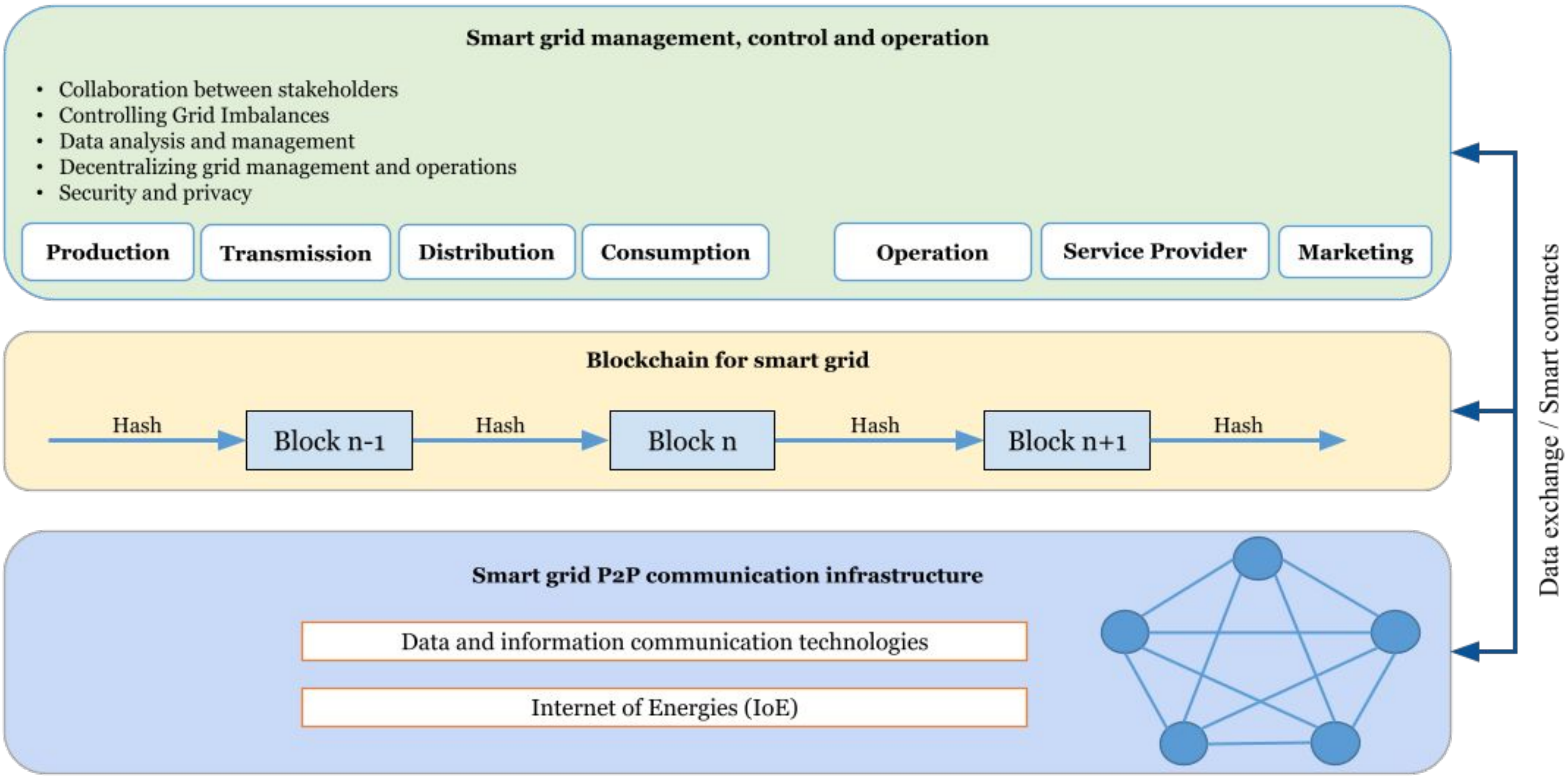
Smart Contract

Business logic and various agreed transactions

Blockchain infrastructure for smart grid



Blockchain infrastructure for smart grid management, control, and operation



Blockchain-based solution: benefits for stakeholders

- energy producers
  - adjust production in a timely manner based on the dynamic needs of the market
- consumers
  - adjust consumption patterns in a timely manner
- aggregators
  - resource distribution
- grid owners
  - configure and coordinate systems in a timely manner to plan load distribution and transmission
- energy authorities
  - regulate energy infrastructure and the marketing

Smart Contract

- A program
  - stored on a blockchain.
  - runs transactions when certain predefined conditions are met.
  - the result of each execution of the program is recorded in the distributed ledger.
  - ensures that no side can unilaterally change the details or results of the transaction.
- Blockchain-powered smart contracts offer a simple, cost-effective solution for building trust between parties and automating processes.

Advantages of smart contract for blockchain

- Self-execution and automation
- Self-verification
- Tamper-proof properties
- Trustworthiness
- Transparency and accessibility
- Security
- Speed
- Reliability
- Availability
- Efficiency
- Accuracy
- Decreased cost

Smart contracts application in the smart grid

- energy and flexibility trading
  - peer-to-peer trading
  - peer-to-grid
  - retail market
  - demand-side response
  - market design
- distributed control
  - grid management
  - virtual power plants
  - audit and certification of supply-chain
  - smart homes and energy management systems

Future applications of smart contracts in the energy sector

- Electric vehicle
- Decentralized (peer-to-peer) energy transactions
- Certification and trading of carbon emissions
- Physical information security with decentralization, high redundancy, security and privacy protection
- Energy transmission between heterogeneous renewable energy systems
- Power-to-X for tracking and tracing energy type, conversion history, and data support for transparency, credibility, and automatic enforcement for future emissions trading.
- The Internet of Energy (IoE) connects new energy and communication technologies with conventional fuel scarcity and progressive global environmental degradation.

Blockchain implementation

- Requirements analysis
  - Understanding what the customer wants
  - Analysis of needs
  - Feasibility assessment
  - Negotiating an appropriate solution
- Design
  - Architecture
  - Consensus algorithm and smart contract
  - Data feed
  - Framework
- Development
  - Peer-to-peer network
  - Blockchain system
  - Interfaces for data exchange
  - Data services

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