EBERHARD KARLS
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FACULTY OF
SCIENCE

Communication Networks

C-DAX: A Cyber-Secure Data and Control Cloud for Power Grids

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C-DAX Project

- EC FP7-ICT-2011-8 call project
  - C-DAX: Cyber-secure Data And Control Cloud for power grids
- Duration: 2012-10-01 –2015-09-30
- Total budget: 4,315,303 Euro
- EU-funding: 2,931,000 Euro

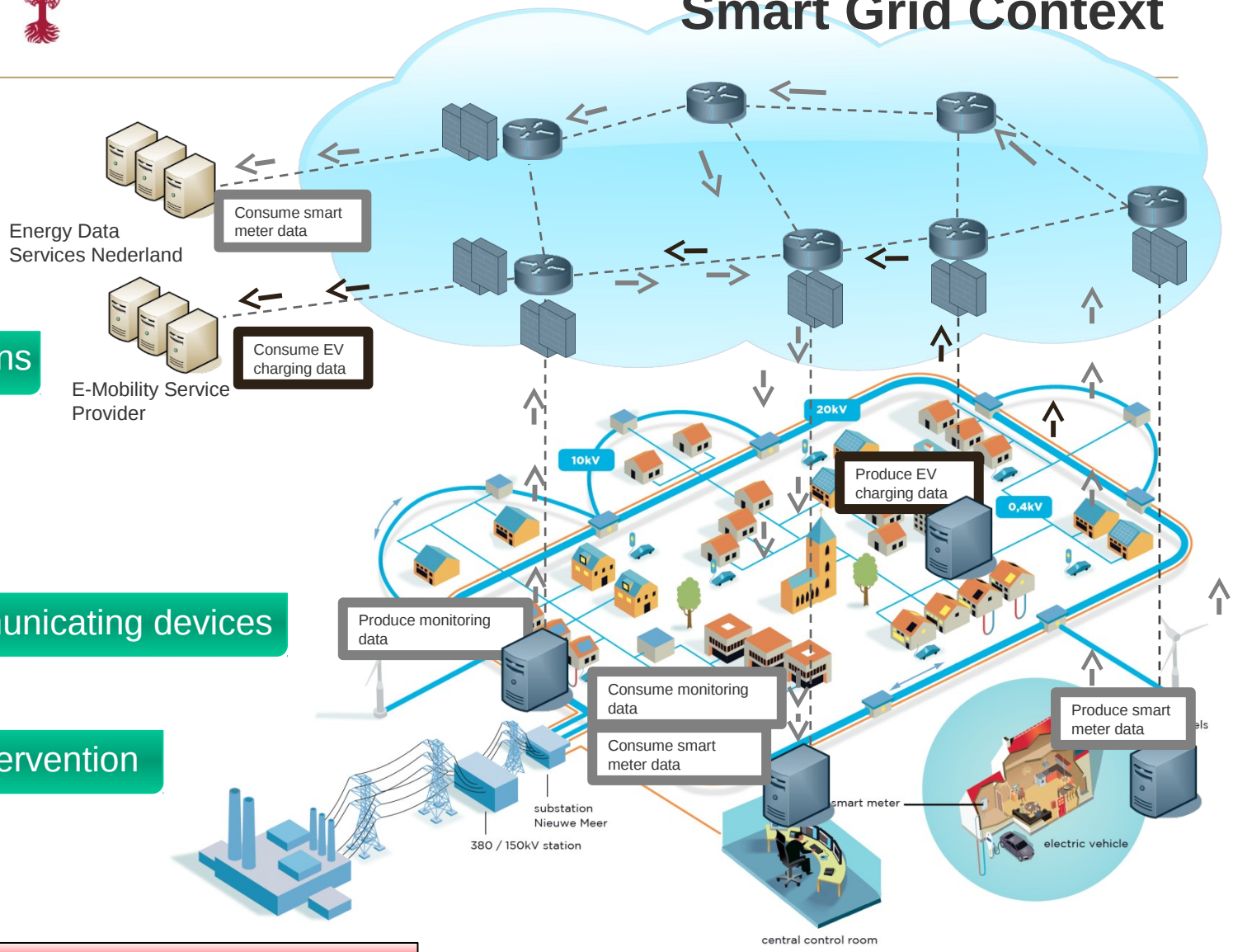
- C-DAX middleware
  - Enables smart grid applications to exchange information securely
  - Implements information-centric networking (ICN) paradigm
  - Supports publish/subscribe across different administrative domains

- Project coordination: iMinds
- Project website: http://www.cdax.eu

- Project partners

iMinds, alliander, EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, UCL, EBERHARD KARLS UNIVERSITÄT TÜBINGEN, UNIVERSITY OF SURREY, NATIONAL INSTRUMENTS, Radboud Universiteit Nijmegen

Smart Grid Context



Multiple applications

✖

Multiple actors

✖

Multitude of communicating devices

✖

Limited human intervention

↓

High configuration / management complexity

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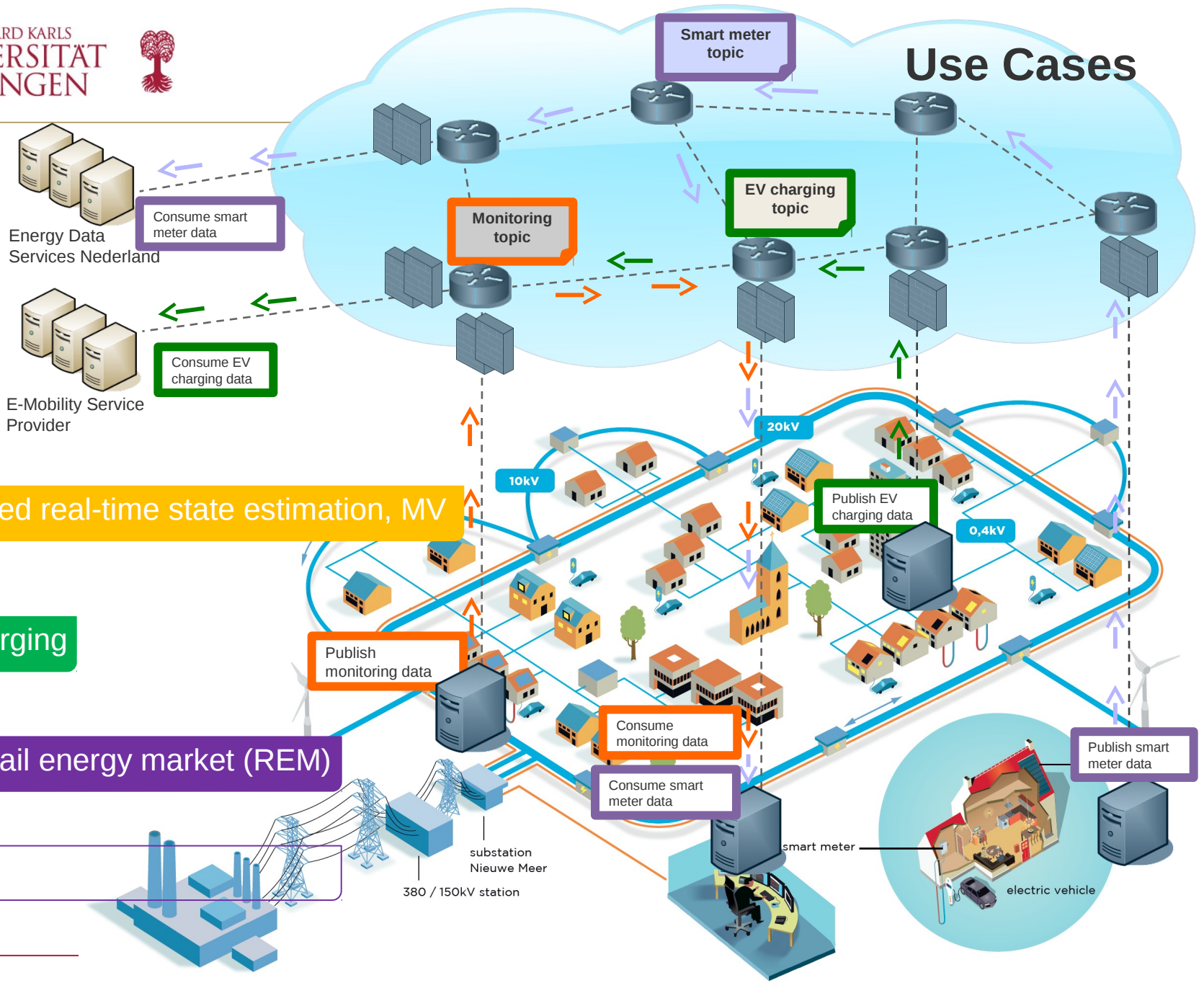
Use Cases

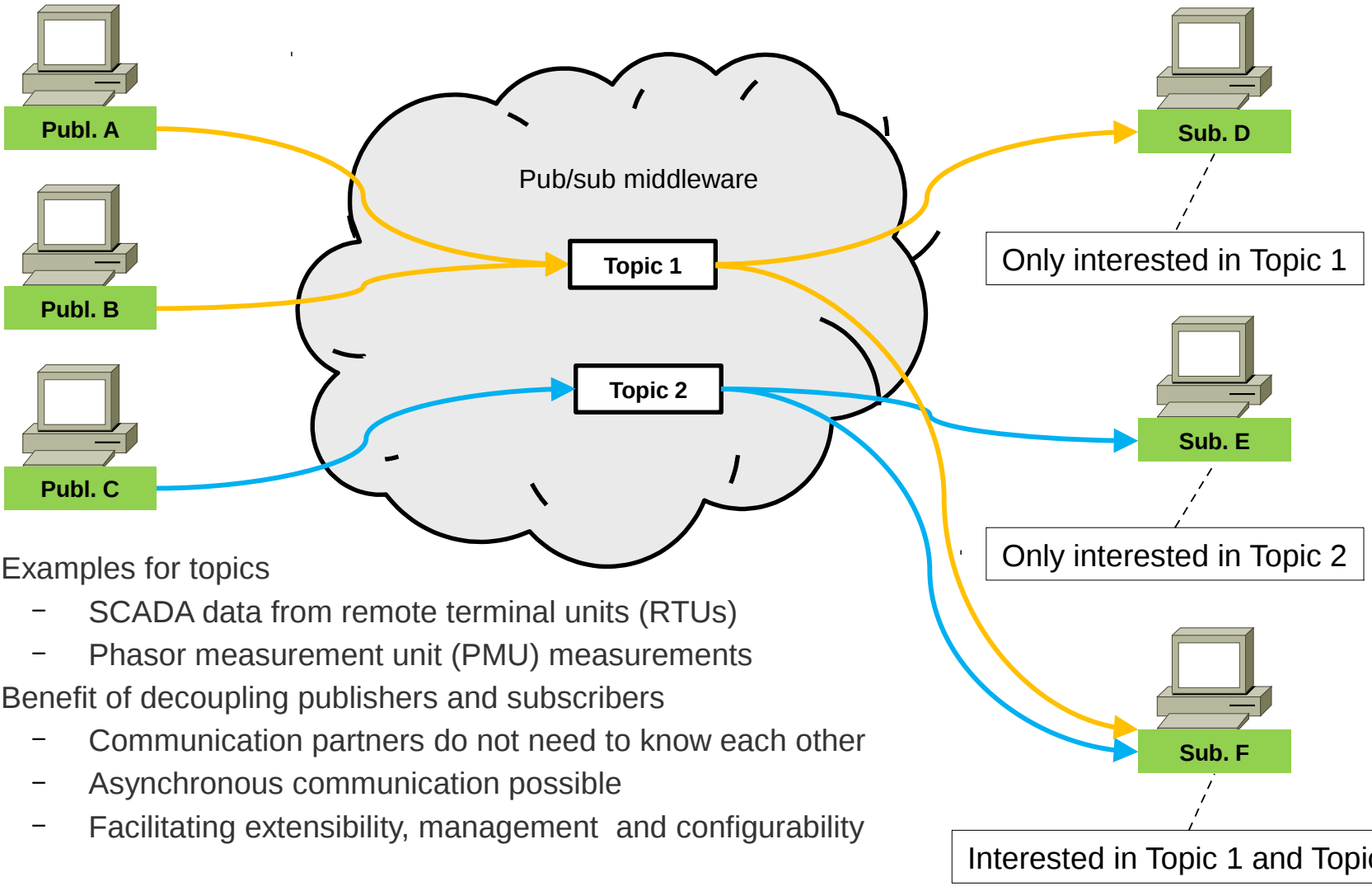


PMU-based real-time state estimation, MV

Smart charging

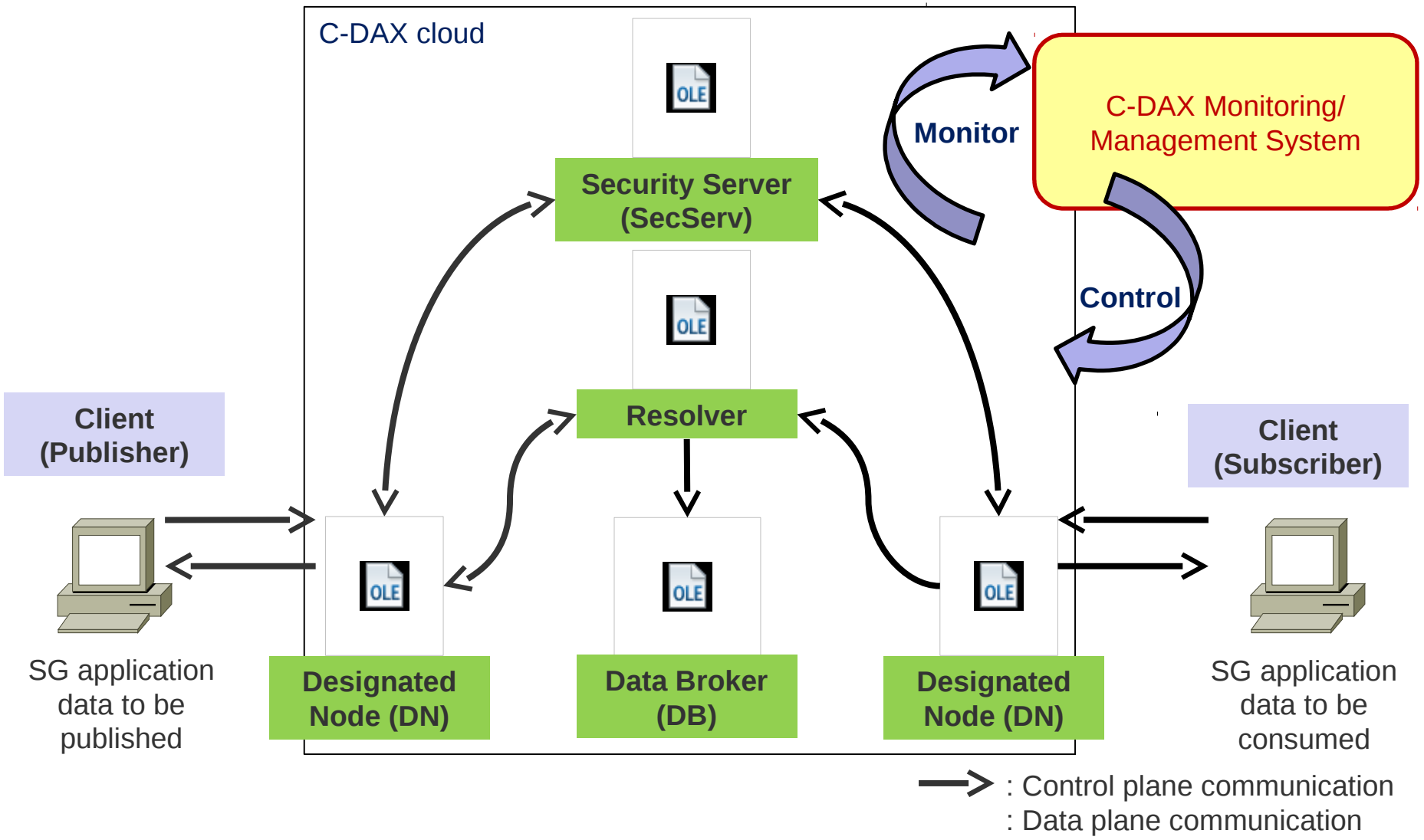
Future retail energy market (REM)

One Platform, Multiple Applications



- Examples for topics
  - SCADA data from remote terminal units (RTUs)
  - Phasor measurement unit (PMU) measurements
- Benefit of decoupling publishers and subscribers
  - Communication partners do not need to know each other
  - Asynchronous communication possible
  - Facilitating extensibility, management and configurability

C-DAX Communication Platform

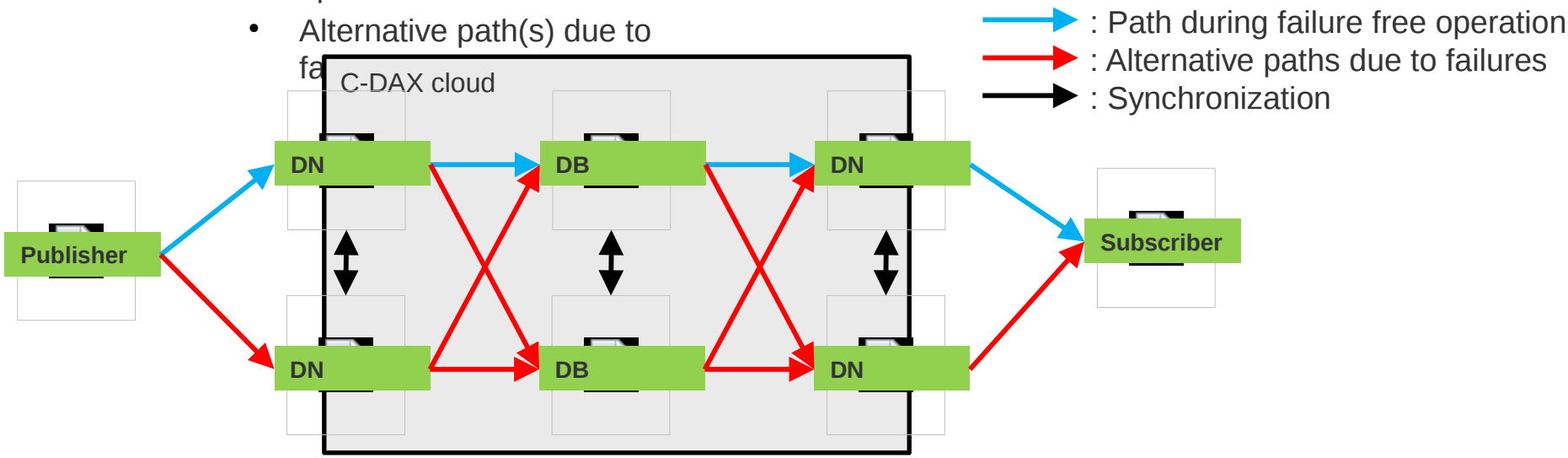


Resilience Support Levels: Overview

- Topic data should be highly available
  - Data is stored on two nodes
- Resilience of the infrastructure
  - Each system component is replicated physically
  - Each critical communication path is divided into
    - A path during failure free operation
    - Alternative path(s) due to fa

- Four resilience support levels:

Level	Data loss (during failover)	Data delay (during failover)	Complexity
L0	Y	Y	Low
L1	Y	N	Low
L2	N	Y	Middle
L3	N	N	High



Michael Hoefling, Florian Heimgaertner, Michael Menth, Konstantinos V. Katsaros, Paolo Romano, Lorenzo Zanni, and George Kamel: *Enabling Resilient Smart Grid Communication over the Information-Centric C-DAX Middleware*, in Proceedings of the ITG/GI International Conference on Networked Systems (NetSys 2015), March 2015, Cottbus, Germany

Security Enhancements

General Security Requirements

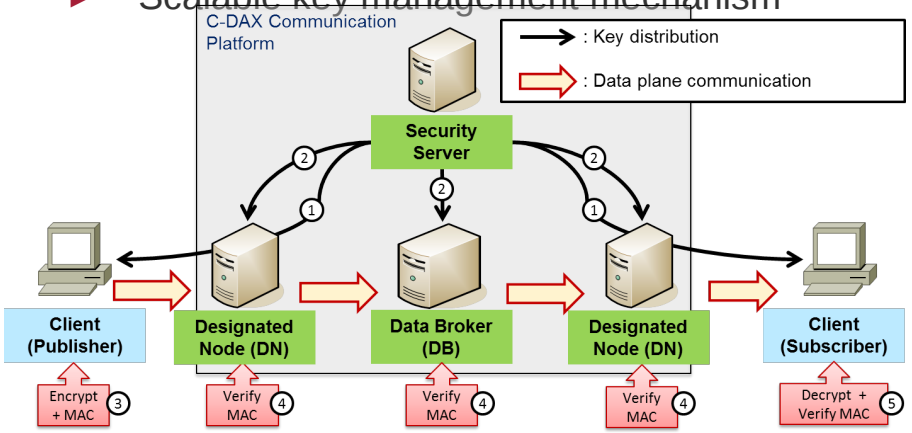
- **Confidentiality** and **integrity**
  - End-to-end security, e.g., IEC 62351
- **Availability**
  - Prevention of attacks, e.g., DoS attacks, replay attacks, spoofing

C-DAX Security Rationale

- Strong authentication of clients and nodes based on asymmetric cryptography
- Asymmetric cryptography for C-DAX control
- Symmetric cryptography for topic data
- Minimal trust in underlying infrastructure
  - Nodes do not have to trust each other inside C-DAX cloud
  - Clients do not have to trust C-DAX cloud for guaranteed end-to-end security
- Flexible match of security parameters to requirements of use cases, e.g., data rates, latency, confidentiality, integrity

Security Features of C-DAX

- End-to-end confidentiality and integrity between C-DAX clients
- Availability of C-DAX infrastructure through resilience and limited exposure through DNs
- Scalable key management mechanism



Florian Heimgaertner, Michael Hoefling, Barbara Vieira, Erik Poll, and Michael Menth: *A Security Architecture for the Publish/Subscribe C-DAX Middleware*, in Proceedings of the IEEE International Workshop on Security and Privacy for Internet of Things and Cyber-Physical Systems (IoT/CPS-Security 2015) collocated with the IEEE International Conference on Communications (ICC 2015), June 2015, London, UK

Interworking with IEEE/IEC Protocols

Problem

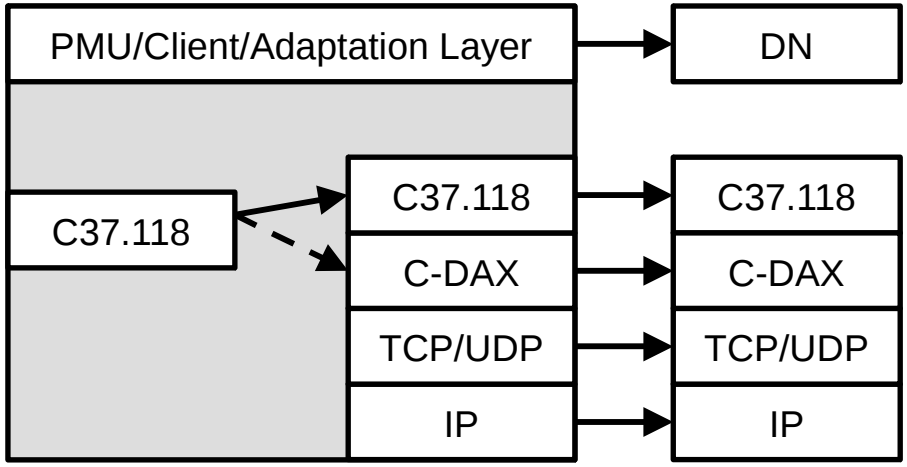
- Existing smart grid protocols rely on bidirectional one-to-one communication, e.g., IEEE C37.118, IEC 61850
- C-DAX provides unidirectional many-to-many communication

Solution

- Protocol adaptation layer translates between smart grid protocols and C-DAX
- C-DAX becomes compatible with existing standards

Benefits for Operators

- Hardware and software compliant to existing standards can be used with C-DAX with little configuration changes



Proof-of-Concept Implementation

- Protocol adaptation layer for IEEE C37.118 has been implemented and tested
- Will be used in the field trial

Michael Hoefling, Florian Heimgaertner, Daniel Fuchs, Michael Menth, Paolo Romano, Teklemariam Tesfay, Mario Paolone, Jimmie Adolph, and Vidar Gronas: *Integration of IEEE C37.118 and Publish/Subscribe Communication*, in Proceedings of the IEEE International Conference on Communications (ICC 2015), June 2015, London, UK

Transparent IP-Tunneling Mode

Motivation

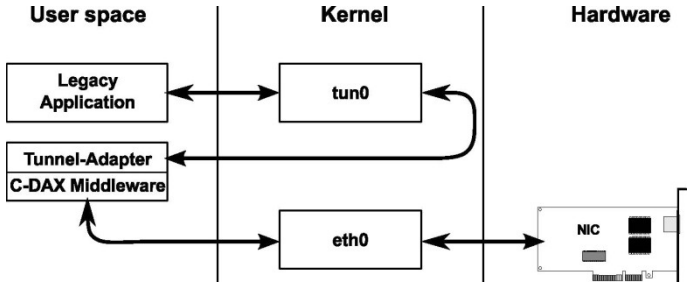
- Support legacy protocols in C-DAX
- Avoid implementation effort for application specific adapter clients
- Re-use C-DAX communication and security infrastructure

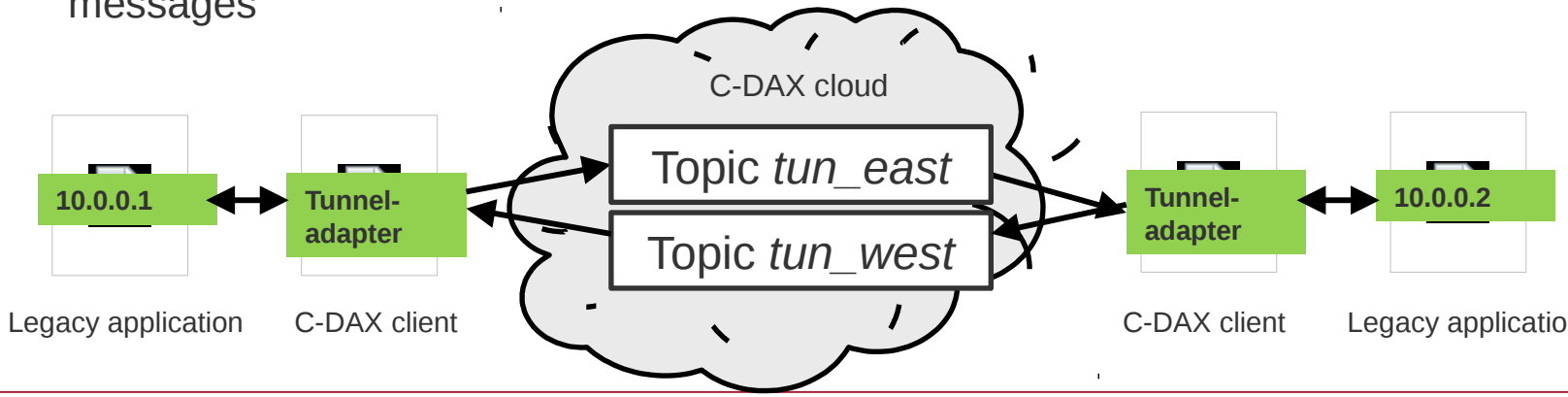
Proof-of-Concept Implementation

- Transparent IP-tunneling adapter
- Uses virtual network interfaces (Linux tun/tap interface)
  - IP packets are handled by user-space application (C-DAX client and tunnel adapter)

Solution

- Map point-to-point communication to topic-based communication
  - One topic per tunnel direction
- Encapsulate IP packets into C-DAX messages





Field Trial

Purpose

- Deploy C-DAX software in an existing distribution grid
- Evaluate applicability of C-DAX under realistic conditions
- Show-case several smart grid applications using a common pub/sub middleware

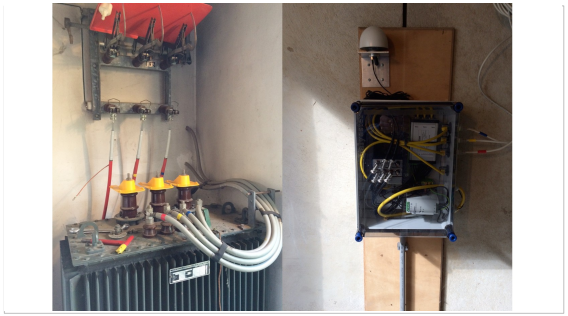
Environment

- **MV feeder** provided by Alliander
- Leased **IP network**
- **PMUs** provided by National Instruments
- **RTSE** application by EPFL
- **PQ** application by National Instruments
- **C-DAX** software

Time plan

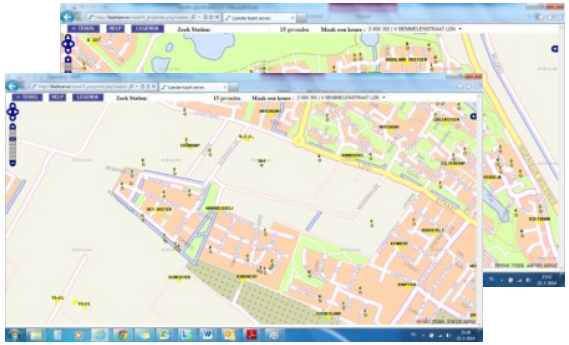
- Deployment of PMUs and C-DAX software: Q3 2015
- Scheduled start of field trial: Q3 2015

- PMU installation at secondary substation of Alliander



Source: Alliander N.V.

- Alliander's MS Livelab



Source: Alliander N.V.

- National Instruments' PMU for MV level

Source: National Instruments Sweden

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