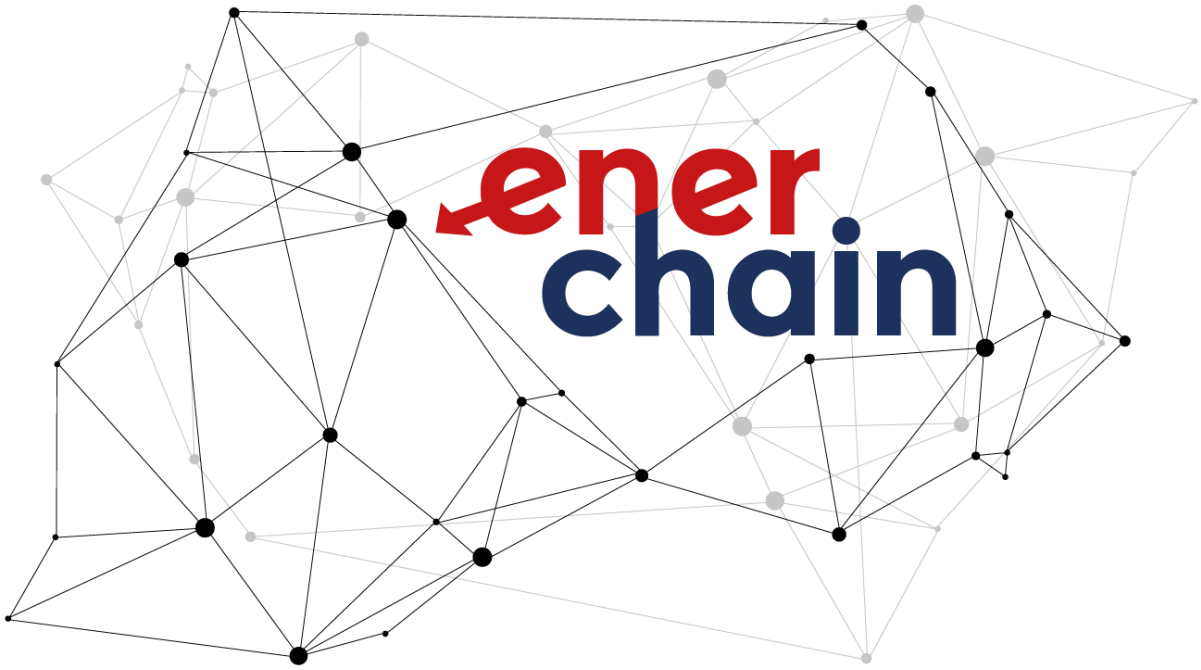
PONTON
WE ARE THE 2 IN B2B



Enerchain Project Overview and Key Insights

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Michael Merz

PONTON GmbH
Dorotheenstraße 64
22301 Hamburg, GERMANY
Email: info@ponton.de
http://www.ponton.de

The following key insights are based on the Enerchain PoC project (abbreviated as "Enerchain") which took place between June 1st, 2017, and March 31st, 2018.

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1. Introduction

1.1. How it all started

Enerchain started as an internal prototype development by PONTON in June 2016. The main trigger was at that point in time the emergence of “P2P trading in the microgrid” as it was promoted, e.g., by the “Brooklyn Microgrid” in April 2016.

As PONTON has a B2B integration focus in the energy sector since its founding over 16 years ago, it was recognised by Michael Merz, Managing Director of PONTON, in early 2016 that technology trends, such as decentralisation and disintermediation, can meet sector requirements of large transaction volumes and providing cost reduction while being compliant with regulations in the energy trading sector. This was documented in a book chapter on the application of blockchain to the energy trading business[1].

PONTON has always considered blockchain as yet another B2B integration technology which co-exists next to classical point-to-point communication, e.g., for supplier switching or meter data exchange. In contrast to point-to-point communication, blockchain-based processes follow a 1:N communication pattern, i.e., one sender publishes data to the entire audience of participants. This obviously was a good match for the execution phase of a transaction in contrast to other less applicable processes, e.g., the bilateral settlement which rather falls under the “point-to-point” pattern.

Based on this assumption, PONTON developed a basic Enerchain prototype between May and August 2016 and presented it for the first time to the public on EMART 2016 in Amsterdam on November 4[2].

Figure 1: The very first live trade over the blockchain on EMART, Amsterdam, Nov. 2016

[1] http://www.ponton.de/downloads/mm/Potential-of-the-Blockchain-Technology-in-Energy-Trading_Merz_2016.en.pdf
[2] http://www.emart-energy.com/blockchain

Interest to improve this prototype within the energy trading sector was high such that a workshop organised in Berlin in February 2017 attracted over 50 people from multiple market participants with various backgrounds (trading, back office, legal, compliance, etc.) who decided to move ahead with a Proof-of Concept (PoC), based on the assumption that a minimum number of 20 participants will participate.

Finally, end of May 2017 this threshold was surpassed and Enerchain started with 23 initial participants. Over time the number of participants further increased and until March 2018 it reached 43.

Figure 2: Enerchain participants (4 logos not displayed)

1.2. Enerchain PoC Project Milestones

The initial project plan of the Enerchain PoC was to achieve the following goals by end of 2017:

- Develop the **Enerchain software infrastructure**, based on a stable, industry-proof blockchain framework that allows a large number of participants to execute trading processes over the blockchain.
- Develop a trading front-end **reference implementation** for standard products that can be used by front offices and that enables market participants to capture deal data from the blockchain.
- Perform a **sequence of functional tests** together with project participants.
- Allow participants to use the infrastructure for **live trading**. I.e., perform trades which are legally binding and therefore require to be nominated and reported.
- Develop an open API to integrate Enerchain with ETRM systems of participants and to be able to connect third party trading front-ends.
- **Extend the system** on demand with additional functionality

The decentralised deployment and the large number of participants led to 6 intensive test phases which were organised for functional tests. Each test required a week for test preparation / ramp-up plus another week for test performance. In addition, a comprehensive performance test under real distributed network conditions took place, which required a substantial knowledge transfer to participants occupying blockchain specialists from PONTON.

Therefore, a 3 months extension of the project until end of March 2018 was proposed by PONTON to cover all test procedures. The following **milestones** were achieved during the PoC:

- **Project start**: June 1, 2017 with 23 participants.
- **Initial development** phase until mid August with first integration test in 3rd week of August. On August 25th, a first test trade was performed by two participants.
- Further **functional and non-functional extensions** until end of January 2018 with another 6 test weeks in the period of February and March 2018.
- **Performance tests** were finally conducted in March 2018 with a focus on end-to-end testing of the overall performance from the Enerchain software.
- By end of March (end of the PoC project phase), PONTON has made available the **Enerchain live environment** to the participants such that is could be used over the following months as an infrastructure for execution of bilateral trades.
- First **live trades** were shown on **EMART 2017 on October 5th**. This was based on a blockchain deployed as an externally hosted P2P layer between the participants.
- Further live trades were shown on **E-World in Essen in early February 2018**, this time based on all software features developed under the PoC, including a simplified (symmetric) credit limit process, and additional high-availability features for higher application layers.
- Since March 2018, individual Enerchain participants may use the blockchain infrastructure for **live trades**.
- **Classification of Enerchain** as a communication infrastructure for trading: An unforeseen extension to the PoC activity was to request consultation support from a

major international auditor in order to classify Enerchain from a regulatory perspective. A detailed report was made available to all project participants by the auditor (see details further down).

- **Hosting the blockchain environment by participants** was the focus of another test session which took place in February and March 2018 in order to test requirements and effort of running the system in a fully decentralised way.
- Moreover, the Enerchain participants have started working on setting up an **Enerchain legal entity**, as an industry-owned governance body, which will represent Enerchain in the future (hereinafter called “Enerchain LE”).
- **Participation** has increased far beyond expectation: as of End of March 2018, 43 participants have joined the Enerchain participants group.
- The Enerchain project is considered as the **most advanced activity** in Europe in the “Blockchain and Energy” space as far as maturity and preparedness for production is concerned. This also applies to the **project efficiency**: compared to other efforts in the blockchain space, the financial contribution of 20.000 Euro made per participants was one of the lowest among current blockchain prototype activities.
- **Level of innovation**: Enerchain was called “the most innovative project currently in the energy sector” by Ernesto Ciorra, global head of innovation at ENEL. Similarly, Enerchain is respected as the most advanced and as a strongly disrupting blockchain-based project in the energy business.

Due to the innovative character of the project not everything was foreseeable, some originally envisioned deliverables were lower ranked in the backlog and therefore delayed, while other tasks, which were not envisioned at the beginning of the PoC, were additionally implemented, as they were adding value to the PoC. The change in scope in order to maximise the output of the PoC was enabled by an agile software development approach.

1.3. Outlook at the end of the Enerchain PoC phase

As of the end of the PoC phase, the following activities took place with regards to future extensions:

- **Further participation:** PONTON expects that the number of Enerchain users will further increase to over 50 by summer 2018.
- Participants are working on forming the **Enerchain legal entity** (Enerchain LE) as an industry owned organisation in which members can participate in different participation roles such as “Founding member”, “Growth member”, “Regular User” and have different rights and obligations – details are being determined by the Enerchain consortium. Members of the legal entity will participate in decision making regarding the future directions of funding, development and operation of Enerchain as well as contractual relationships.
- PONTON will keep the **live and test environments** running for participants under a dedicated Interim Agreement until the Enerchain LE is fully operational.
- **Development:** Available time and budget is used to further extend the system at the functional and horizontal layer to support additional products, refine the processing of credit limit data and develop a list of further software features for later production phases.

2. Lessons learned from Enerchain

Decentralised Trading

The main goal of Enerchain is to **deploy a technical infrastructure** allowing participants in the energy wholesale markets to trade power and gas in a decentralised way, thus avoiding intermediaries and central market platforms.

Several public and non-public **live trades** have shown, that this is going to become reality. The Enerchain trading model is based on the OTC initiator / aggressor model, which uses a decentralised decision making (by the aggressor) whether a trade is executed or not.

These live trades were executed in public “on stage” during the project phase:

1. Iberdrola and Total at ETCSEE in Prague on June 2017
2. EON & ENEL at EMART 2017 in Amsterdam on October 4.
3. Wien Energie & NEAS at EMART 2017 in Amsterdam on October 4.
4. ENDESA & Gasnatural Fenosa at E-World 2018 in Essen on February 6.
5. Energie AG Oberösterreich & Stadtwerke Leipzig at E-World 2018 in Essen, same day.
6. Verbund & Salzburg AG at E-World 2018 in Essen on February 7.

Statkraft and ES FOR IN performed a live trade in January 2018 that was published on February 1, 2018[3].

Additionally, further live trades were bilaterally performed by individual participants end of March. It is expected that during the Interim Phase, trades will continue and increase.

Technically, the trading process was supported by a **reference implementation** of the user interface (GUI), which allows MPs to enter and execute orders for standard base load products. This reference implementation may be individually replaced by third-party vendor tools as soon as those vendors decide to support Enerchain:

- VisoTech[4] has extended their algo-trading platform “autoTRADER” for trading over Enerchain.
- A start-up for the optimisation of gas deliveries is going to use Enerchain as a data exchange infrastructure.
- NDAs exist with further ETRM system vendors and suppliers of trading front-end tools.

These first co-operations show how Enerchain is developing into an ecosystem shared by trading organisations and vendors of add-on technology.

[3] http://www.energate-messenger.de/news/180612/blockchain-ersetzt-kurzfristhandel
[4] https://www.visotech.com

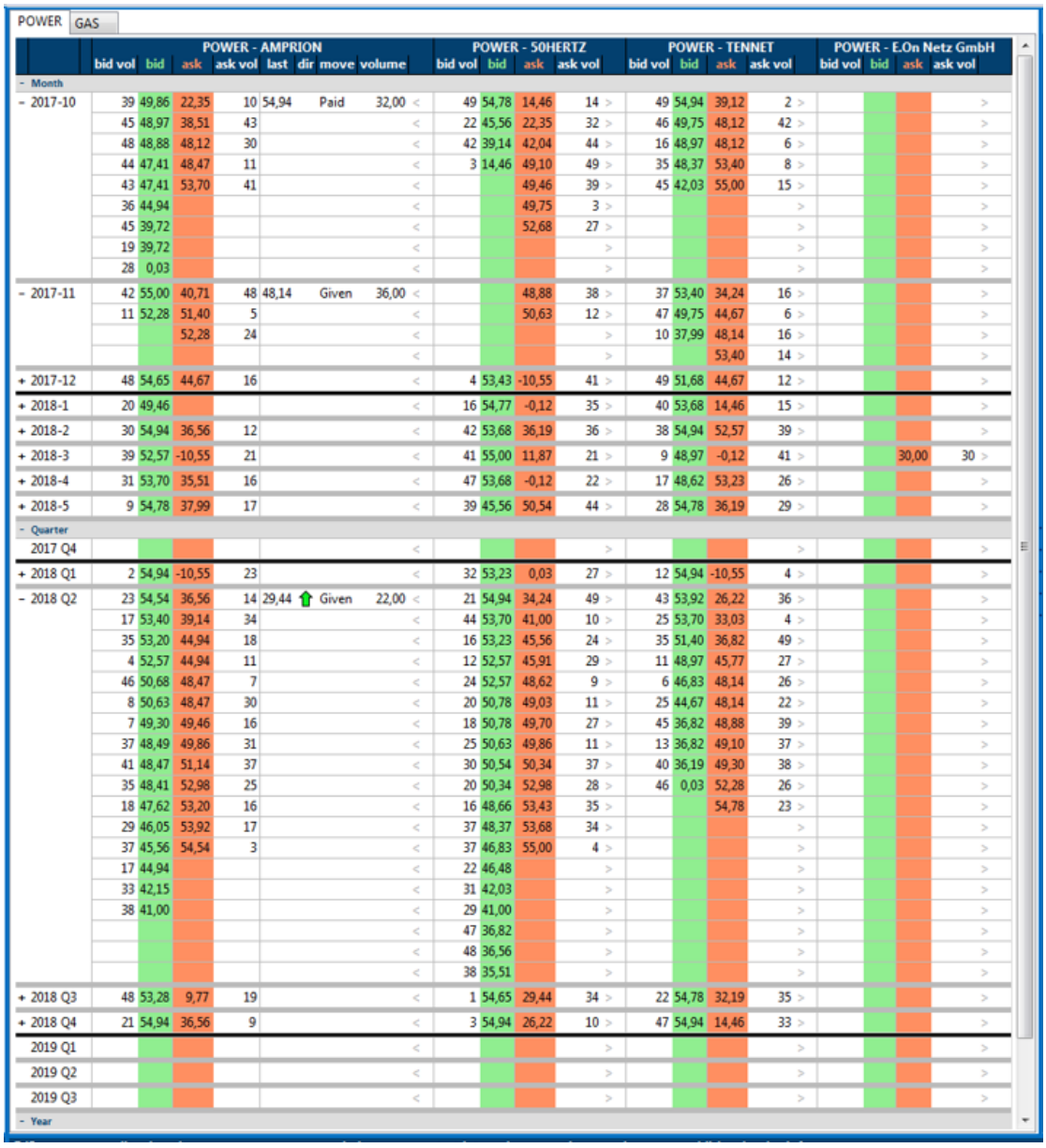

Figure 3: Enerchain Trading Screen developed by pdv-FS[5]

Traded Products

The following **standard products** are currently supported:

- Intraday quarter hours and hours; day-ahead; weekly, monthly, quarterly and yearly baseload deliveries,
- commodities are gas and power,
- with physical delivery (financial products are excluded),
- in all European delivery zones for power (market areas / balancing zones) or hubs for gas.

[5] pdv Financial Software is a sister company of PONTON with a focus on the development of trading and execution systems for financial markets such as equity, FX, and interest rates, see http://www.pdv-fs.de.

These standard products can be traded directly using the reference application (Enerchain Trading Screen) or API.

Apart from these standard products, the following **non-standard products** could be implemented with little extension effort:

- Load curves (e.g. day-ahead, monthly, yearly),
- Plain Vanilla options,
- Gas Prompt products,
- Non-standard delivery periods (e.g., 5 minutes, 30 minutes, any combination of delivery periods).
- Products with non-standard delivery periods can even be traded today, as there is no agreement on product codes required. Traders may use algos on top of the Enerchain API in order to create orders and executions for these products.

It is expected that the first three product types from the list above can be made available during the interim phase unless there are functions with higher priority selected from participants.

Regulation

From a regulatory perspective, PONTON engaged an international auditor in order to get external advice about their view how Enerchain would be classified. Their assessment was that under certain circumstances, decentralised trading over the blockchain does not fall under the MiFID regulation and that, consequentially, Enerchain does not have to be classified as MTF or OTF.

Instead, Enerchain is considered as a communication infrastructure (non-OTF) used to exchange messages “peer to peer”. Legally speaking, Enerchain is an infrastructure of its own kind (“suis generis”). The main precondition for this classification, is the ability of the market participants to discretionally decide on entering into a transaction or not. There is also no third party, which arranges such a trade at its own discretion.

Governance

The Enerchain PoC led to the general understanding that – although the execution of trades takes place fully decentralised – a legal entity is required, which represents decision making and strategy finding. Moreover, a legal body for the cooperation among Enerchain users is required and can be achieved easiest, if this Enerchain LE is set up with a clear set of rules that determine the rights and obligations of Enerchain users.

Enerchain participants have decided use a Dutch foundation (Stichting) as corporate structure for Enerchain. Enerchain participants have also established different working groups to agree on statutes and the contractual basis for co-operating with members and business partners. It is expected that it takes beyond the runtime of the Enerchain PoC phase to finalise the legal foundation of the Enerchain LE. As a result of the Enerchain governance group, the following membership types have been identified:

- **Founding members** (participant in the Enerchain PoC phase) who are LE members with voting rights and a discounted initial investment in the LE.

- **Growth members** (participants who have joined Enerchain after the PoC phase has ended) who are LE members with voting rights and with a non-discounted investment in the LE.
- **Regular Users** without voting rights and who do not carry the cost of an initial investment.

Expected operational cost and effort

During the PoC, PONTON operated three different blockchain environments (functional test environment, performance test environment and PoC-live environment) and took over hosting fees and all other OPEX. Live trades could be executed without any additional cost apart from a flat contribution made by each participant.

Operating cost for a decentralised system is different from operating a “classical” central platform, i.e., dramatically reduced: Roles such as management, market control, market supervision, legal, regulation, compliance, support, IT, marketing and sales, etc. do not apply any more or significantly reduced in a decentralised form. Following the Market Abuse Regulation, MPs are themselves responsible to perform supervision and surveillance of their front-office activities. Additionally, Enerchain-based trades have to be reported by each Enerchain participant to ACER under the REMIT regulation.

A part of the external cost of trading still applies in case of Enerchain (e.g for hosting the blockchain and providing infrastructure support), yet at a very different price level compared to traditional marketplaces: Pricing will be based on flat annual fees. MWh-based fees or per-transaction fees shall not apply. I.e., it depends on the number of markets on which a participant trades, the product volumes, and, finally, the number transactions, which cost reduction can be individually achieved. The final fee model is developed by the Enerchain participants themselves during the Interim Phase.

Operation of the blockchain infrastructure costs at a low level ca. 50 Euro hosting fee per node and per month during the PoC. In case of 10 nodes this would add-up to 6.000 Euro per year. Support and maintenance of the different Enerchain architecture components leads to additional costs as staff is involved here:

  - **2nd level support** to participating organisations,
  - **Maintenance** of the blockchain infrastructure (reactive maintenance and evolutionary maintenance),
  - **Continuous extension** of the system functionality.

The PONTON blockchain team ensures that:

- A test and live environment is available to project participants,
- The system is documented at the latest version level,
- tools are provided for testing, deployment and monitoring,
- All components are diligently tested before a new Enerchain release is made available.

Once Enerchain has been transferred to the Enerchain LE, owned by the participants, PONTON will still be available to support Enerchain in the design of future system extensions and to help out organising the continuation of the project.

3. Software Architecture

Applicability of blockchain technology to energy trading

Only with the short block time of the Tendermint blockchain technology the execution of trades can be performed in near-real time. It is important to understand that a further approximation of real-time would drastically increase the blockchain's consensus overhead. This leads to the assessment that a high-frequency trading scenario known from asset classes such as forex, interest rates, or equity cannot be supported well by the blockchain.

However, less frequent trading processes apply to energy trading as a whole: Most energy-related markets are less liquid than financial markets and therefore qualify well for blockchain-based trade execution. E.g., annual baseload contracts 3 years ahead with only a few transactions per day are of very low-liquidity. On the other hand, even the most liquid energy market segments (quarter hours for German balancing zones) see at most a few transactions per second. In more relaxed phases, there are consequentially only few trades per minute.

Less liquid platforms reach a throughput of only 100 – 1000 trades per day (regional exchanges, smaller brokers or platforms for specialised products). Here, the average transaction rate is less than 1 trade per minute. And even in high load situations, it is rarely higher than 1 trade per second.

Blockchain technology

There has been an ongoing discussion on the "right" blockchain technology for executing energy trades. PONTON has chosen Tendermint[6] as the current underlying blockchain (specifically "consensus") technology. Tendermint allows for an extremely short block time of down to one second which, in turn, allows for an unprecedented reduction of transaction latency.

While Ethereum transactions, e.g., take as long as the Ethereum block time lasts (15-20 seconds on average), other fast blockchain solutions achieve only 3-5 seconds per block (e.g. Steem). Tendermint can actually be operated with one second per block plus consensus overhead. This has been proven during performance tests under the Enerchain PoC.

As the Tendermint blockchain technology just focuses on core functions as the PBFT (Practical Byzantine Fault Tolerance) consensus mechanism and on storing blocks in the chain, any further functionality needs to be bridged in order to provide a consortium blockchain infrastructure as it is required for Enerchain. Such additional functions have been developed by PONTON. The core functions are as follows:

- Horizontal functions
    - Management of pubic key certificates to authenticate process participants,

[6] https://www.tendermint.com/

  - Connection management and re-start function in case of node crashes or disconnections,
  - Data caching of blockchain content,
  - Re-connecting between local participant logic (Client Adapter) and node-related logic (Node Adapter),
  - Key and access management for end users,
  - Message routing between Client Applications through the hierarchy of Client Adapters, Node Adapters, and blockchain nodes.
- Vertical functions
  - Routing of orders and executions
  - Message content processing, e.g., encryption for anonymity reasons.
  - Transaction validation functions inside Client Adapters and Node Adapters.
  - Provision of trade files to ETRM systems through the Client Adapter API.
  - Management of the credit limit process.

The chosen approach of Enerchain allows to intercept and transform application-level messages at various processing steps: Application code may be added

- within Client Applications,
- within Client Adapters (by deploying Enerchain-specific plug-ins) and
- within Node Adapters (by deploying Enerchain-specific plug-ins).

This is visualised by the red components which each represent vertical processes such as energy trading or settlement, which could be added at a later stage.

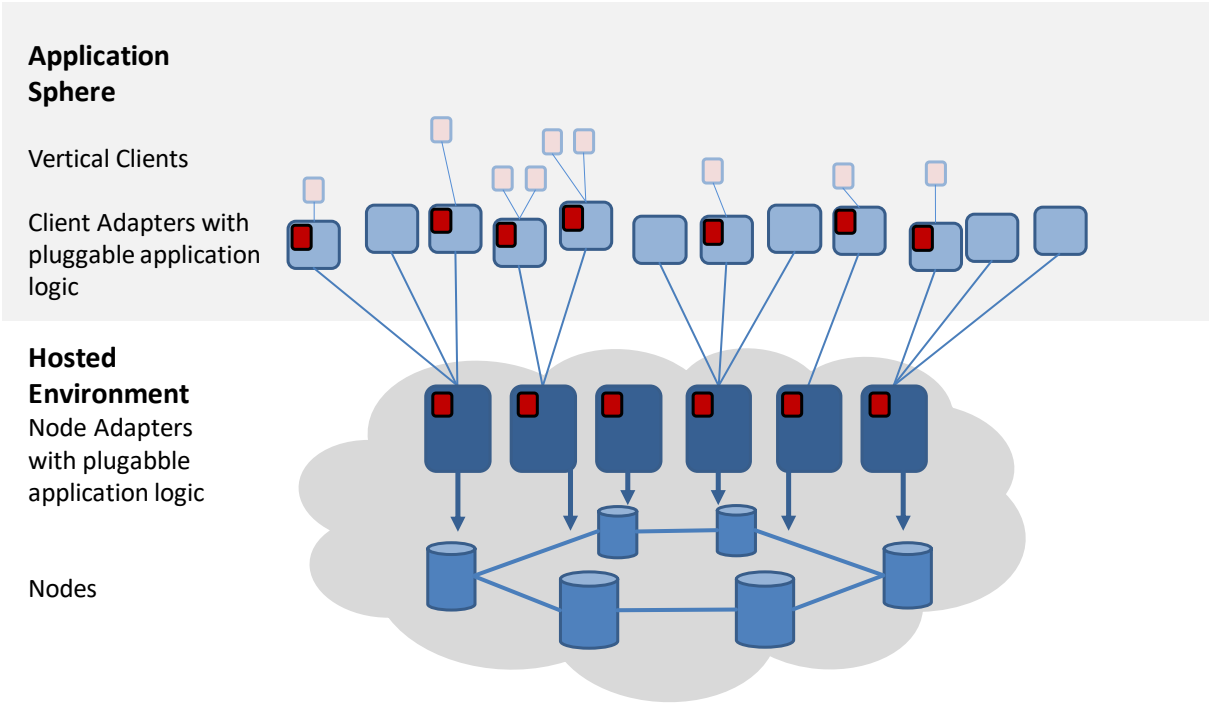

Figure 4: Enerchain system architecture

This way, application-level programmers have the highest-possible flexibility to design their individual processing logic for distributed processes:

- While, e.g., Ethereum smart contracts only allow to centrally process unencrypted data on the blockchain and therefore store it only in unencrypted form, Enerchain allows to route encrypted data end-to-end, if required. This way, Node Adapters and Nodes may even be publicly hosted without hosting parties or operators being able to access that data.
- While, on the other side, Hyperledger allows to store “assets” on the blockchain and transfer them between owners, Enerchain allows to store any data which is exchanged between participants. This might be “assets” such as token values and transfers between accounts, or just messages between participants, which do not have asset-like characteristics.

The development of Enerchain has helped proving the basic architectural approach of distinguishing a horizontal and a vertical layer where

- The horizontal layer (aka “WRMHL Framework”[7], coloured in blue in the figure above) provide a generic data communication platform, and
- The vertical layer (coloured in red in the figure above) which can be implemented at the three different locations of Client Application, Client Adapter Plug-in, and Node Adapter Plug-in.

[7] Speak: “wormhole”

4. Blockchain Operation

Experience gained for the Deployment of a Consortium Blockchain

It is one level of experience writing a smart contract to book a KWh from one account to another as, e.g., presented with the “Brooklyn microgrid”, but it is another level to organise the operation of a blockchain for a consortium with over 40 energy trading organisations, all using the blockchain at the same time. The Enerchain project achieved to

- set-up several test and live chains across different hosting environments (e.g., at M Azure®, Amazon AWS®, PONTON, and locally by individual Enerchain participants).
- connect the Enerchain PoC participants with their Client Adapters to the blockchain.
- create key pairs and distribute certificates for all participants to support authentication, authorisation, encryption and anonymisation.
- coordinate testing between these participants such that they perform test trades in a purposeful way.

This was done several times and with each test step, PONTON has improved the software deployment such that the Enerchain environment could be set-up within shortest time for 40 participants by just parameterising a central deployment script. Whatever the next WRMHL infrastructure is needed for, deployment will be simplified a lot compared with the first attempts back in summer 2017.

Experience gained from performance tests

PONTON organised several performance tests with the Enerchain consortium in March 2018. These tests did not focus on ideal lab conditions to maximise transaction throughput[8]. But such figures (which are often circulated by technology vendors) are usually misleading. It is meaningless to show-off with simple transactions which could be performed 10.000 times per second and it has no meaning if blockchain transactions are processed with zero overhead (on the same processor, without validation effort, with minimal transaction size, without any per transaction application-level processing, with zero consensus latency, etc.).

Performance tests under Enerchain

- tested the **application-level end-to-end behaviour**, i.e., from Client Application to Client Application, including several cryptographic layers.
- tested **entire processes**, i.e., orders and related executions, where the latter referred to existing orders.
- included **actual Enerchain participants** who were invited to host an own node and use an own trading robot designed by PONTON to create test transactions to achieve a set-up that is as realistic as possible.

[8] This was already done by PONTON in early 2017 based on a Tendermint environment where a throughput of > 10.000 Tx/s could be reached.

- Used a selection of **realistic hosting environments,** which was used based on cloud geographically distributed services operated by various hosting environment and which added another level of diversity and realistic latency.

Based on these parameters, tests were performed in order to test the maximum possible performance in terms of time required for order roundtrips, and to monitor latency and general system behaviour.

Under worst conditions (see above), more than 35 transactions per second were reached in a globally distributed Enerchain test. We expect that processes with less encryption overhead at the application level reach 100-300 transactions per second.

The main insight confirmed by performance testing is that latency, bandwidth, and node performance are key for the overall system behaviour, not core blockchain performance. Any operator – be it an outsourced node or a node operated by a participant, needs to implement the node service according to quite strict SLA requirements in order to approach an optimum level of throughput and transaction processing speed.

It is good news that the Enerchain principle “as decentralised as possible – as centralised as necessary” also applies here: a sustainable average throughput of 35 Tx/s exceeds the throughput required for energy trading by far. I.e., decentralised hosting of nodes works well such that a further optimisation which would lead to a centralised hosting can be avoided.

5. Press coverage (extract)

- Live trade between ENEL and EON (October 9, 2017):
  - https://www.bloomberg.com/news/articles/2017-05-29/europe-s-biggest-utilities-join-blockchain-energy-trading-trial
  - https://www.cleanenergynews.co.uk/news/efficiency/e.on-and-enel-combine-for-landmark-blockchain-first
  - https://globalprocurement.enel.com/pr/Historias/news/d201712-enel-and-eon-trade-the-first-mwh-of-digital-energy-using-blockchain.html
  - https://www.coindesk.com/european-energy-firms-trial-blockchain-trading-marketplace/
- Live trade between GasNatural fenosa and Endesa:
  - https://cryptovest.com/news/spanish-energy-companies-conduct-first-real-energy-trade-on-blockchain/
- Live trade between Statkraft and ES FOR IN (February 1, 2018):
  - http://www.energate-messenger.de/news/180612/blockchain-ersetzt-kurzfristhandel
  - https://www.windpowermonthly.com/article/1456138/statkraft-esforin-team-up-blockchain-trading
- General articles on Enerchain in various languages:
  - English:
    - https://spectrum.ieee.org/energywise/energy/the-smarter-grid/enerchain-a-decentralized-market-on-the-blockchain-for-energy-wholesalers
    - https://www.trustnodes.com/2017/06/14/e-edf-rwe-swedens-state-owned-vattenfall-others-trial-blockchain-energy-trading
    - http://www.emart-energy.com/enerchain-press-release
    - https://cointelegraph.com/press-releases/european-energy-trading-firms-test-peer-to-peer-trading-over-the-blockchain
    - http://www.klgates.com/blockchain-energizer--volume-22-02-16-2018/
  - German:
    - https://www.energie-und-management.de/nachrichten/alle/detail/enerchain-energiegrosshandel-auf-der-blockchain-121167
    -
  - Italian:
    - http://rienergia.staffettaonline.com/articolo/33015/Enerchain:+il+trading+elettrico+punta+tutto+sulla+blockchain/Kempcke
    - https://www.corrierecomunicazioni.it/digital-economy/enerchain-nasce-il-mercato-europeo-per-il-trading-dell-energia/
    - http://www.ansa.it/canale_ambiente/notizie/focus_energia/2018/02/07/blockchain-prima-transazione-enerchain-tra-endesa-e-gas-natural_2a73037e-22f8-47d7-abdc-132a4e4b3543.html
  - Spanish:
    - http://www.eleconomista.es/energia/noticias/8391047/05/17/Enerchain-la-plataforma-de-trading-energetico-basada-en-blockchain-arrancara-este-ano.html

6. Presentations on Enerchain (2018 only)

- Presentation of the Enerchain Project at Platts Inaugurial Digital Commodities Summit, Singapore, July 12, 2018
- Presentation on Blockchain & Energy at Distribute Conference, Hamburg, 28. June, 2018
- Presentation on Unchain Bitcoin & Blockchain Convention, Hamburg, 31. May - 1. June
- Panelist at GEODE Spring Seminar 2018, Brussels, 29. May 2018
- Presentation on CXO Event, organised by Wirtschftsrat, Westerland, 11. May 2018
- Presentation on P2P trading of energy on "Blockchain Masters" Conference, Hamburg, May 3, 2018
- Presentation on Berenberg blockchain conference, London, April 19th, 2018
- Presentation of Enerchain on EventHorizon Conference, Berlin, April 17, 2018
- Presentation on Enerchain at Platts Inaugural North American Digital Commodities Summit, New York, 26 March 2018, https://www.platts.com/events/americas/north-american-digital-commodities/agenda
- Presentation on Berenberg / Taylor Wessing / Deloitte event on blokchain technology, Hamburg, March 1st
- Presentation on Enerchain at Future Camp Blockchain, Essen, 22 February 2018
- Presentations on E-World Fair (Smart Tech Forum and Trading & Fincance Forum), Essen, 6.-8. February 2018
- Presentation of several Enerchain live trades at E-World fair, Essen, February 6-8, Germany
- Presentation on NEW 4.0 at Hamburg Chamber of Commerce, Hamburg, 25. January