TESLA as Internet of Things

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Learning Objectives

Throughout this lecture, it is aimed for the students to be able to

- **Understand the vision of “TESLA as Internet of Things”**
- **Understand the information domain related to electric vehicles**
- **Understand the Blockchain concept and its application for energy systems**

Industry Invited Talk Today

- **Speaker**: Arne Øvrebø Lie, *Consultant, Energy Markets & Technology, DNV GL*
- **Title**: Blockchain Technology and its Application in Energy Systems

- **DNV GL**: a global quality assurance and risk management company. The largest technical consultancy and supervisory to the global renewable energy and oil & gas industry: 65% of the world's offshore pipelines are designed and installed to DNV GL's technical standards.

DNV·GL

Outline

TESLA as Internet of Things

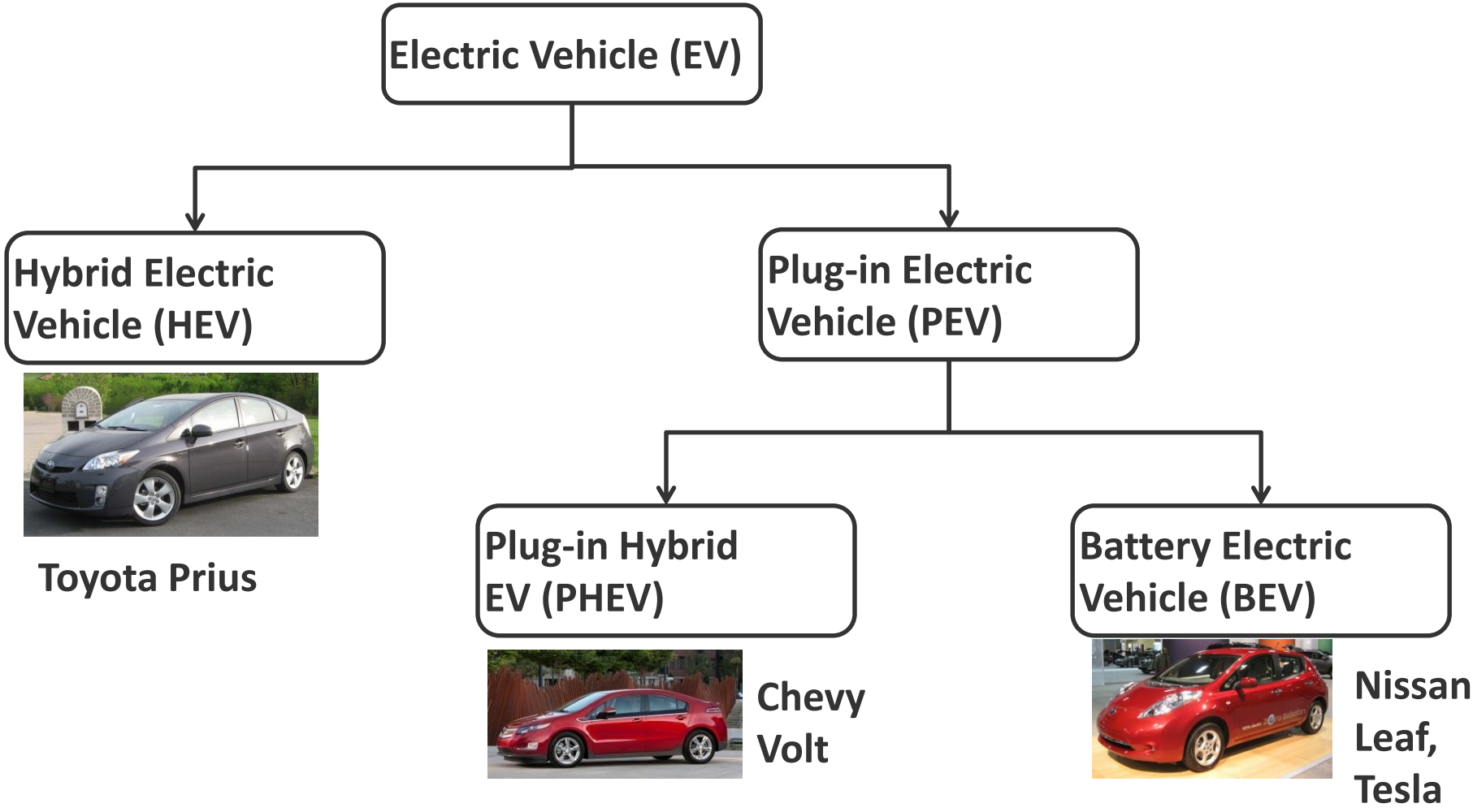
Information Domain

Blockchain for Energy Domain

TESLA AS INTERNET OF THINGS

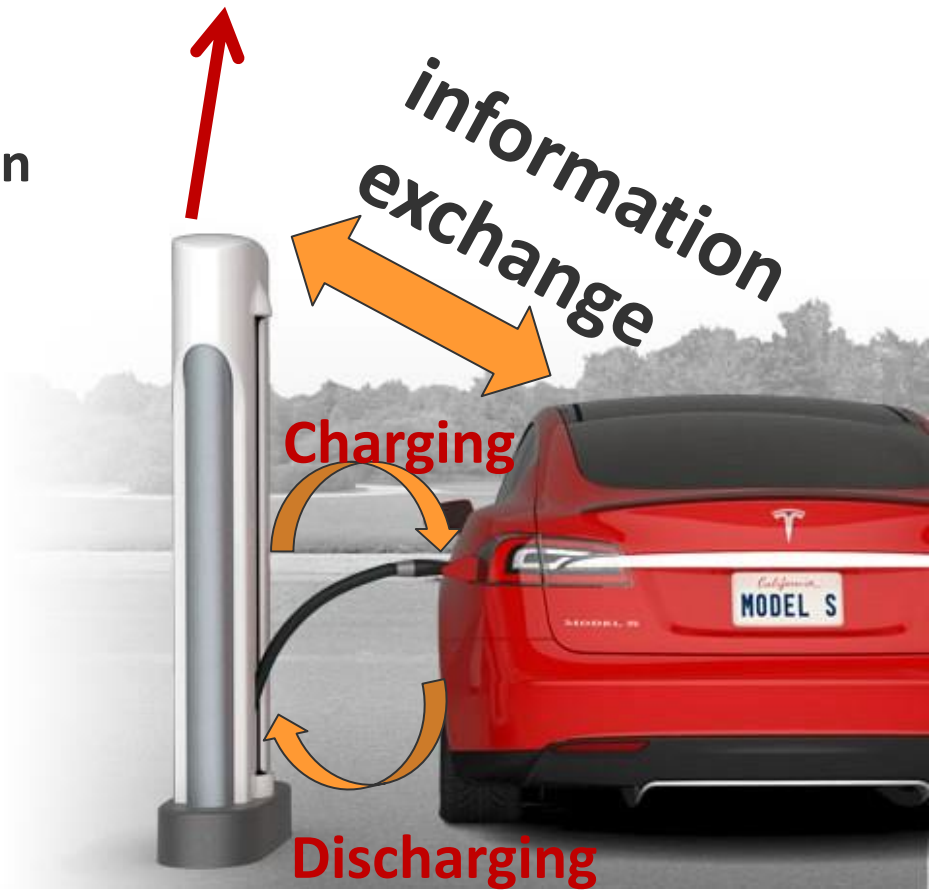
Different types of EVs

- Norway has the largest electric cars per capita in the world. 70% of world oil is consumed by the transportation sector. Transport electrification is on the rise worldwide



Electric Vehicles (EVs)

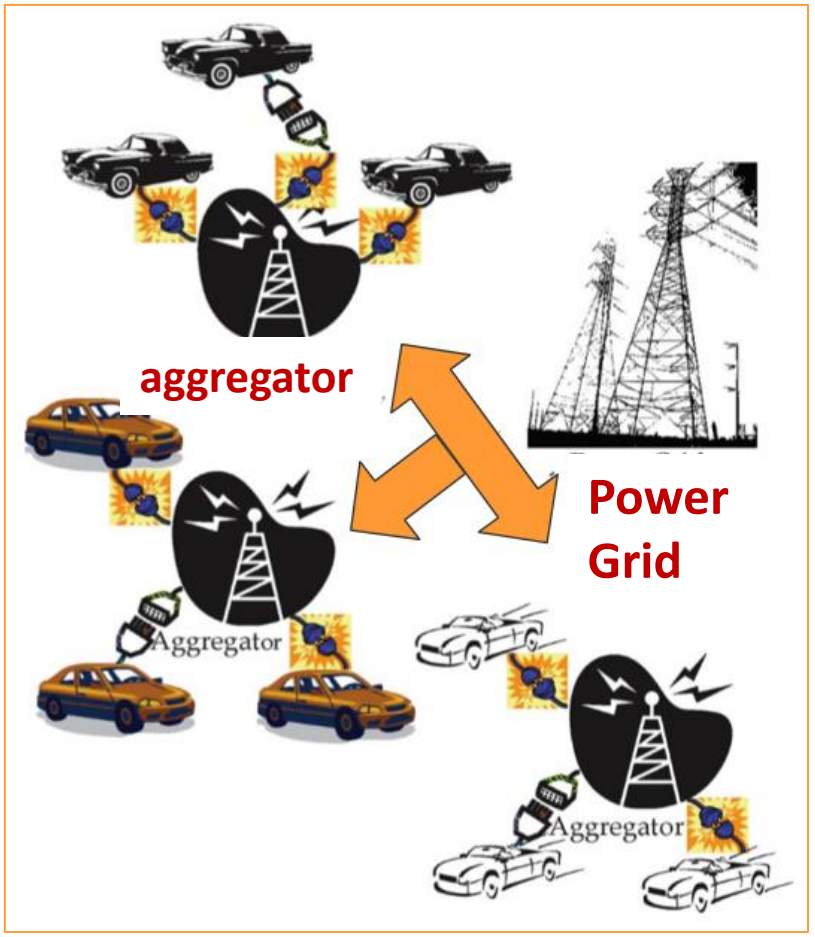
- Charging stations/Aggregator
  - Energy domain: power charging and power discharging
  - Information domain: information exchange between EVs and charging station
- Electric Vehicles roles
  - Energy consumer
  - Energy storage
  - Energy provider



- Q: why do we need discharging?

Vehicle-to-Grid (V2G) Systems: information and energy domains

- Three main components in this system: power grid, aggregators, and EVs. Each aggregator serves as an interface between the grid and a group of EVs.
- **Information:** The communications among EVs, aggregators, and grid can go through a two-way digital communications (wired or wireless) infrastructure.
- **Energy:** EVs in the system charge or discharge their batteries via an aggregator.



An EV example: Tesla Model S

- Range, Battery: Range is between 350-540km depending on driving conditions and battery choice.
- In a test, Tesla was able to go 375km on a single charge in Norwegian winter (-6Celsius).
- There are supercharging stations that will charge the car 50% in 20 minutes.

Keywords related to TESLA

energy storage

battery management

Self-driving

transport

energy

smart devices

electronics

communications

computation

machine learning

Then, is TESLA still a car?

- Yes, it is a car!
- But, it is more than a car…

It is

- a super computer
- smart device
- mobile robot

Important: TESLA is a NOT a car. TESLA is an IT device that has the car function!

- IPhone is not just phone. It is a smart device that we can make a call.
- Making a call is just one function of the device.

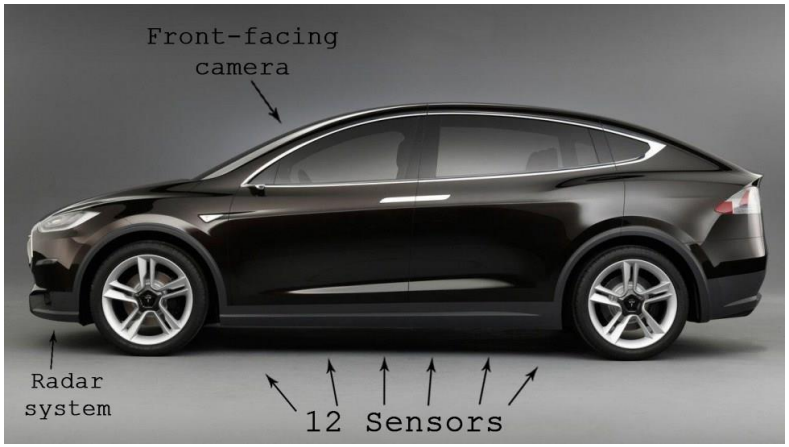
- TESLA is not just a car. It is a smart device that we can drive. Driving is just one function of the device.
- TESLA is smarter than IPhone, it can even drive by itself.
- TESLA is learning by itself: learn how drivers use the car and then build the autopilot system

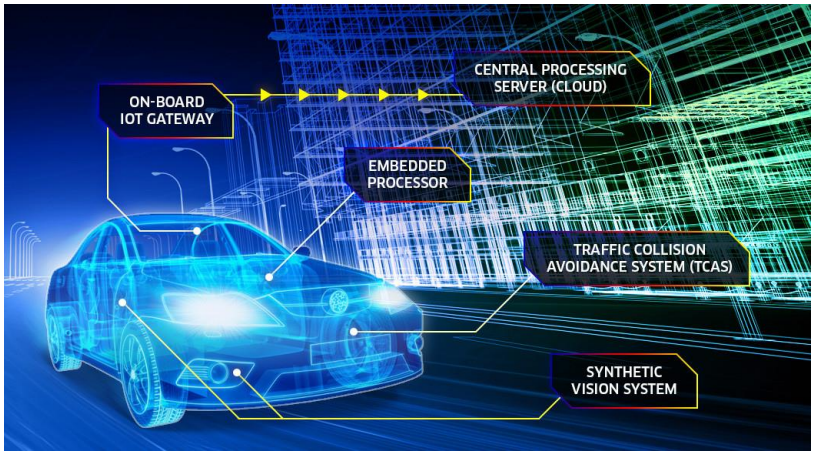
Internet of Things (IoT) Vision

- **Concept**: a network of connected objects that collect and exchange data at anytime anyplace. This includes everything from cellphones, coffee makers, washing machines, wearable devices, airplane, a jet engine of an airplane and almost anything else you can think of.

- **Anything connected**: anything will be connected and information can be accessed and shared from anywhere and anytime.

IoT Features of TESLA (I): information sharing





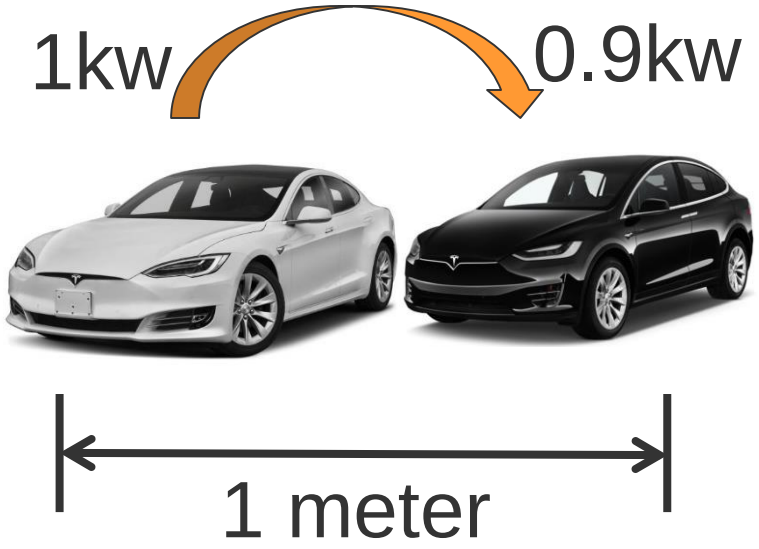
- **8 cameras:** provide 360 degrees of visibility at up to 250m of range.
- **12 ultrasound sensors around the car:** detect objects in range to 500m
- **A forward-facing radar:** radar produce electromagnetic waves and detects the reflection of those waves to determine the distance, angle, and velocity of those objects (i.e., where they are and how they are moving).
- **Digitalization**: Tesla has a free 3G connection to the Internet that is paid by Tesla. With built Wifi, Bluetooth, these make it access information from anytime anywhere. All aspects of the cars are digitized and available for inspection, including brakes, seat positions…

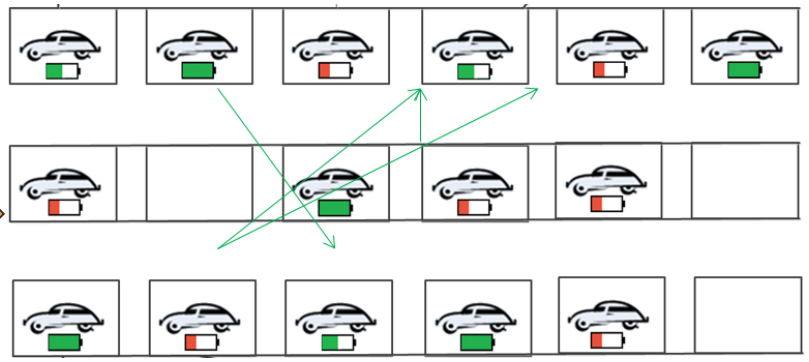
IoT Features of TESLA (II): smart energy

- The car has a smart charging system that can adapt to almost any electrical source that is plugged into the car.
- It has the ability to regulate the power consumed to the capability of the line it is connected to.
- It can reduce consumption as the batteries can allow the user to designate lower power levels or even a timer to control when it starts charging. **(Q: Demand Response Management?)**

IoT Features of TESLA (III): energy sharing probably in the near future

Wireless Power Transfer





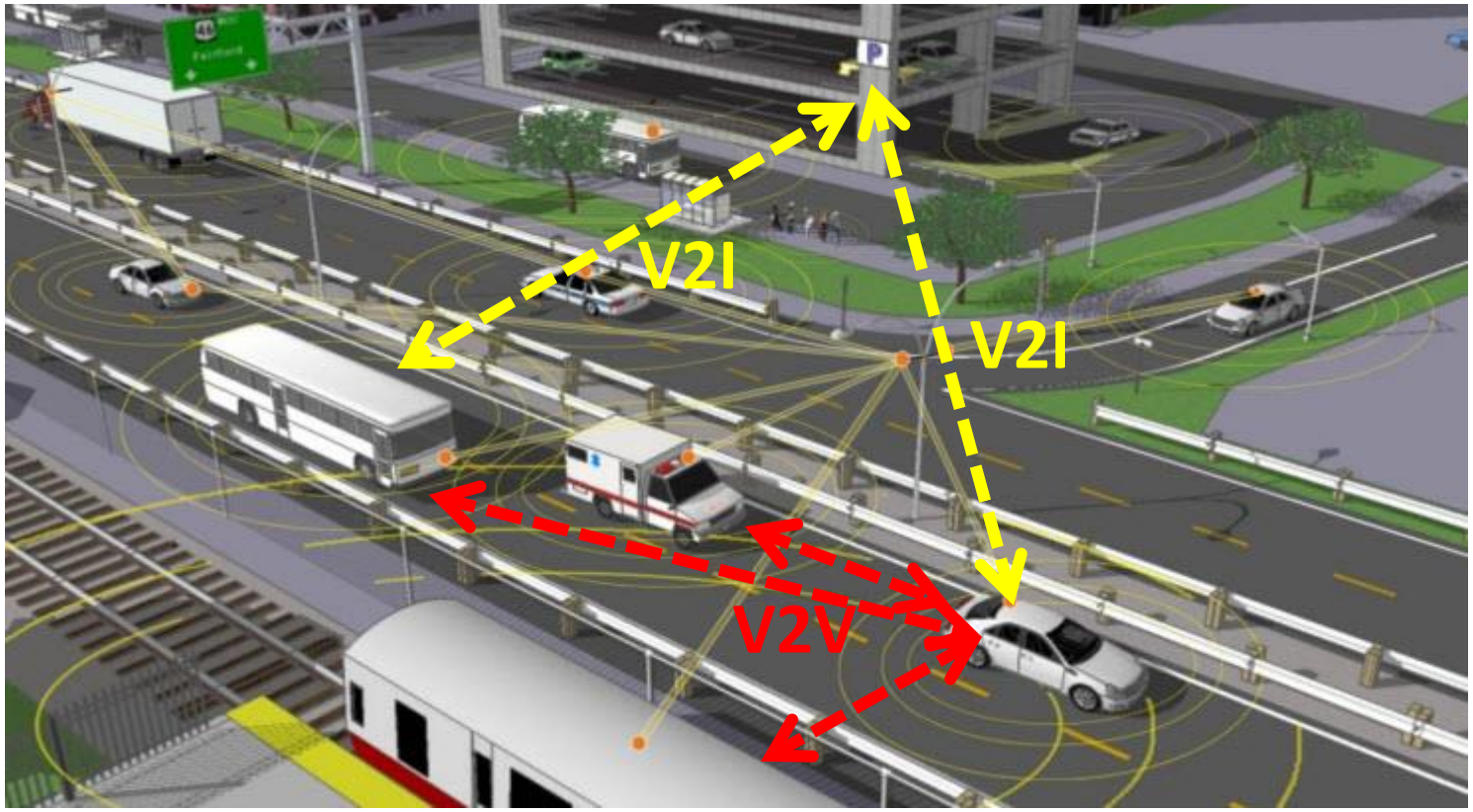
Airport Parking

- **Wireless Power Transfer experiment: At kilowatts power level, the transfer distance can be several hundred millimeters with efficiency above 90% (*)**

(*) S. Li and C. Mi, "Wireless Power Transfer for Electric Vehicle Applications", IEEE Journal of Emerging and Selected Topics in Power Electronics, vol.3, no.1, March 2015.

INFORMATION DOMAIN

V2V & V2I for Connected Vehicles



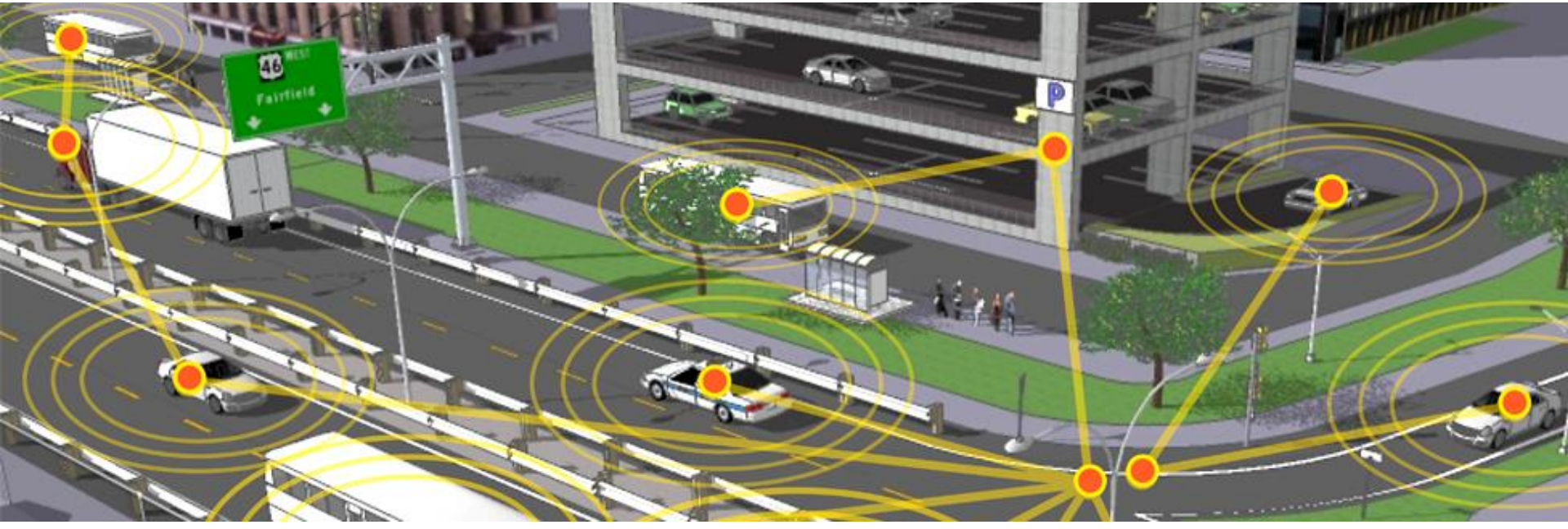
- **Vehicle-to-Vehicle (V2V) Communications: communications between vehicles**
- **Vehicle-to-Infrastructure (V2I) communications: communications between vehicles and road infrastructures**

V2V & V2I

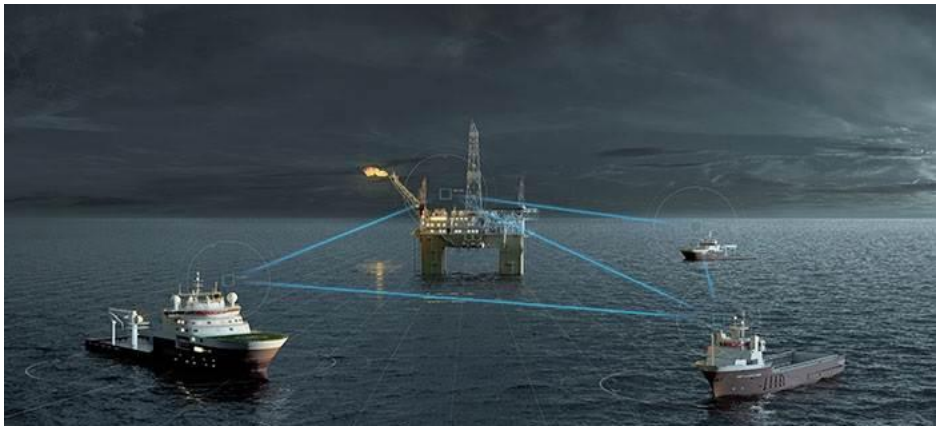
- Cars, trucks, buses, and other vehicles can “talk” to each other. They continuously share important safety and mobility information. Connected vehicles can use wireless communications to “talk” to traffic signals, work zones, toll booths, school zones, and other infrastructures

- **Safety applications:** safety packets transmission, emergency alert, driver assistance

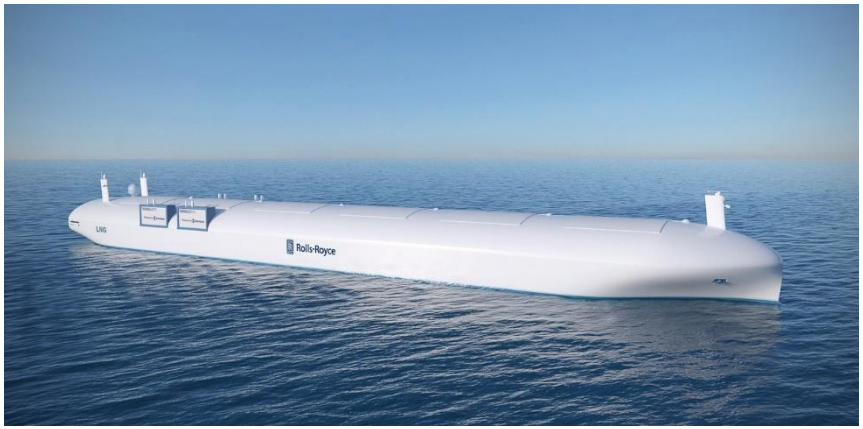
- **Non-safety application:** advertisements, map update, entertainment



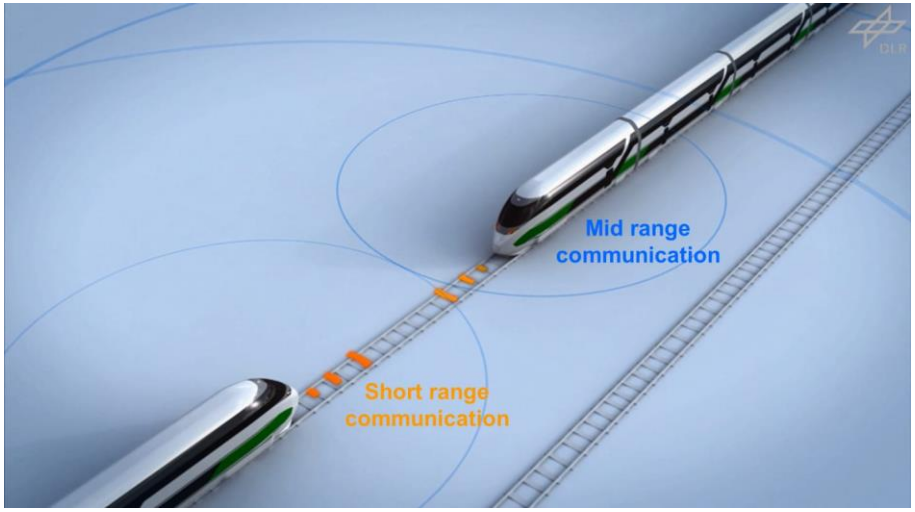
V2V concept can be easily extended to other applications



Ship-to-Ship Communications



Autonomous/unmanned ships



Train-to-Train Communications

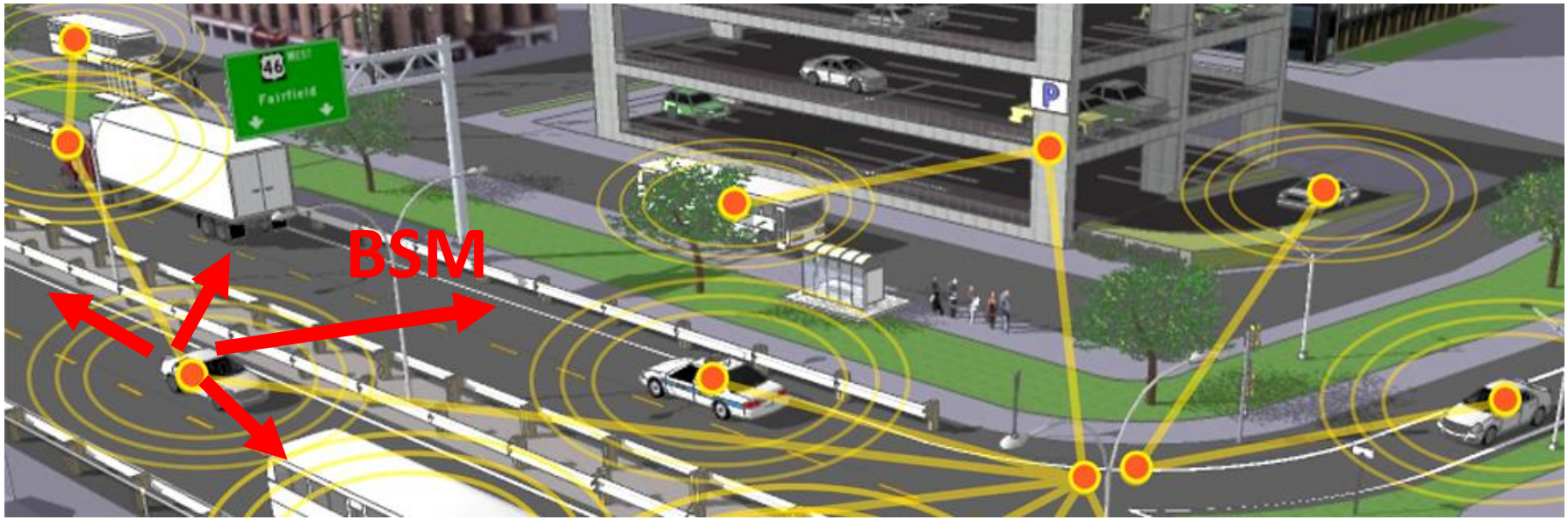
Dedicated Short-range Radio Communication (DSRC)

- **DSRC-based devices can be installed directly in vehicles, or could be carried into vehicles by drivers in the form of a handheld device (e.g., smartphone).**
- **In general, safety-related applications are expected to rely on DSRC. DSRC uses spectrum dedicated by the FCC for transportation safety applications.**
- **Non-safety-related applications may use other forms of wireless communications, such as cellular or Wi-Fi.**

Dedicated Short Range Communication (DSRC)

- **Goal:** A short to medium range communications service that supports both public safety and private operations in V2V and V2I communications modes.
- **Frequency**: 5.9GHz; **Bandwidth**: 75MHz. This spectrum has been exclusively allocated for vehicle safety and mobility applications.
- Key Benefits
  - Low latency communication (<< 50ms). Safety has stringent communications requirements, and future pre-crash and automation requirements may be even more stringent.
  - High data transfer rates (3 – 27 Mbps)
  - Line-of-sight, up to 1500 m and 360º
- Benefits of Safety Applications:
  - Collision avoidance; Improved mobility; Improved environmental protection

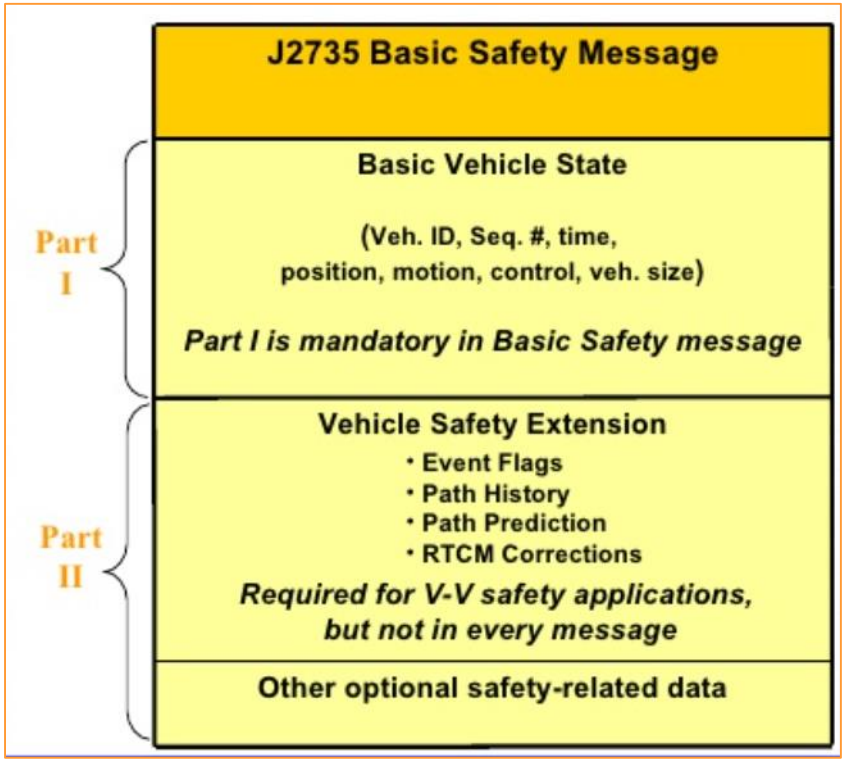
V2V Working Principle



- Each vehicle broadcasts its state information in a “Basic Safety Message” (BSM) up to 10 times per second to surrounding vehicles.
- BSM is sent in 360 degree pattern using DSRC technology. Upon receipt of BSM, vehicle builds model of each neighbor’s trajectory, assesses threat and warns driver (or takes control) if threat becomes acute.
- Q: is it too frequent to send BSM up to 10times/second? How to solve this?

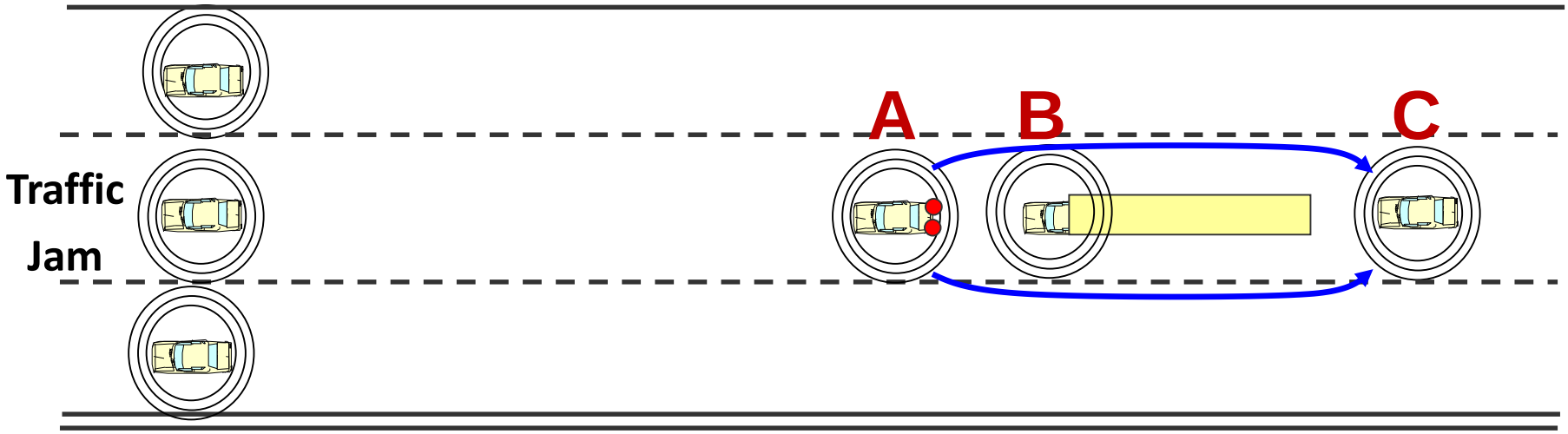
Basic Safety Message (BSM)

- Average message size: 320 ~ 350bytes
- Default transmit rate: 10time/second
- BSM is exchanged between vehicles and contains vehicle dynamics information such as heading, speed, and location.
- BSM is transmitted only through the control channel and is tailored for low latency, localized broadcast required by V2V safety applications



V2V Safety Applications – Emergency Electronic Brake Lights

- **Emergency Electronic Brake Lights**: approaching a vehicle stopped in roadway, but not visible due to obstructions
- Car **A** decelerates when it is approaching jam. Car **B** will inform Car **C** via DSRC within 100 msec.



BLOCKCHAIN FOR ENERGY DOMAIN

Energy sector has great interest in Blockchain

BLOCKCHAIN NEWS AUGUST 12, 2016 15:38

Perth Startup Set to Begin Trials of P2P Energy Trading on the Blockchain

Nov 29, 2016 | Jamie Redman | 6669

Siemens Partners With LO3 Building Blockchain Microgrids

USA

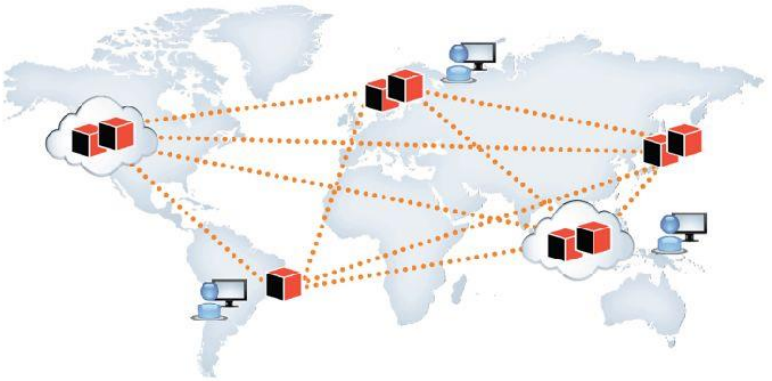
The largest engineering corporation in [illegible] AG and energy collaboration with fintech startup LO3 Energy to microgrids. The blockchain protocol aims to enable energy distributed ledger platform.

ACCEPTS BITCOIN NOVEMBER 18, 2016 13:18

A Majority of the German Energy Industry is Interested in Blockchain Tech

Two concepts: Blockchain and Bitcoin

- **Blockchain**: a distributed database where anyone can create and complete transactions stored permanently. There are no central nodes and all nodes are equal. Each node stores the whole database.

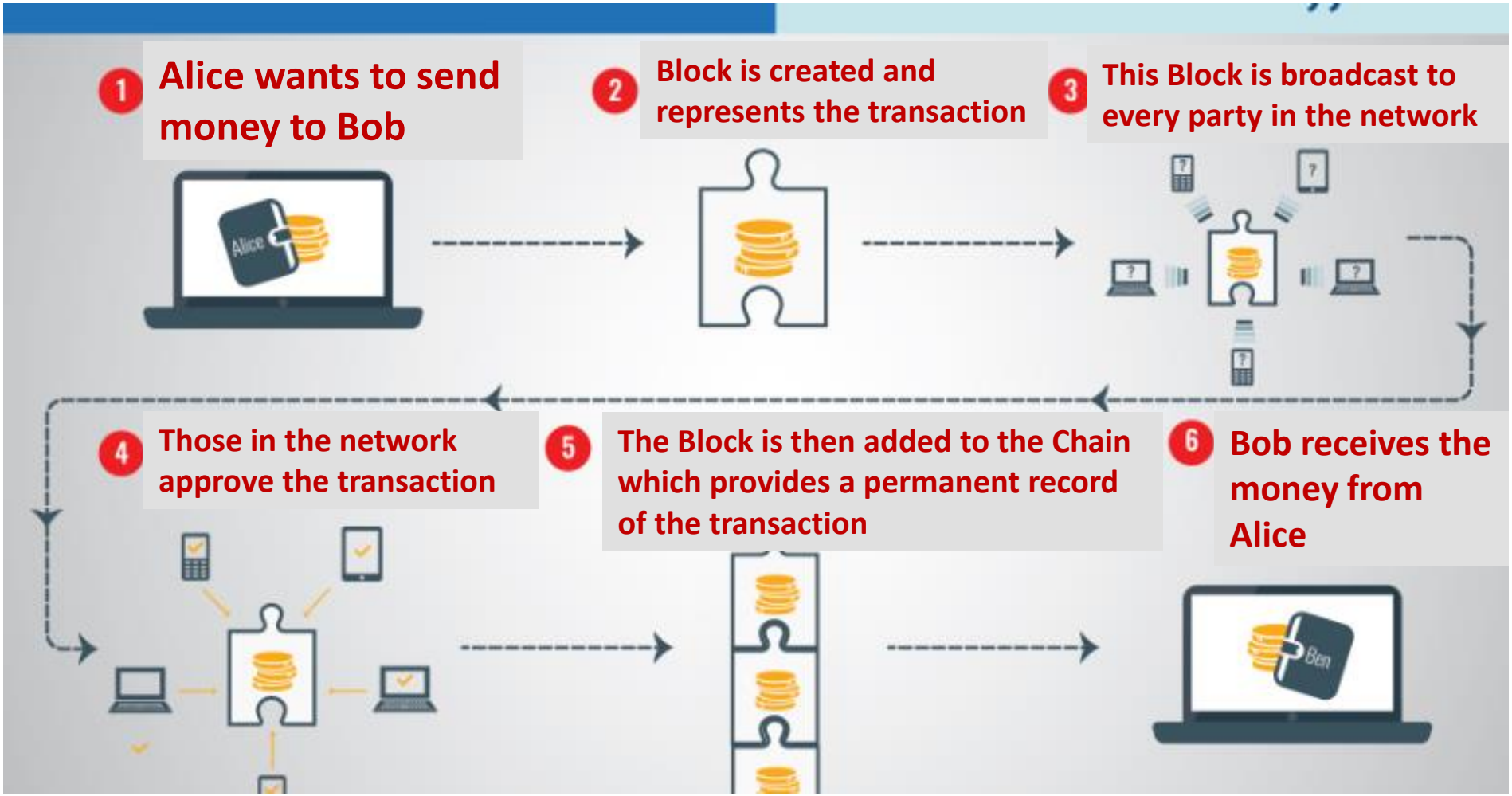


- **Bitcoin**: unregulated digital currency designed to bypass currency controls and simplify online transactions by getting rid of third-party payment processing intermediaries.

- **Blockchain&Bitcoin relationship**: Bitcoin was an application of Blockchain. Blockchain has applications far beyond Bitcoin.

Bitcoin Price

An example of transaction using Blockchain concept

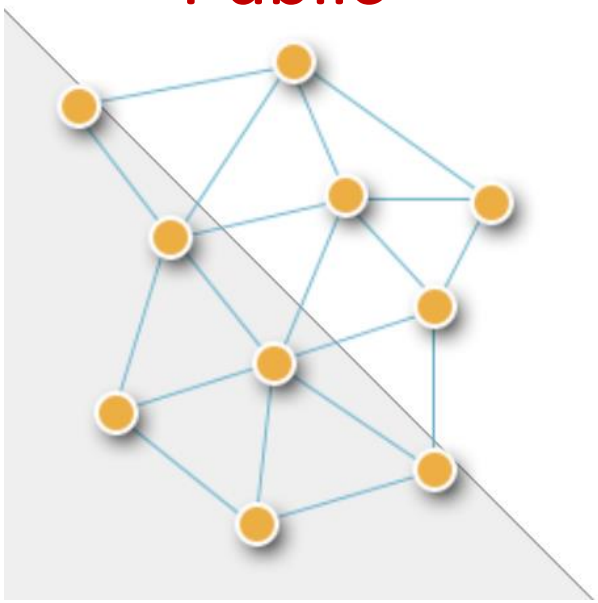


- **Blockchain: decentralized database that keeps a record of all transactions. This provides a perfect way for systems to record transactions that should be transparent and permanent.**

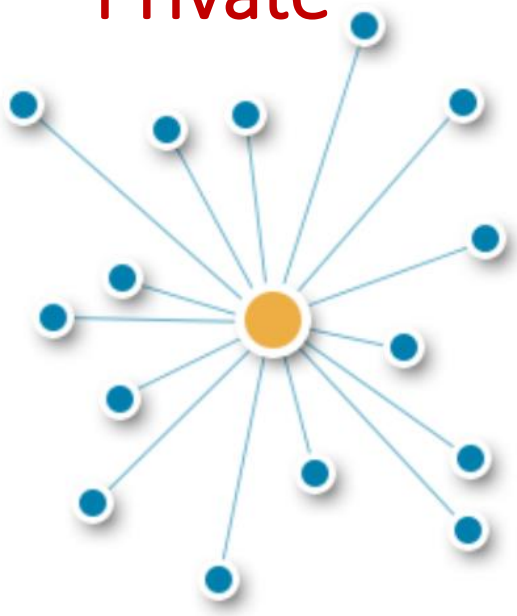
https://https://www.linkedin.com/pulse/securing-internet-things-iot-blockchain-ahmed-banafa/

Blockchain types

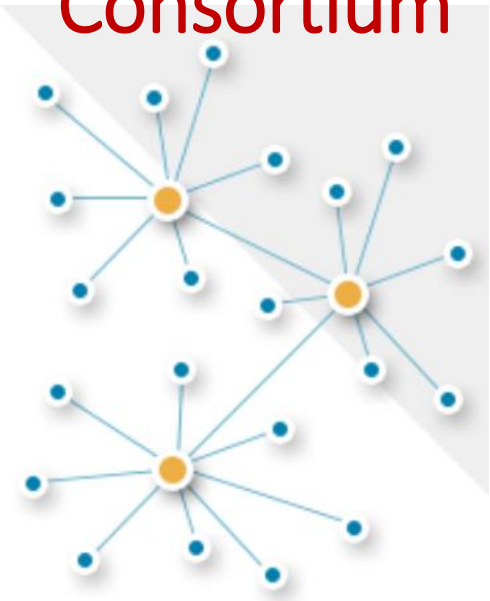
Public



Private

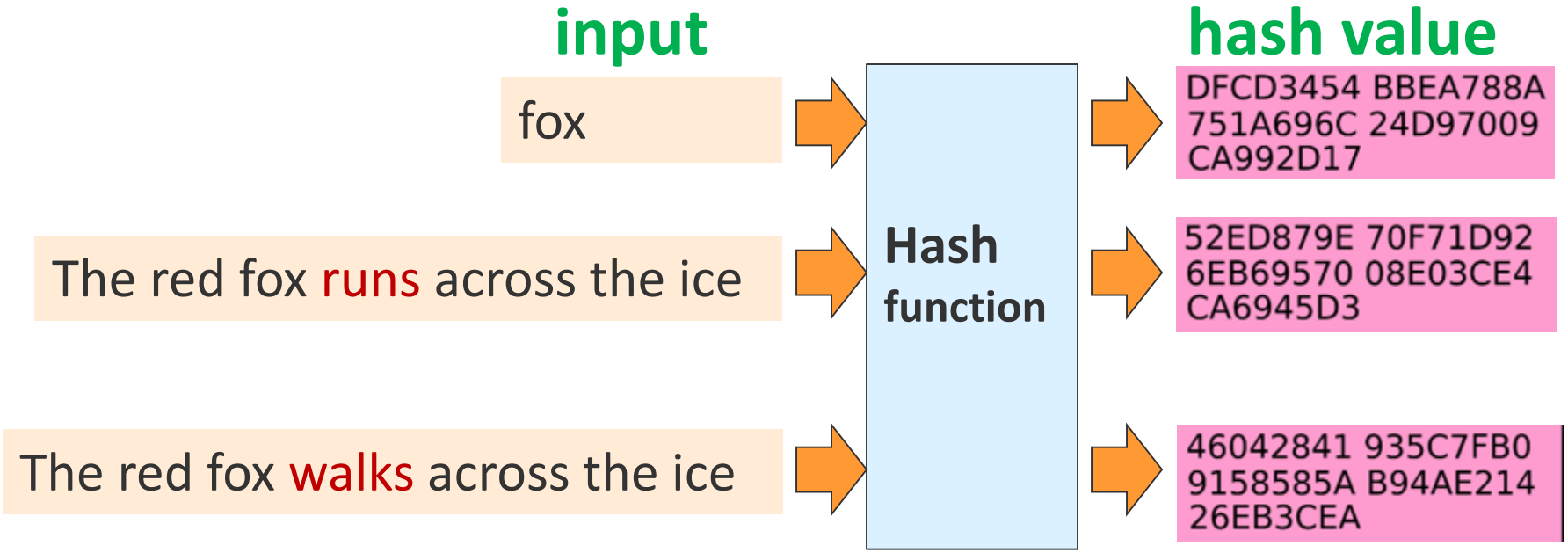


Consortium



	Public	Private	Consortium
Administration	No administrator	Single	Multiple
Permission	Permissionless	Permissioned	Permissioned
Computation cost	High	Low	Medium
Applications	**Bitcoin**	**Bank, international organization**	**Consortium of Banks, e.g., DNB, NORDEA**

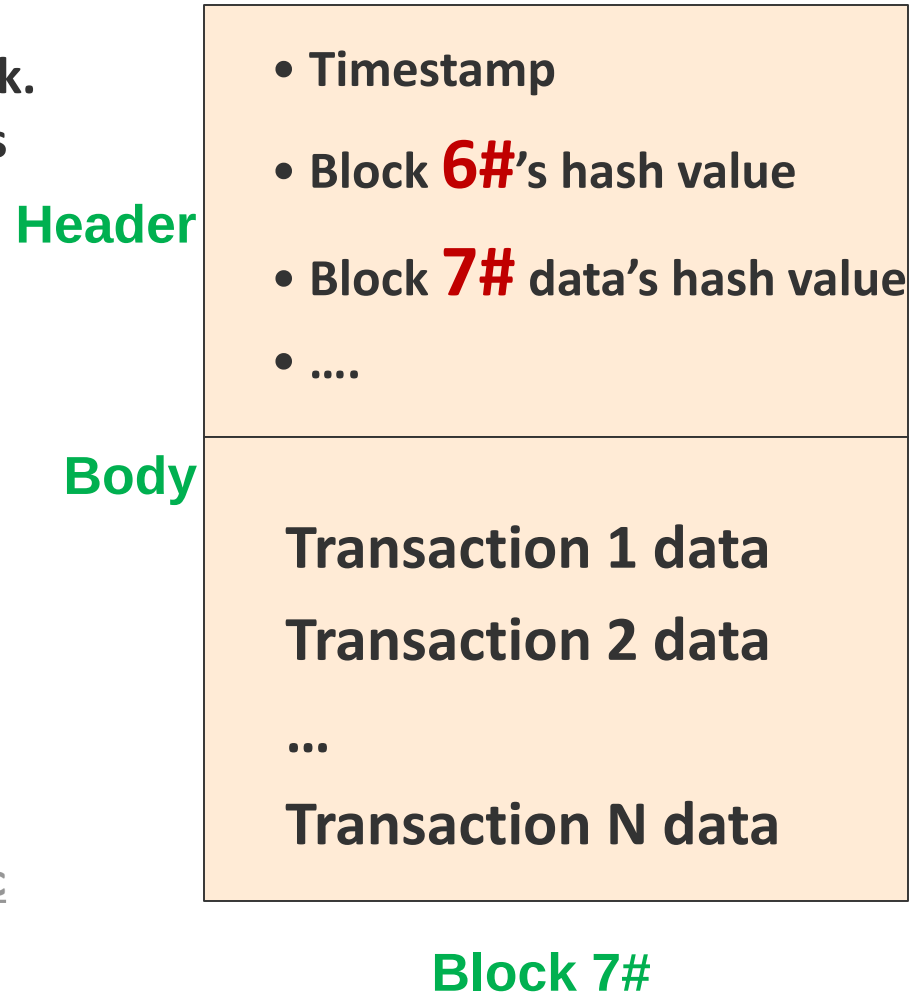
Concept: hash function and hash value



- **Hash function:** takes any size input text and returns a fixed size string (i.e., hash value).
  - Easy to calculate a hash for any given data
  - Hard to calculate the original text that has a given hash
  - Two slightly different messages produce drastically different hash value
- Bitcoin uses a standard SHA-256 hash algorithm which generates a 256 bit hash value. For example: SHA256(123) = a665a45920422f9d417e4867efdc4fb8a04a1f3fff1fa07e998e86f7f7a27ae3

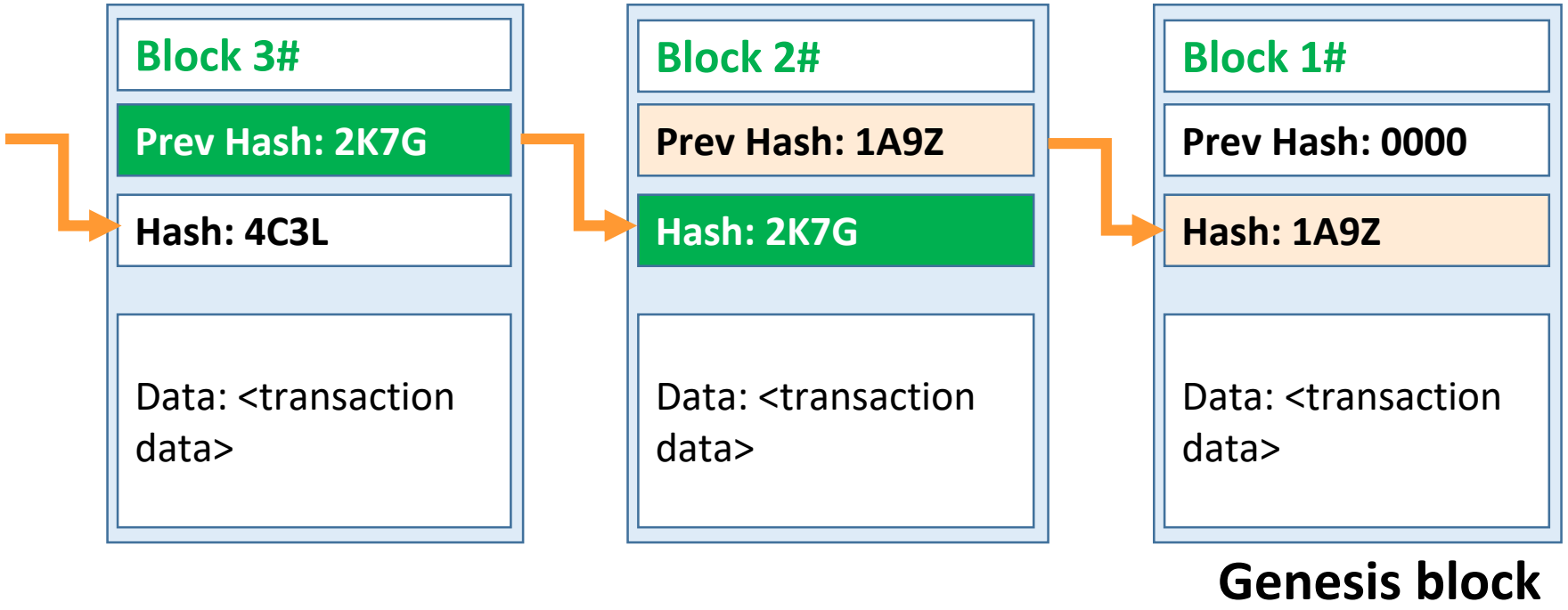
Blockchain data structure (I)

- **Block**: blockchain is composed of block. Block refers to a group of transactions at a specific time and hash pointer of the previous block. Each block includes: header and body (i.e., data).
- Each block contains its own hash and also hash of the previous block. For instance, block 7 contains the hash of block 6, and block 6 contains the hash of block 5.
- A simple blockchain in Python: https://github.com/EricAlcaide/pysimplechain



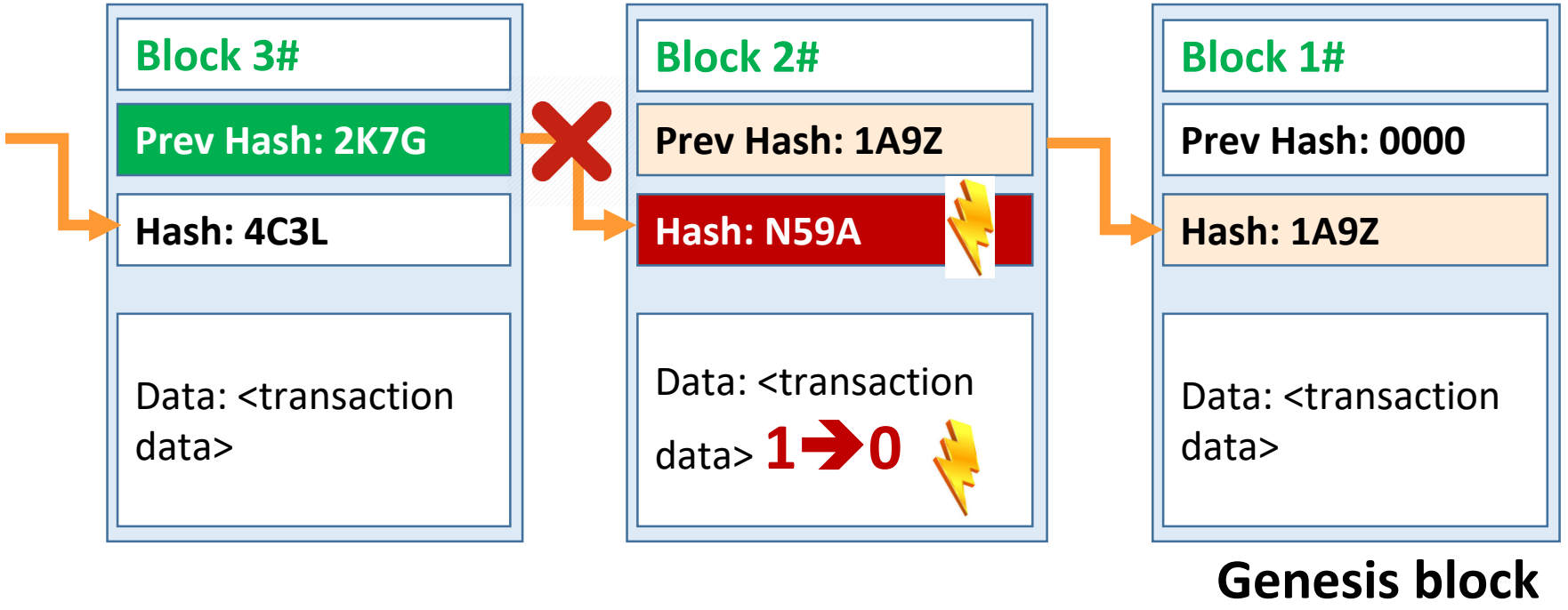
Blockchain data structure (II)

- **Blockchain data structure**: a linked list with hash pointers used to record all transactions. New blocks are added to the end of the chain.
- **Hash pointer**: gives you a way to retrieve data along with the hash of the data. A regular pointer only gives you a way to retrieve data.



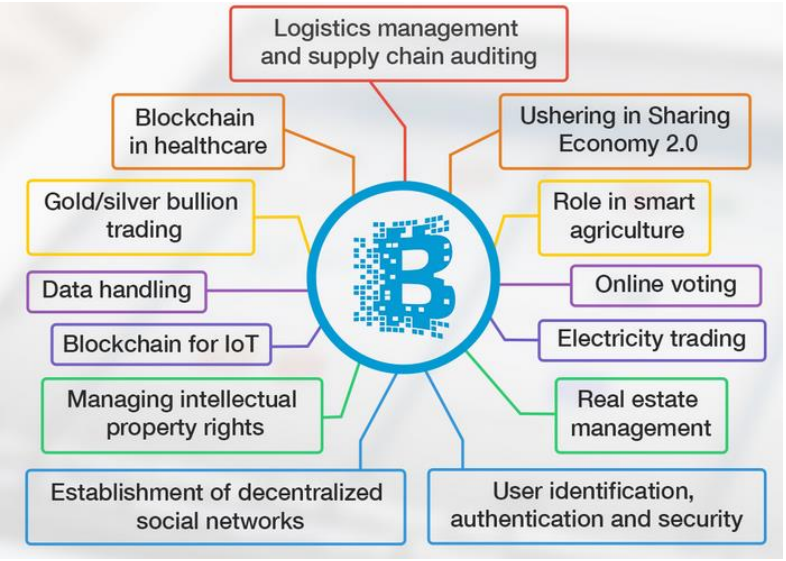
Tamper-proof mechanism

- **Tamper-proof**: an adversary is not able to tamper data in any block without getting detected.
- If anyone changes the data in **Block 2**, even just one bit from 1 to 0, the hash value of this block changes dramatically. Then, **Block 3#'s** "Prev Hash" is not same as **Block 2#'s** hash value, this makes the whole chain invalid.



Blockchain applications in general

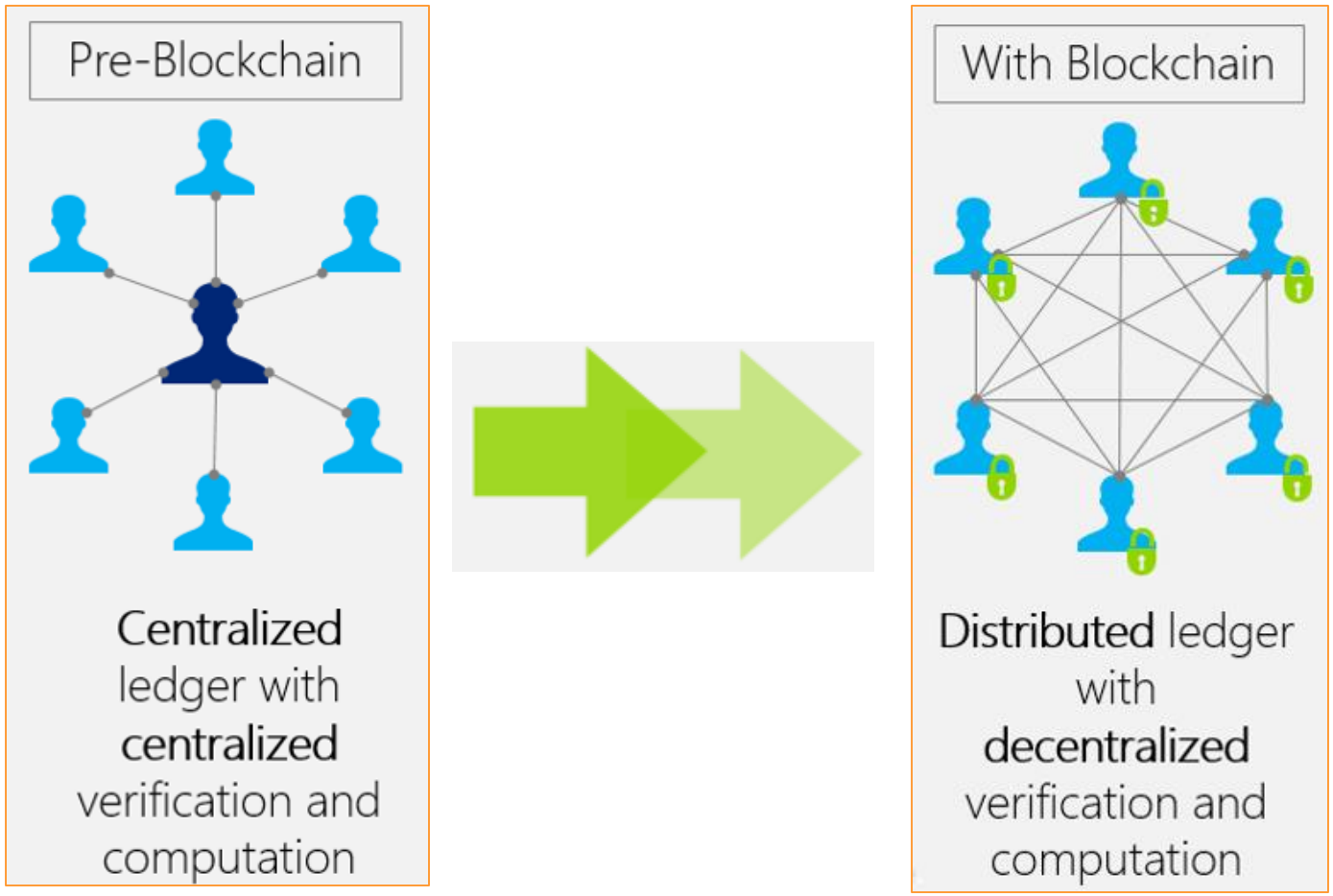
- **Blockchain: decentralized database that keeps a record of all transactions.**
- **This provides a perfect way for systems to record transactions that should be transparent and permanent.**



Sweden officially use Blockchain to register land and properties

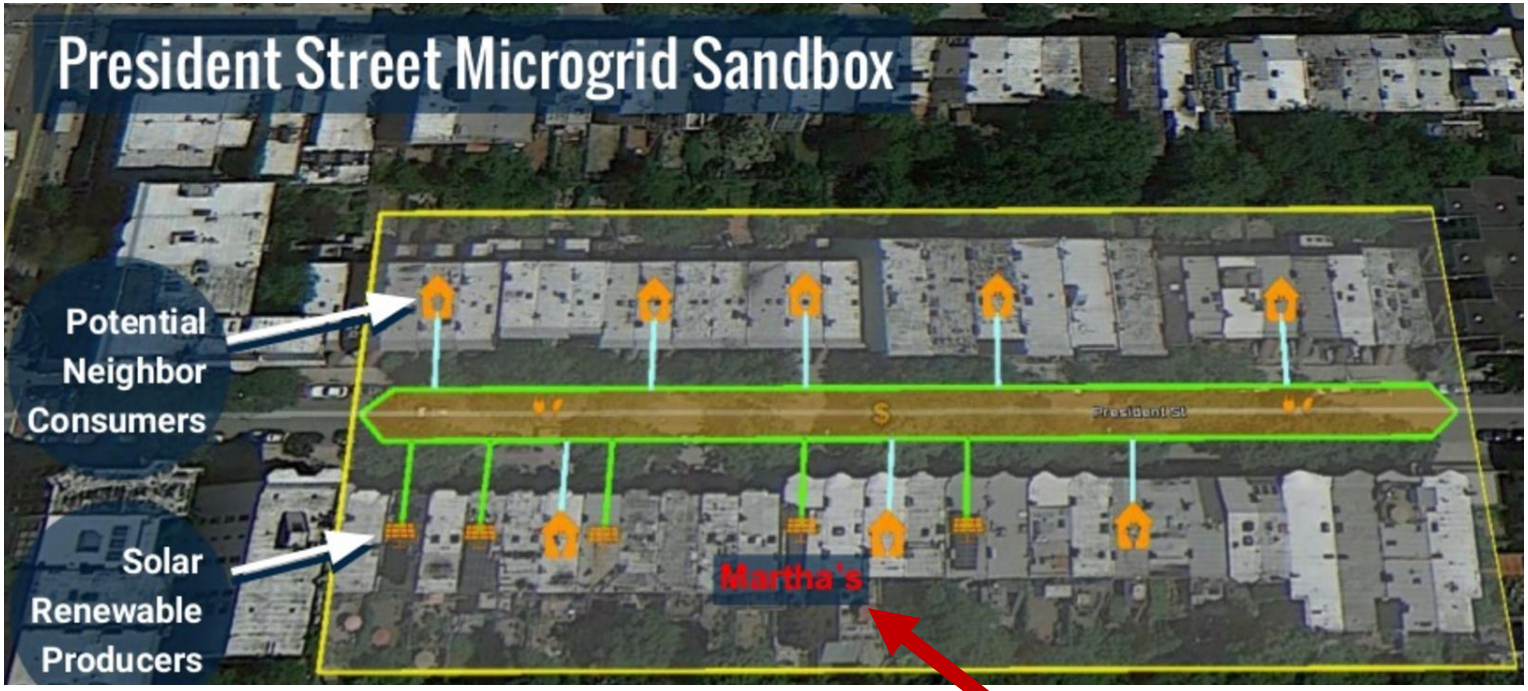
Second-hand car value certification

Blockchain for energy systems



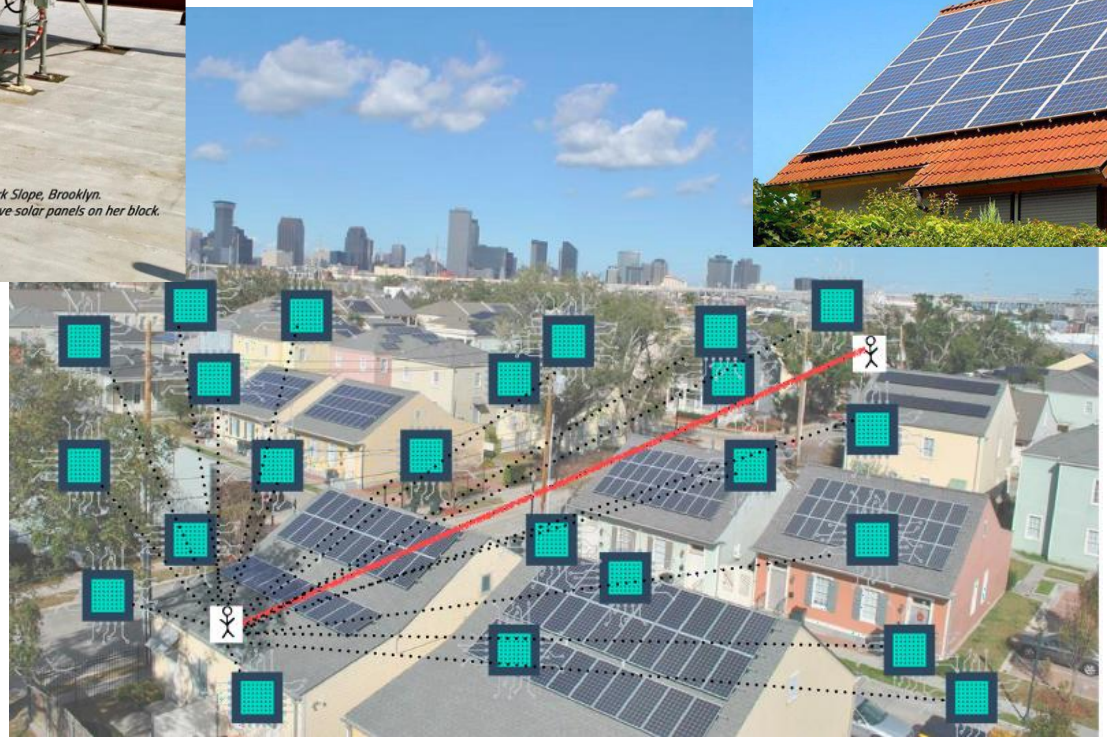
- **Main observation:** **Blockchain provides a perfect way for ensuring secure transaction: (1) in distributed market/environments without trusted third-party; (2) nodes do not trust each other**

Blockchain for energy (I): Neighborhood Energy Trading



- **Brooklyn Microgrid:** In your house roof, you have solar power. The power can be used by yourself. If you are not able to use all power, you can sell to your neighbors.

Blockchain for energy (I): Neighborhood Energy Trading



- Each house can: (1) buy and sell its own electricity with other houses in distributed environment; (2) the houses do not trust each other; (3)) we need a method to ensure secure energy trading among houses. ➔ Blockchain's principle!

Blockchain for energy (I): Neighborhood Energy Trading

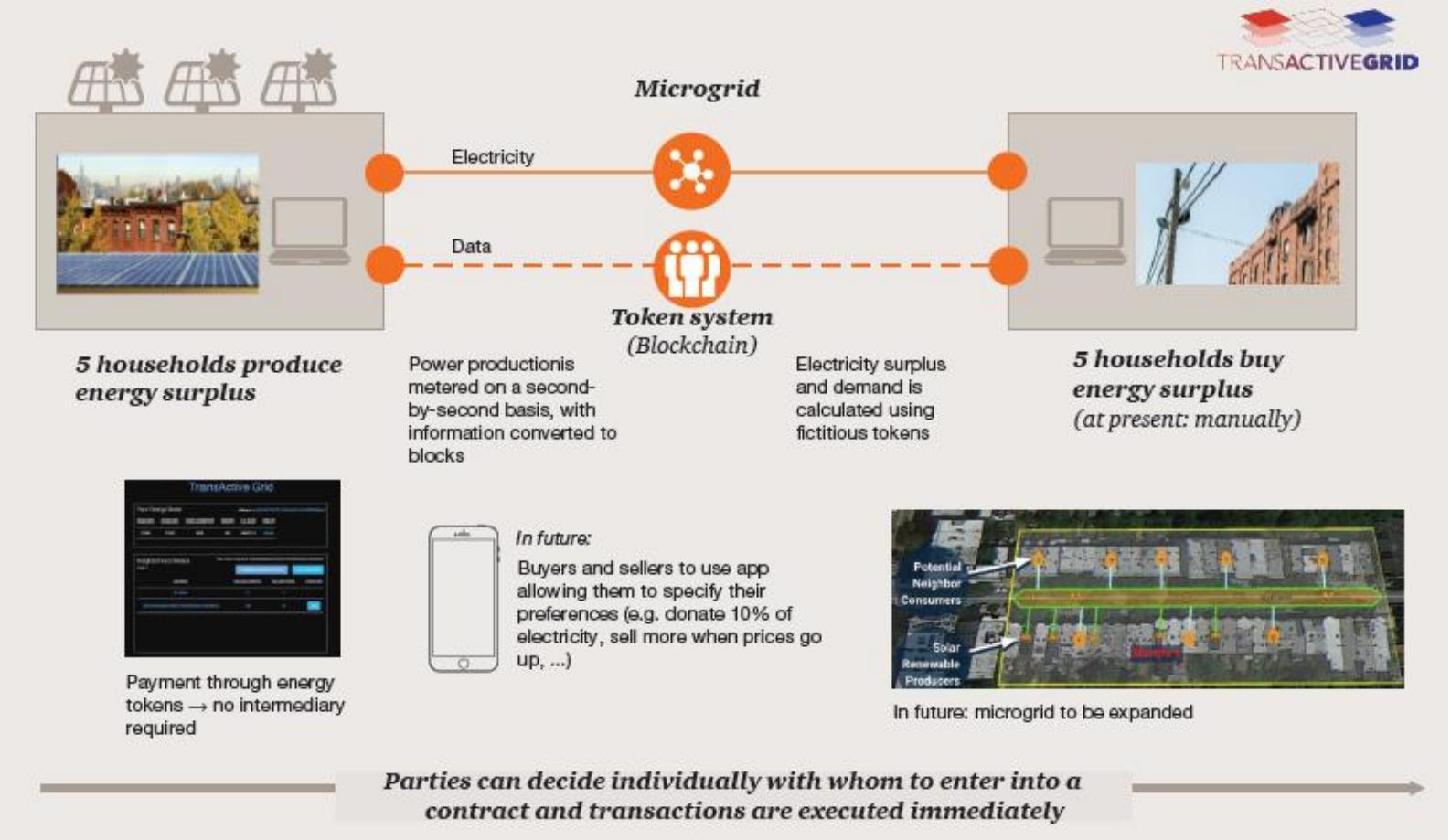
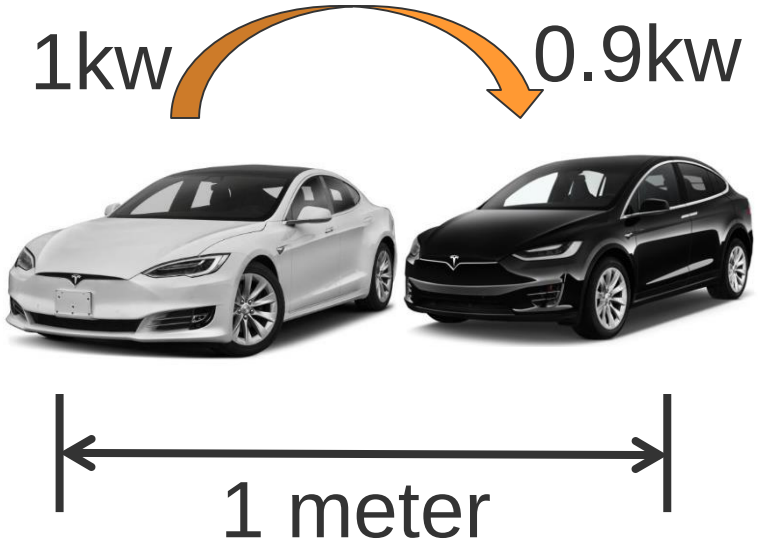


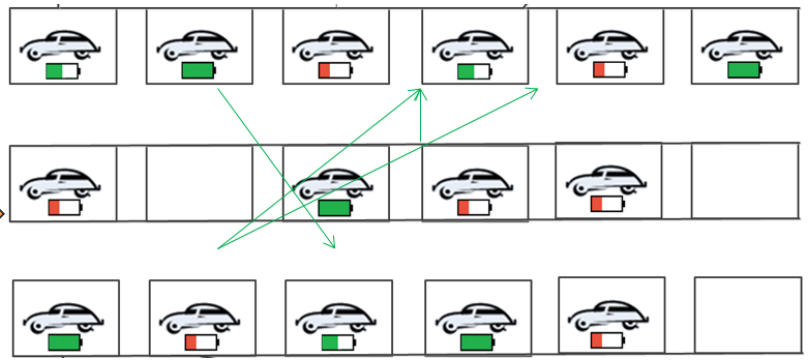
Fig. source: pwc Global power and utilities, "Blockchain- an opportunity for energy producers and consumers?"

- **Brooklyn Microgrid project:** Customers can choose to power their homes via local renewable energy sources. People with their own solar panels can sell surplus electricity to their neighbors. Blockchain is used to ensure accurate records of these transactions. The accounting is decentralized and shared by everyone on the network.

Blockchain for energy (II): P2P (Peer-to-Peer) Energy Sharing

Wireless Power Transfer



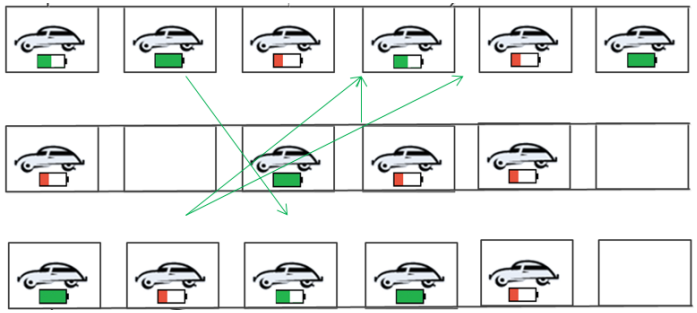


Airport Parking

- **Each vehicle can: (1) buy and sell its own electricity with other vehicles in distributed environment; (2) the vehicles do not trust each other; (3)) we need a method to ensure secure energy trading among EVs. ➔ Blockchain's principle!**

Blockchain applications: energy sharing where everyone can contribute/share power

- Each house can generate, store, buy and sell its own electricity with neighbors

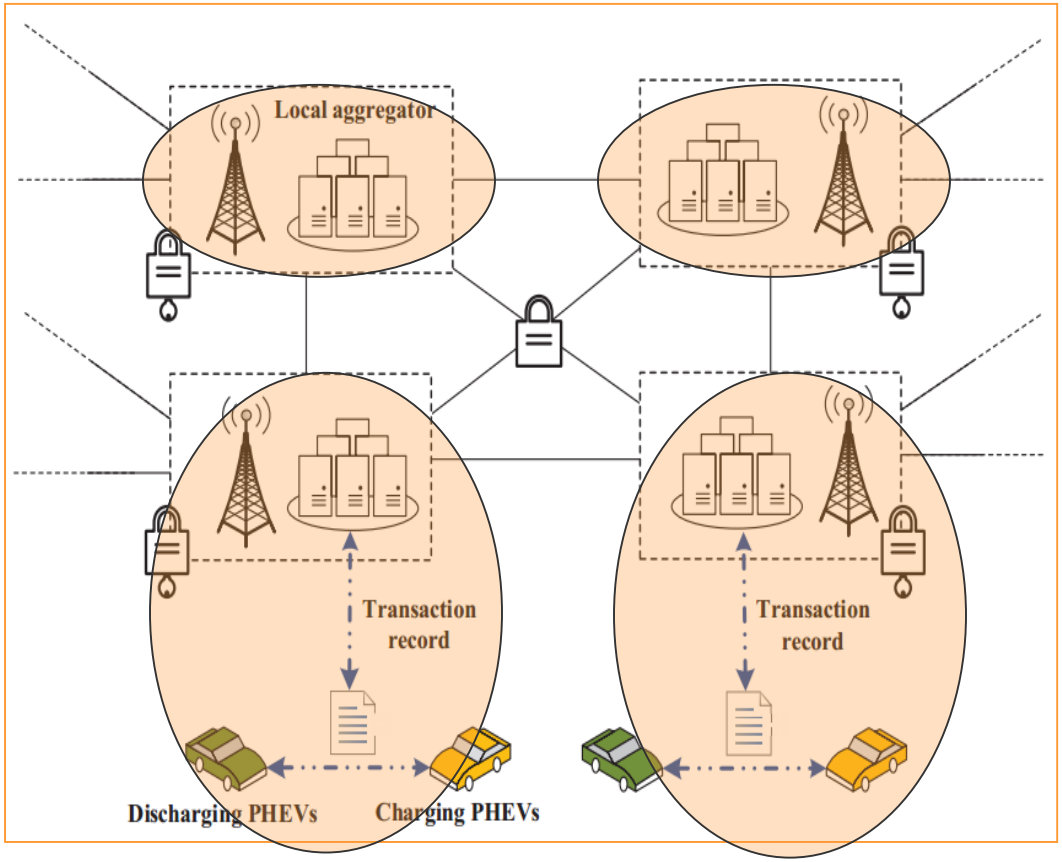


- An electric vehicle may charge or discharge
- Each vehicle can buy and sell its own electricity with other vehicles.

- **Common feature**: (1) distributed energy trading; (2) houses/EVs donot trust each other
- **Challenge**: need a method to ensure secure energy trading among houses or EVs. ➔ Blockchain's principle!

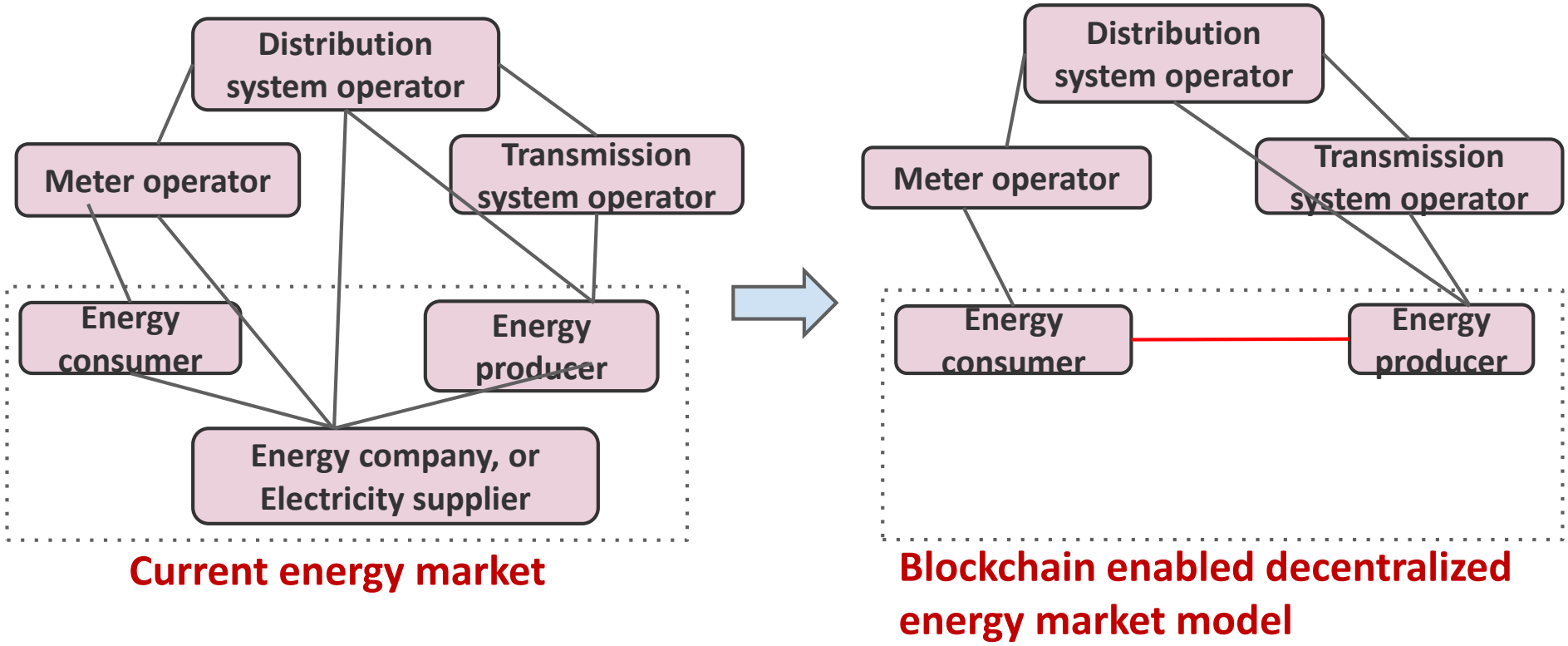
Blockchain for Vehicle-to-Vehicle Energy Trading

- EVs can trade energy via wireless power transfer
- Aggregators are authorized nodes to audit the transactions and record them into the shared ledger.
- The ledger is publicly accessible for EVs and aggregators



- Q: which blockchain should we use, public, private or consortium?
- Consortium blockchain: blockchain with multiple authorized nodes to establish the distributed shared ledger with moderate cost

Blockchain will transform energy market



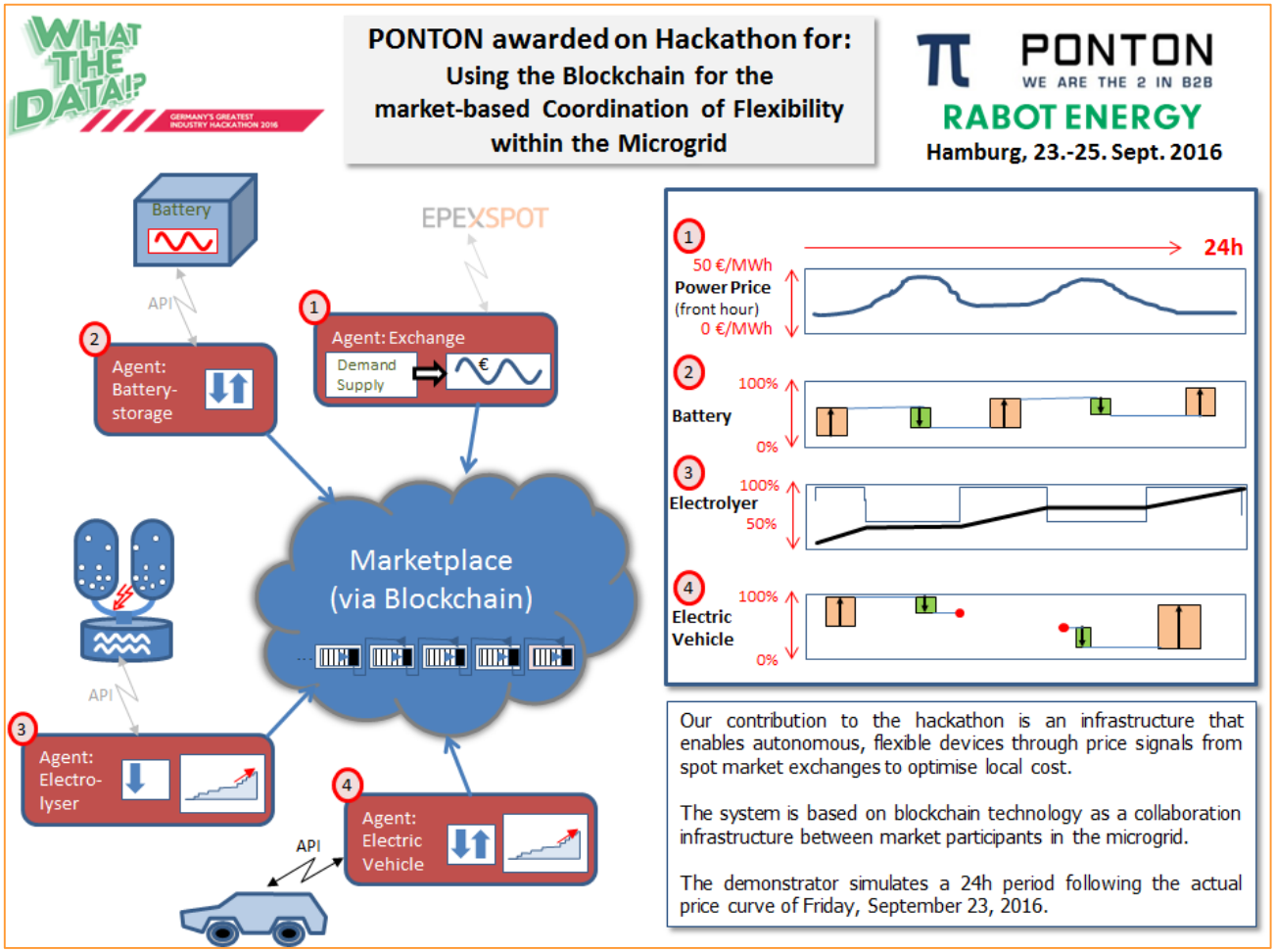
Current energy market

Blockchain enabled decentralized energy market model

- Energy companies or suppliers will not be used in the new energy market.
- Energy consumers and energy producers trade energy directly with each other without a third party.
- Q: what is the role of electricity suppliers in the future?

Blockchain in energy management (III): aggregation microgrid to virtual power plants

- **PONTON developed a simulation of a local energy market via blockchain**

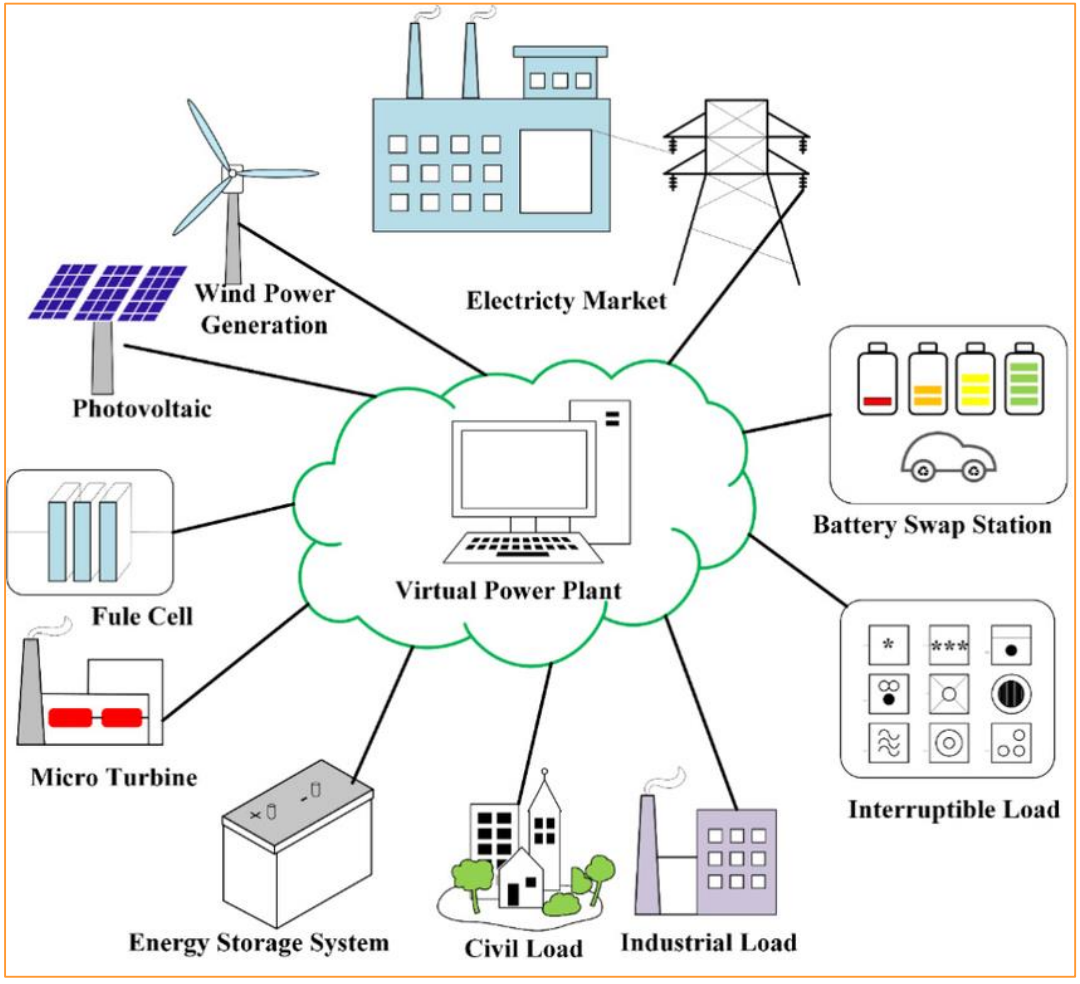


https://enerchain.ponton.de/index.php/articles/2-uncategorised/10-trading-flexibility-in-the-microgrid

Blockchain in energy management (III): aggregation microgrid to virtual power plants

- **Virtual power plants (VPP)**: cluster of electricity generators, loads and storage systems are pooled in an intelligent manner and controlled jointly.

- VPP represents a central platform from which dispersed assets can be monitored and controlled remotely



Blockchain in energy management (III): aggregation microgrid to virtual power plants

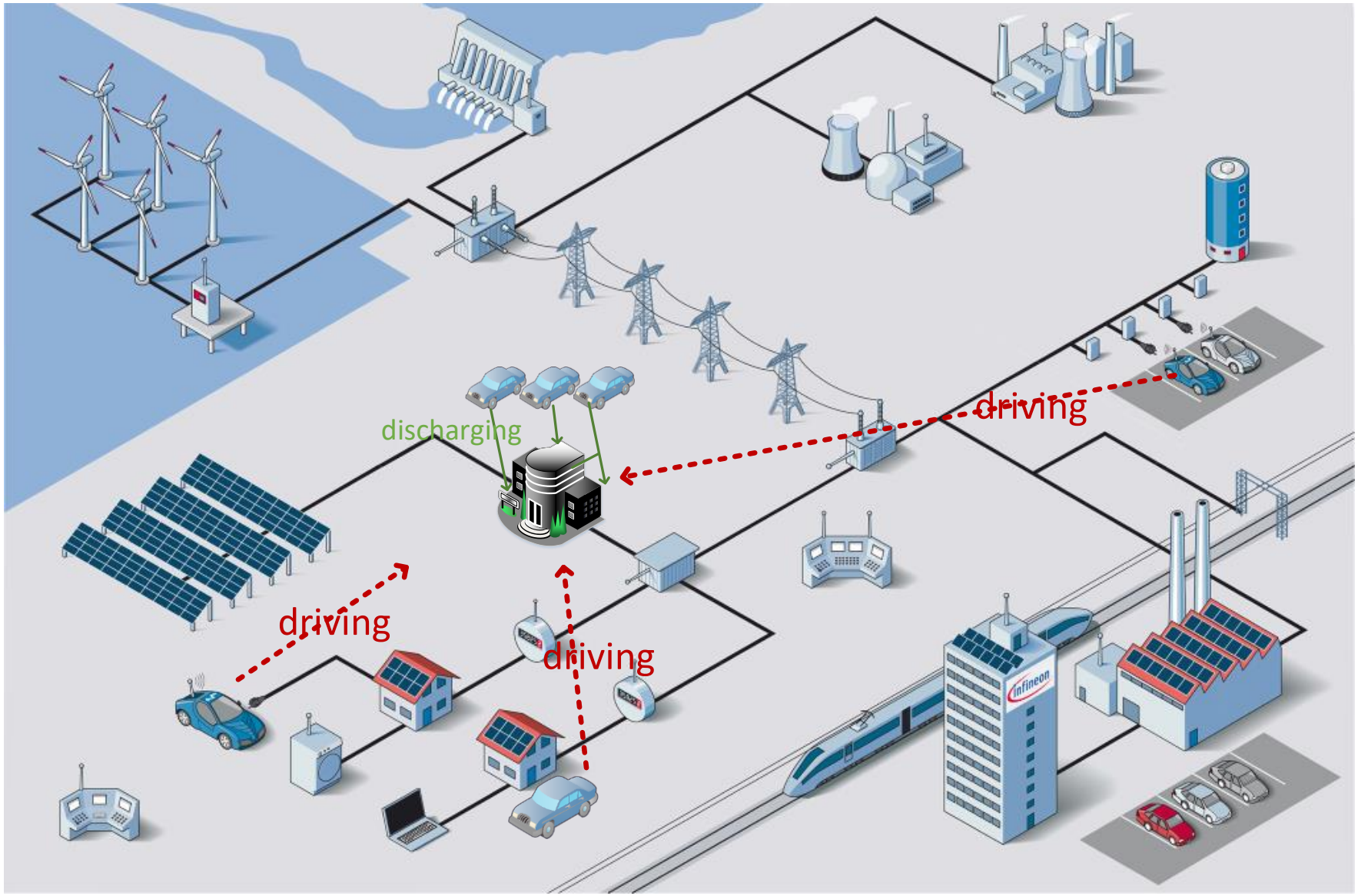
- **Challenge**: VPP operators have to produce accurate forecast to minimize fluctuations; otherwise, imbalance occurs. Forecasting is however complex: types of generation facility, wind and solar power output

- **Blockchain solution**: central actor can deploy blockchain that automatically integrates local information and local grids. The local grids are then integrated into virtual platforms, providing stable power capacity and low cost. Blockchain here is mainly used for network management, important events management, and log information management.

- **Blockchain benefit**: management of VPP becomes efficient with low cost.

MORE CONSIDERATIONS…

EVs as Emergency Power Supply



Similar as Bitcoin, can we create a new cryptocurrency for use within the energy market?

- The SolarChange project was created to financially reward producers of solar energy via a blockchain.
- The project was launched by the company SolarCoin, which has developed its own cryptocurrency – similar to Bitcoin – for the purpose of selling solar energy.
- **Main idea:** for every MegaWatt of solar energy fed into the grid, the producer is awarded one SolarCoin, which they can either store in their SolarCoin wallet or convert to bitcoins.

SolarChange platform for the exchange of SolarCoin. See more: http://solarcoin.org/

References

- **PWC Global power and utilities, “Blockchain- an opportunity for energy producers and consumers?”**