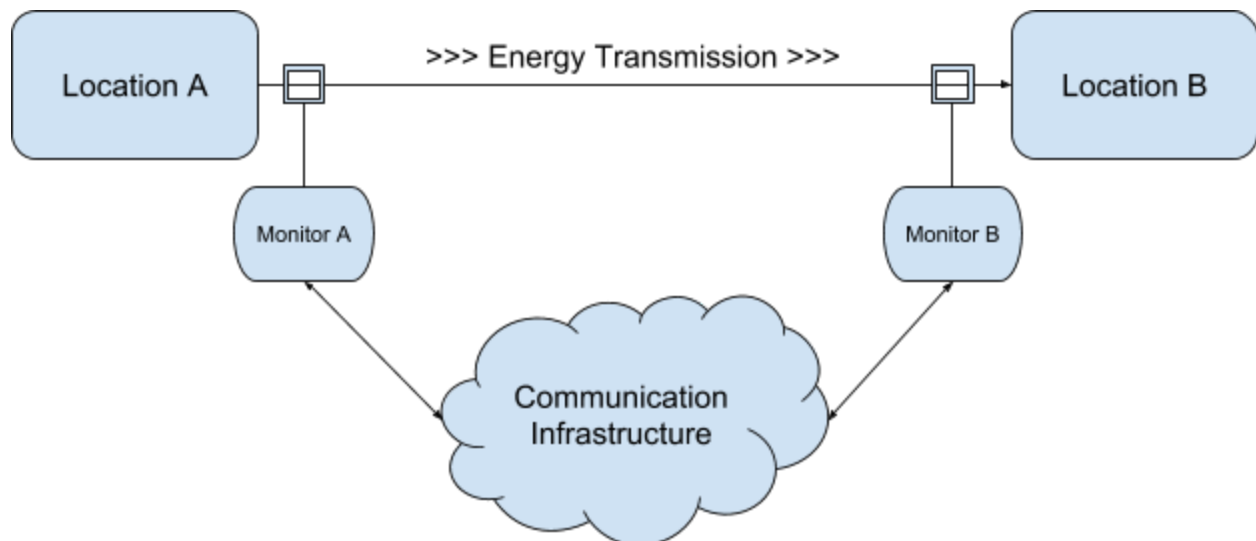


Proof of Delivery

Proof of delivery is a mechanism to validate/verify/prove/asses/confirm/adjudicate whether energy has been transferred/transmitted/moved from one property/building/device/equipment/plant/unit to another.

A mechanism for proof of delivery can be delivered by using two or more monitoring units, these monitoring units could be anything including the Verv home energy assistant, a smart meter or any device that is a part of the electrical system that gives readings of power e.g. an inverter or battery sub-system that can be periodically queried.

Transfer of electrical energy maybe from a controllable source (e.g. battery or any other device with capacitance) or from a source that can not be controlled (e.g. solar generation). Controllable sources may also be from generation assets that can be turned on and off. If it is from a controllable source it does not necessarily have to be the device monitoring the supply or delivery controlling the source it could be controlled from another system connected over the communication infrastructure present (i.e. a centralised control system).



Communication infrastructure can be any one of cloud, internet, mobile (2/3/4/5G), low powered radio network (e.g. LoraWan), WiFi or other radio communication system capable of data transfer. This would be used but not limited to transmitting the information to monitor A and B in regards to the agreed contract, it could also be used to transmit information once proof of delivery has been achieved or during transfer.

Monitors may also be virtual or remote from the locations or devices, if there is an implicit method of periodically querying a sub-system/part of location/device then this may be used as the means to monitor the electricity. For example a seperate monitor would not be explicitly

needed if exporting/transferring energy from a solar generation source if the inverter can be used to monitor.

Where the energy or electricity transmission takes place may be any combination or local or national grid, internal building infrastructure, microgrid or other novel means of allowing for electrical energy to be transmitted (over the air charging for example). Consideration for transmission costs may be taken in to account when agreeing trade. There may also be losses associated with certain types of transmission medium and these too could be taken in to account.

Once a trade is agreed a contract or agreement is created that encapsulates certain pieces of information this information may be composed of any one of the following:

- Trade identifier
- Time of transfer starting
- Time of transfer ending
- Time of discharge starting
- Time of charge ending
- Type of transfer
- Transmission fees or costs
- Quantity or Volume of electricity
- Price in fiat, tokens or other cryptocurrency
- Discharge Rate (if a limit is present from the location supplying)
- Charge Rate (if a limit is present within the location acquiring)
- Monitor specification (Serial Number, MAC address, IP address, unique ID or any other identifying information)
- Source or Origin of Energy (e.g. Green/Brown/Black energy, Solar/Gas/Fossil)

Pseudo code for a proof of delivery could be:

- Trade agreed with time of trade and volume to be delivered (the contract).
- If the energy is from a controllable source, at the time of trade the source is instructed to discharge energy, if the energy is to be received by a controllable source at the time of trade the receiving device is instructed to receive energy.
- Monitoring of supply of energy begins in device A prior to or at time of trade
- Monitoring of receipt of energy begins in device B prior to or at time of trade
- Once monitor A has monitored/logged the quantity agreed and monitor B has monitored/logged the quantity agreed both devices agree that a certain quantity or volume of energy has been delivered thus reaching and providing proof of delivery

Proof delivery could also be reached by a third party using the measurements taken by the monitors present (such as smart meters). As well as third party a centralised control system or

other sub-system within the system as a whole could be where measurements are compared and proof is reached. It could also be reached by consensus, monitor A checking monitors B's measurement and vice versa.

There may also be a kind of trust within the system such that only one monitor is needed. If the receiving party trusts the sending party (or vice versa) then a unilateral proof of delivery could be achieved.

It is possible that the proof of delivery algorithm or system can be executed within a smart contract for example on an Ethereum based blockchain or other blockchain solution that allows for execution of code on-chain. This would simplify the facility to move tokens or other symbolic representation of value from one agent/person/company to another. This does not discount the proof of delivery algorithm executing in any other type of system or programming environment.

What happens if the devices disagree? This could be dealt with by arbitration by a third party, the use of an on/off-chain oracle or a dispute resolution method agreed to by both parties or the system operator as a whole.

Notes

This paper uses the phrase energy and electricity interchangeably.

Author: Thomas Clarke (Lead Engineer at Green Running)

The system could also have the Verv unit itself provide power signature on the line. Therefore if you are monitoring the solar and the mains and/or the battery. You will be able to see the solar acting on the mains power line. Therefore if you send a power cycling on the processor of the Verv unit, you will be able to send a certain signal on the line which will then immediately be picked up by its own current clamp so will be able to confirm that it is on the system and that the solar is linked to the amount that is going out of the mains of the building or home.