Decentralized Operation and Security in the IoT Space

The IoT space and where SOFIE fits in

What kind of results are produced

A broader sense overview

George C. Polyzos

Mobile Multimedia Laboratory

Department of Informatics
School of Information Sciences and Technology
Athens University of Economics and Business
Athens, Greece

polyzos@aueb.gr, https://mm.aueb.gr/
Tel.: +30 210 8203 650

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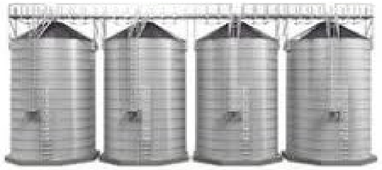
Motivation & Vision

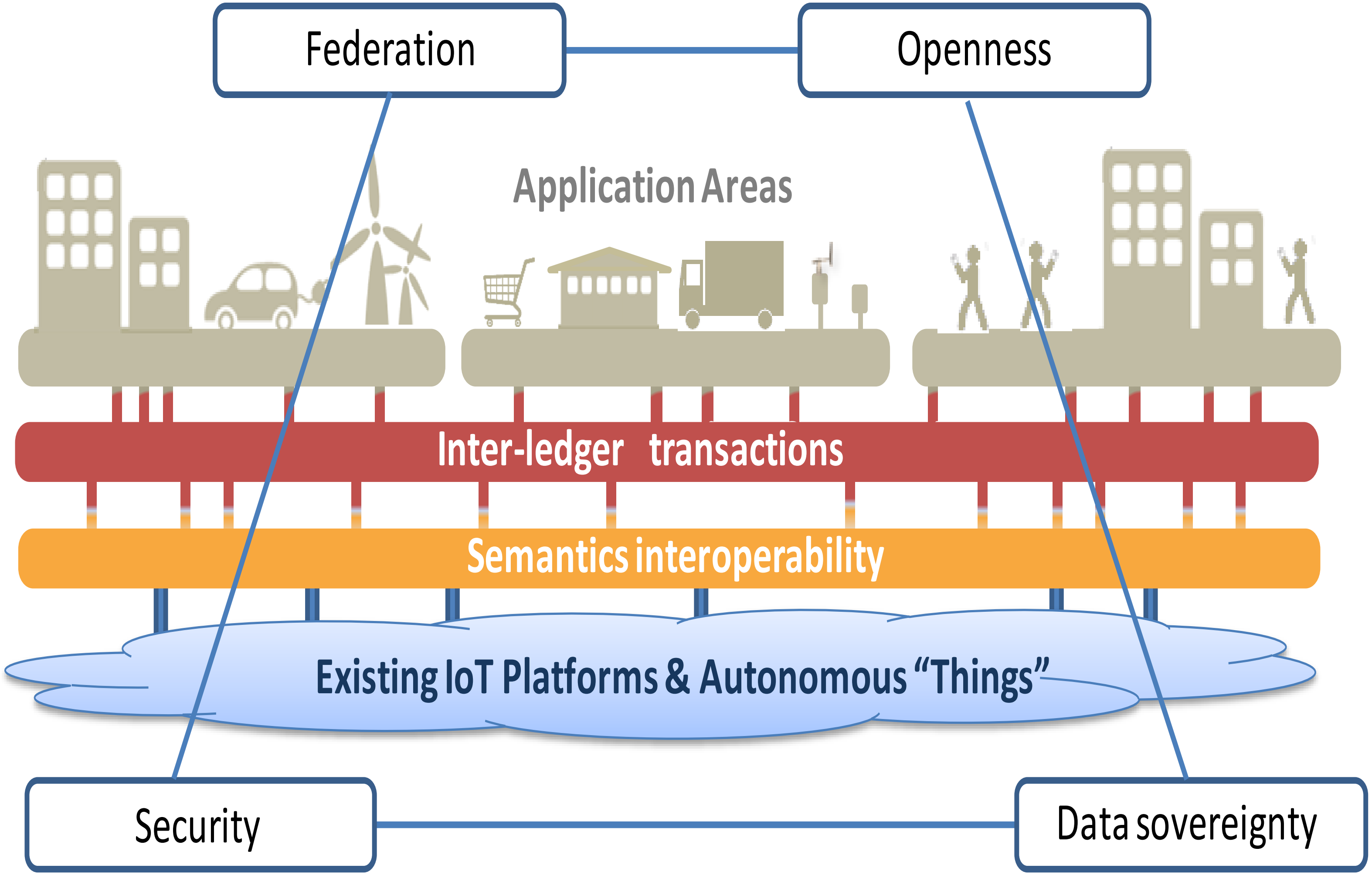
- The Internet-of-Things (IoT): vision
  - unattended operation
- Key IoT issues
  - IoT Fragmentation
  - security & privacy
- Most of IoT: Vertically oriented, *closed* systems



  - Silos!
  - mostly for non-purely-technical reasons
- Interoperability and interconnection
  - well over 300 different IoT platforms
  - several dozens … standards
  - …
  - **business** counter-incentives
  - **privacy** concerns and constraints

- Vision: **4th Generation *Open* Business Platforms**
  - across IoT systems and business platforms
    - exchange data in an automatic and controlled way
    - ... & perform actions
  - Smart Contracts on open public blockchains can contribute towards this goal
  - Distributed Ledger Technologies (DLTs)
    - … blockchains
    - decentralized trust, automation (Smart Contracts)
    - various types, various characteristics & properties
      - permissionless/open, permissioned…
    - combine different DLTs for various trade-offs
  - **Interledger**!

SOFIE: Overall Concept and Key Ideas



Federation
Openness
Application Areas
Inter-ledger transactions
Semantics interoperability
Existing IoT Platforms & Autonomous "Things"
Security
Data sovereignty

- Openness
  - inclussiviness
  - system expansion
- Federation
  - loose interconnection
  - diverse systems interoperability
- Security
  - increases trust
  - proper operation
- Data Sovereignty
  - key principle
  - incentive for cooperation/interoperation

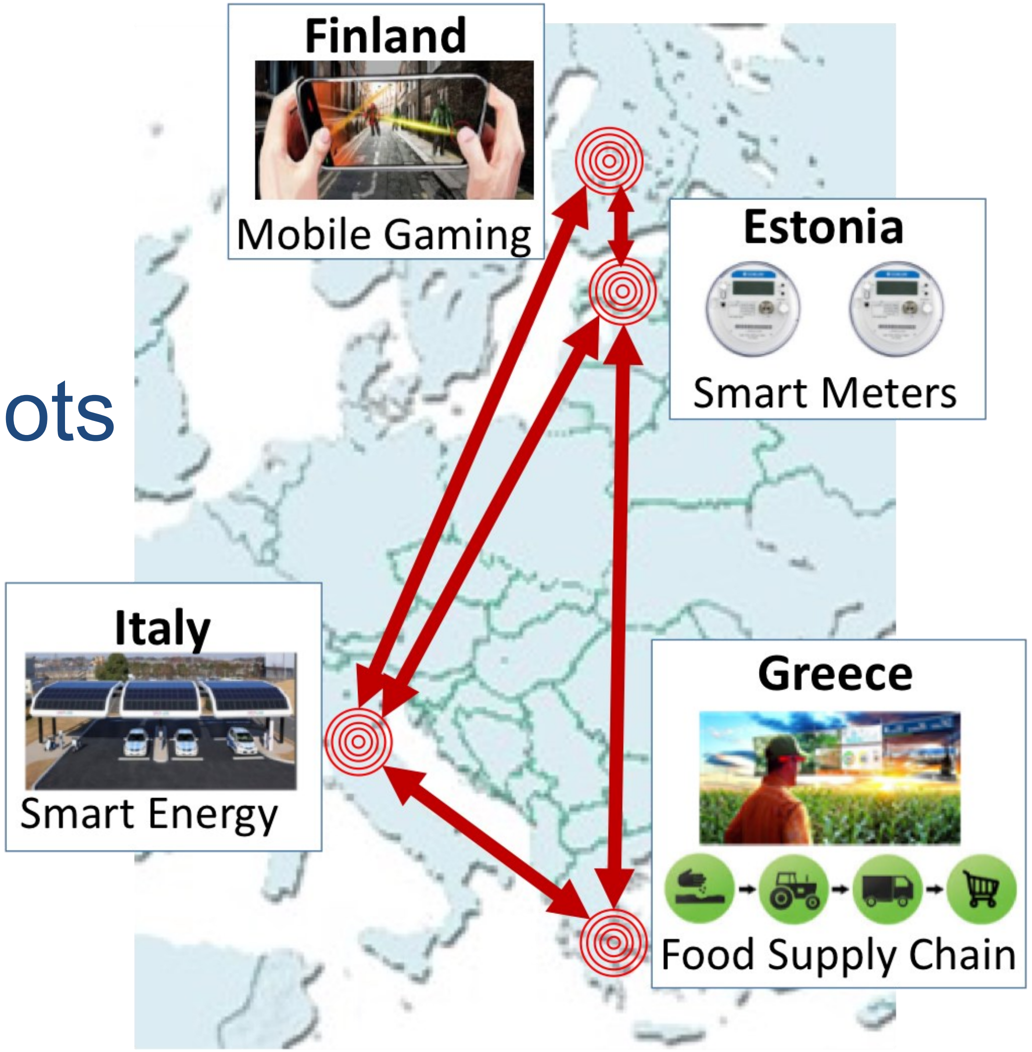
H2020 **SOFIE**:
Secure Open Federation for Internet Everywhere

- Distributed Ledger Technology to
  - **securely** and ***openly***

  federate IoT platforms

- ***interconnected*** distributed ledgers
  - to interconnect diverse IoT systems
  - decentralized business platforms
    - open business rules on how to join platforms
  - accessible metadata
    - & semantic interoperability
  - securely record **audit trails**
    - to resolve disputes

4 Pilots



- Project
  - 1/1/2018 – 31/12/2020
  - €4.5M

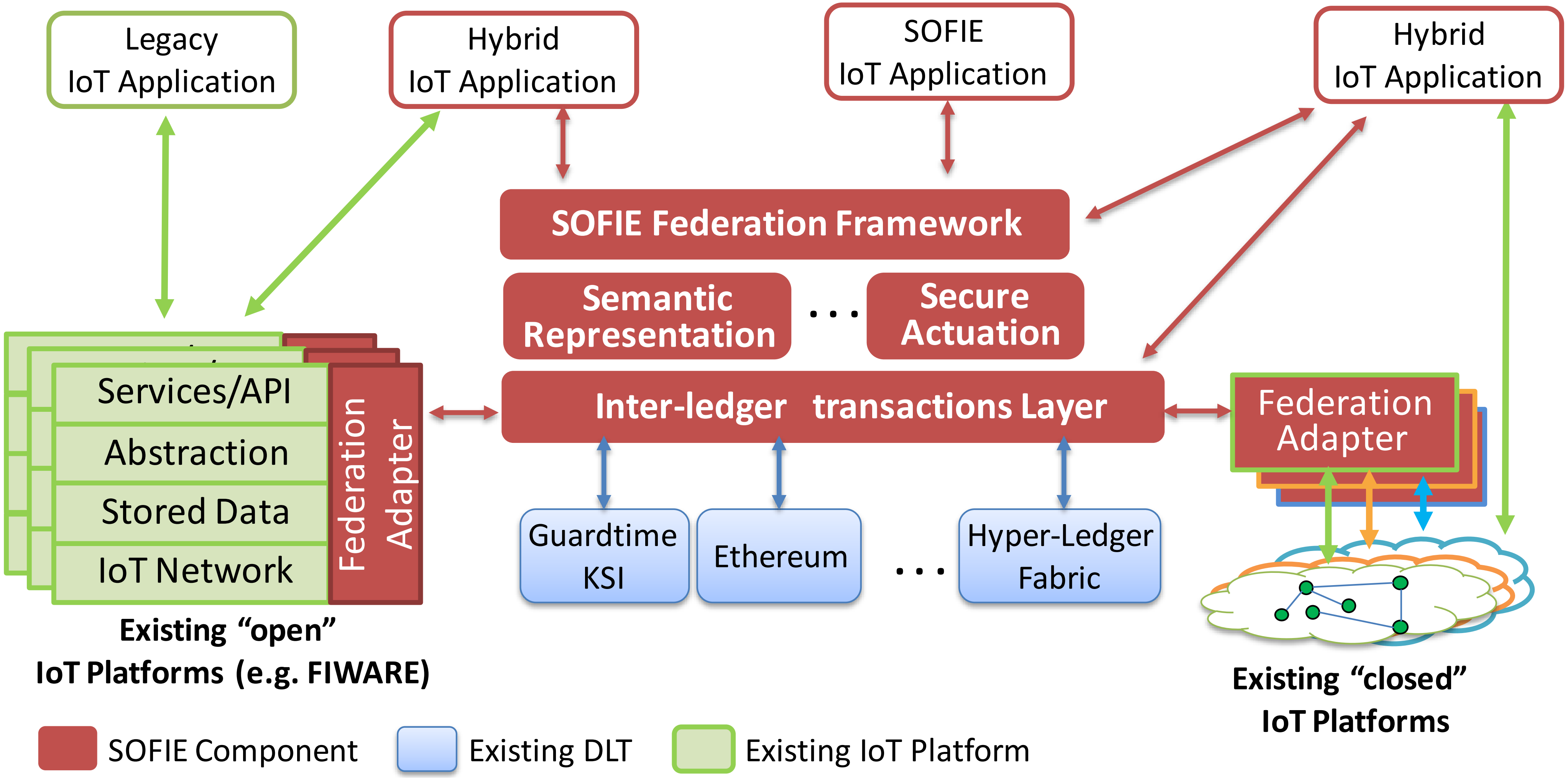
- Partners
  - Aalto University, Ericsson, Rovio (Finland)
  - Guardtime (Estonia)
  - AUEB, Synelixis, Optimum (Greece)
  - Eng, Asm Terni Spa, Emotion Srl (Italy)

http://www.sofie-iot.eu/

DLTs: Properties, Guarantees, and Trade-offs

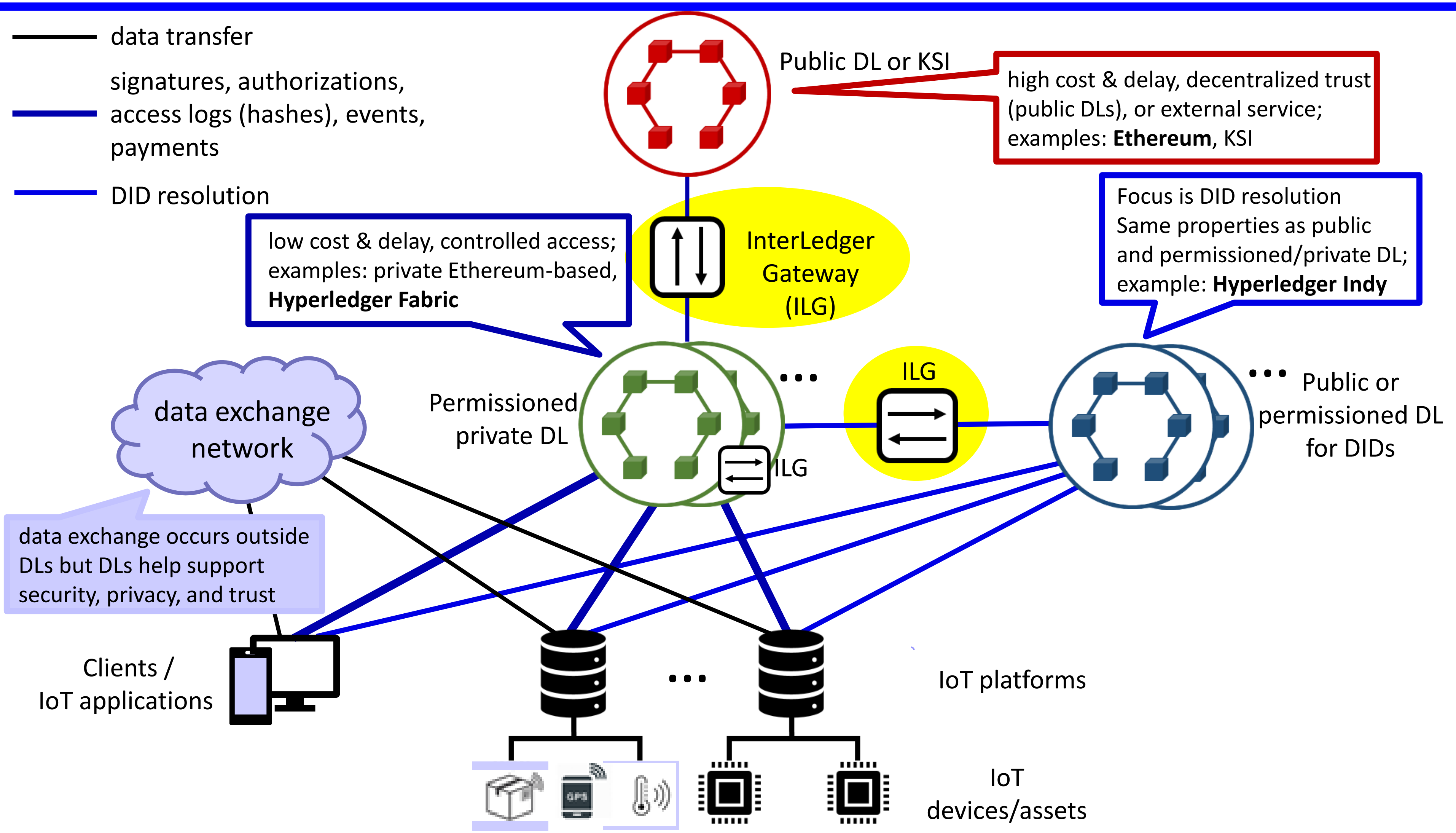
- DLTs (Distributed Ledger Technologies) / blockchains
  - **Decentralized trust**: no dependence on a single trusted (“third”) party
  - **Immutability**: signatures & majority of nodes need to agree on state changes
  - **Availability**: decentralized storage and execution – robust against multiple node failures
  - **Transparency**: not only a feature, but a requirement for decentralized trust
    - could conflict with **privacy** requirements & **business** logic ➔ permissioned DLTs
  - Off-chain transactions … starting and ending on the blockchain…
    - Scope of trust between two parties (e.g., funds set aside…) ➔ fast direct transactions with limited overhead (& signed receipts)
- Interledger: interconnection of multiple DLTs
  - Tradeoffs: permissionless/public/open ledgers vs. permissioned/private ledgers
    - wide-scale decentralized trust vs. consortium trust
    - full transparency vs. privacy
    - monetary cost, overhead, performance/latency, scalability trade-offs
- Decentralized Identifiers (DIDs) and Verifiable Credentials (VCs)
  - Improved privacy, availability

SOFIE’s Federation Architecture



Three ***types of ledgers*** with ***different functionality*** and ***features*** interconnected using interledger mechanisms

Interledger



data transfer

signatures, authorizations, access logs (hashes), events, payments

DID resolution

high cost & delay, decentralized trust (public DLs), or external service; examples: **Ethereum**, KSI

low cost & delay, controlled access; examples: private Ethereum-based, **Hyperledger Fabric**

Focus is DID resolution
Same properties as public and permissioned/private DL;
example: **Hyperledger Indy**

data exchange occurs outside DLs but DLs help support security, privacy, and trust

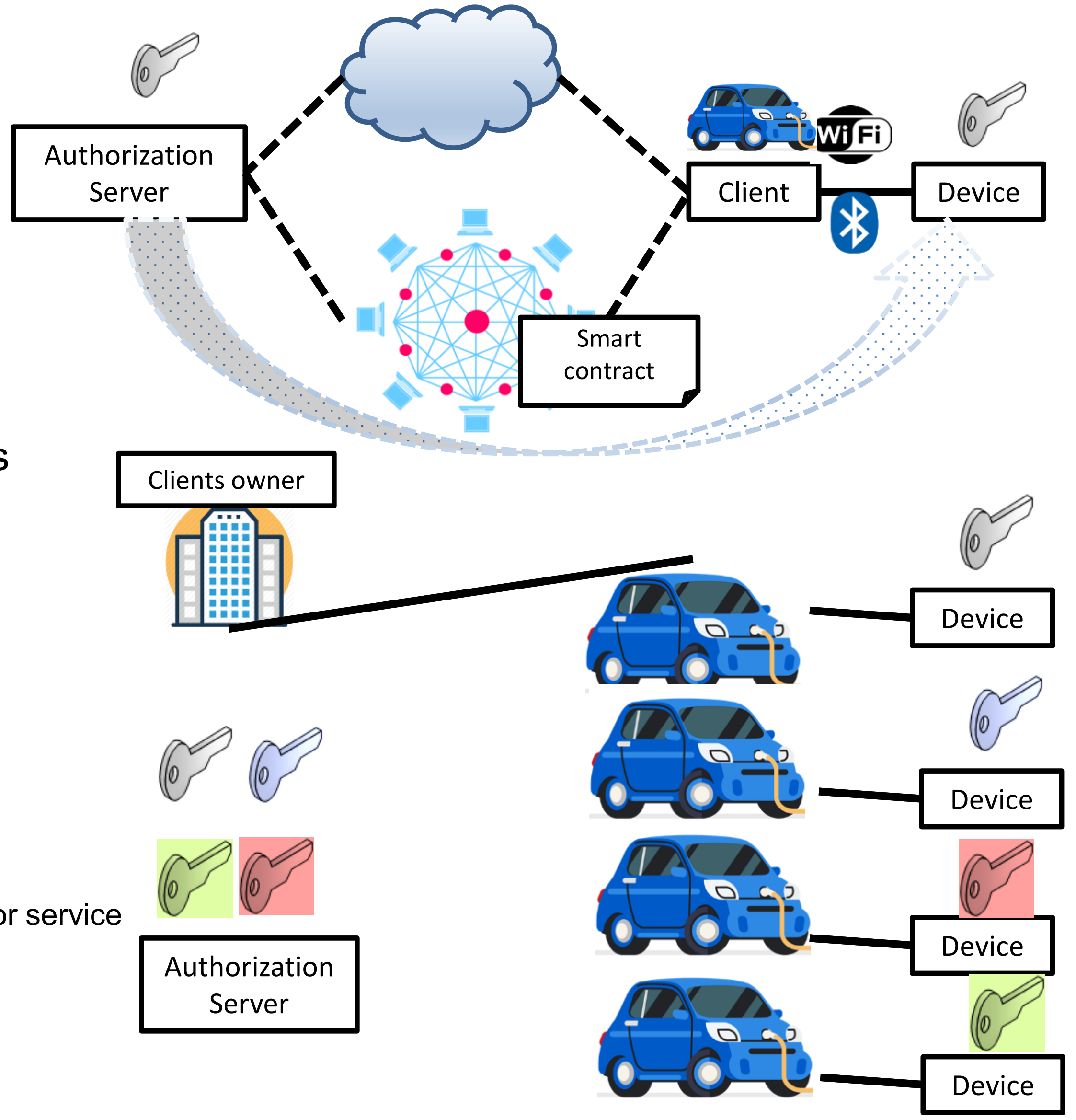
Interledger: Why, What, Who, and How

ILG

- **Why** an interledger function (or operation)
  - Interconnection of otherwise existing/operating ledgers
  - Exploitation of different properties (performance, cost, privacy etc.)
  - Long-term evolution/robustness (smooth transfer of functionality across DLTs)
- **What** is an interledger function (or operation)
  - Transfer of information or value between ledgers
  - Basic operations: listen to events and submit transactions
  - Events & transactions on multiple ledgers can be cryptographically linked and can satisfy timing relations
- **Who** performs interledger functions: Three alternatives …
  - Interledger service provider (third party)
  - Existing entity, e.g. client or IoT platform
  - Private/permissioned or public decentralized system of interledger gateways
    - distributed execution and trust similar to blockchains but with specific function
- **How** is an interledger function performed
  - Listen to events or verify transactions on one ledger and perform transactions on another
  - Hash-locks cryptographically link events and transactions on multiple ledgers
  - Dependency of events or transactions on different ledgers
    - one-to-one, one-to-many, many-to-one, or many-to-many
  - Time-locks ensure timing relations of events and transactions
  - Hash-locks and time-locks enforced automatically and transparently by smart contracts

Bridging the Cyber & Physical worlds using DLTs and smart contracts
Electric Vehicle fleet management: charging at 3rd-party stations

- we leverage two existing solutions
  - Payment channels
  - Hash-based one-time passwords (HOTP)
- realistic approach for paid IoT interactions
  - limit loss in case of disruption
    - micro-payments for micro-transactions
    - make blockchain related micro-transactions efficient/inexpensive
- blockchain-based micro-payments to constrained IoT devices
  - incapable of
    - performing public-key encryption
    - (directly) participating in the blockchain
    - storing blockchain-related secrets
- enable “payment delegation”
  - allowing users without blockchain credentials to pay
    - up to a pre-configured amount
    - for a specific service
- support many-to-one payments
  - enabling multiple users that share the same blockchain credentials to pay for service
- a feasible solution now
  - relies on existing, deployed technologies



Agenda

- **Combining multiple ledgers for better control – Interledger approaches in IoT**
  - Santeri Paavolainen, Aalto University (Finland)
- **Enabling Decentralised Identifiers and Verifiable Credentials for Constrained IoT Devices**
  - Prof. Vasilios A. Siris, Professor, AUEB (Greece)
- **Enabling next generation secure energy services through data exchange liberation**
  - Priit Anton, Guardtime OÜ (Estonia)
- **A marketplace for flexibility: improving power network efficiency using electric vehicles**
  - Giuseppe Raveduto, Engineering Ingegneria Informatica (Italy)
- **Exploring DLT & IoT use-cases in mobile gaming**
  - Max Samarin, ROVIO (Finland)
- **Blockchain-based Architectures for Food Supply-Chain Management**
  - Prof. Spyros Voulgaris, AUEB (Greece)

- **Conclusion**: George C. Polyzos, AUEB (Greece)
- **Closing Remarks**: Nicholas Ferguson, Cyberwatching.eu Project Coordinator (Italy)

Summary & Conclusions

- Blockchains/DLTs as enablers for
        - the IoT &
        - 4th Generation Business Platforms
    - support unattended operation
        - the heart of the IoT & 4GBP

  through
    - automatic (smart) contract enforcement
    - trust between devices/systems with unplanned interactions
    - decentralized payments
    - audit trails

- Interledger & multiple DLTs improve
    - privacy
    - cost
    - scalability
    - efficiency
    - performance
    - longevity

- SOFIE is driven by 4 pilots
    - grounded in real applications
    - direct impact in diverse industries
    - indirect impact in
        - IoT architecture
        - business platforms
        - identification, privacy…
        - …

- Major challenges remain
    - sustainability & business issues
    - real-world events not directly verifiable by smart contracts
        - oracles... (decentralized oracles…)
    - performance issues
    - … blockchains record transactions “in the open”
        - privacy issues
            - some data can be recorded encrypted on public ledgers
                - what?
                - how to pass on keys to unplanned future parties?
        - **interledger**… (with private ledger)
        - …

Selected SOFIE Publications

Journal Publications

- V.A. Siris, P. Nikander, S. Voulgaris, N. Fotiou, D. Lagutin, G.C. Polyzos, “Interledger Approaches,” ***IEEE Access***, vol. 7, 2019.
- S. Voulgaris, N. Fotiou, V.A. Siris, G.C. Polyzos, M. Jaatinen, Y. Oikonomidis, “Blockchain Technology for Intelligent Environments,” ***Future Internet***, vol. 11, 2019.
- Y. Kortesniemi, D. Lagutin, T. Elo, N. Fotiou, “Improving the Privacy of IoT with Decentralised Identifiers (DIDs),” ***Journal of Computer Networks and Communications***, March 2019.
- V.A. Siris, D. Dimopoulos, N. Fotiou, S. Voulgaris, G.C. Polyzos, “Decentralized authorization in constrained IoT environments exploiting interledger mechanisms,” ***Computer Communications***, Elsevier, vol. 152, February 2020.

Conference and Workshop Publications

- A.S. Ahmed, T. Aura, "**Turning Trust Around: Smart Contract-Assisted Public Key Infrastructure**," Proc. 17th IEEE International Conference On Trust, Security And Privacy In Computing And Communications/ 12th IEEE International Conference On Big Data Science And Engineering (TrustCom/BigDataSE), August 2018.
- S. Paavolainen, T. Elo and P. Nikander, "**Risks from Spam Attacks on Blockchains for Intemet-of-Things Devices**,” Proc. 9th IEEE Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), Vancouver, BC, Canada, Nov. 2018.
- N. Fotiou, V.A. Siris, G.C. Polyzos, “**Interacting with the Internet of Things using Smart Contracts and Blockchain Technologies**,” Proc. 7th International Symposium on Security and Privacy on Internet of Things (SPIoT) with the 11th SpaCCS, Melbourne, Australia, Dec. 2018.
- N. Fotiou, V.A. Siris, S. Voulgaris, G.C. Polyzos, D. Lagutin, “**Bridging the Cyber and Physical Worlds using Blockchains and Smart Contracts**,” Proc. Workshop on Decentralized IoT Systems and Security (DISS) with the Network and Distributed System Security Symposium (NDSS), San Diego, CA, USA, Feb. 2019.
- D. Lagutin, Y. Kortesniemi, N. Fotiou, V.A. Siris, “**Enabling Decentralised Identifiers and Verifiable Credentials for Constrained Internet-of-Things Devices using OAuth-based Delegation**,” Proc. Workshop on Decentralized IoT Systems and Security (DISS) in conjunction with NDSS, San Diego, CA, USA, Feb. 2019.
- D. Lagutin et al., “**Secure Open Federation of IoT Platforms through Interledger Technologies – The SOFIE Approach**,” Proc. European Conference on Networks and Communications (EuCNC), Valencia, Spain, June 2019.
- N. Fotiou, I. Pittaras, V.A. Siris, S. Voulgaris, G.C. Polyzos, “**OAuth 2.0 Authorization using Blockchain-based Tokens**,” Proc. Workshop on Decentralized IoT Systems and Security (DISS) in conjunction with the Network and Distributed System Security Symposium (NDSS), San Diego, CA, USA, February 2020.
- S. Voulgaris, N. Fotiou, V.A. Siris, G.C. Polyzos, A. Tomaras, S. Karachontzitis, “**Hierarchical Blockchain Topologies for Quality Control in Food Supply Chains**,” Proc. European Conference on Networks and Communications (EuCNC), June 2020.

Thank you!

George C. Polyzos

Mobile Multimedia Laboratory
Department of Informatics
School of Information Sciences and Technology
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http://mm.aueb.gr/, polyzos@aueb.gr

Let’s discuss cooperation!

We welcome discussions
&
we are open to various types of collaboration

Each SOFIE pilot has a **dissemination** and **exploitation** agenda – contact each pilot lead directly!

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