Enabling Smart Grid Applications with ICN

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ABSTRACT

We have harnessed the salient features of information-centric networking (ICN) and implemented a communication infrastructure, called C-DAX, for supporting smart grid applications. We will demonstrate the operations of C-DAX both in a laboratory setup and a real field trial that involves the deployment of C-DAX in a live electricity grid in the Netherlands. This demo will showcase the capabilities of C-DAX, highlighting how ICN satisfies stringent smart grid application requirements.

1. INTRODUCTION

Recent research has pointed towards a paradigm shift from the current host-centric Internet model to one which is centric to information, namely the information-centric networking (ICN) paradigm. Currently, there is a strong ongoing research effort in realizing an ICN-based public Internet, tackling important but complex open issues such as scalability. While the exact form of ICN to be realized is still evolving, there are already work pointing towards alternative domains for ICN (e.g., [1]). We harness the main salient features of ICN and implemented an ICN-based communication infrastructure, called C-DAX, for supporting smart grid (SG) applications [2][3]. We demonstrate how various ICN features can be readily exploited in a domain of smaller scale compared to the public Internet yet still with stringent and varied requirements. We demonstrate C-DAX prototype in both a laboratory setup and in a real field trial involving a live electricity grid in the Netherlands.

2. SMART GRID COMMUNICATION

Smart grids are expected to support new dynamic active components, e.g., distributed energy resources and electric vehicles (EVs). This dynamicity poses new challenges to the power system stability (e.g., voltage regulation). Monitoring and control of SG applications target these challenges, featuring several characteristics / requirements that make the ICN especially well-suited.

Flexibility – Moving the power supply of a feeder requires concurrent reconfiguration of multiple monitoring devices (e.g., phasor measurement units (PMUs) described in [4]). Maintenance operations (e.g., asset change, islanding operations etc.) require the simultaneous change of data delivery structures. Per-flow management is cumbersome and error-prone. With ICN, devices only need to express interest in specific information, regardless of the hosts.

Large-scale decentralized data exchange – The current aging Supervisory Control and Data Acquisition (SCADA) environment is centralized and supports uni-directional communications. This is inadequate for SGs involving many different stakeholders requiring access to data that originates from large number of devices (e.g., EVs [5]).

Resilience – Robust and seamless communication is critical for the operation and protection of the grid. ICN enhances resilience of information delivery (requests can be satisfied by any node/cache) against anomalies/failures.

Security – Mission-critical grid applications suffering from network intrusions often cause severe economic impact. ICN security features (e.g., location independence) are especially beneficial since host locations are not exposed.

Traffic patterns - Many SG applications involve machine-to-machine communications. The traffic patterns are more predictable than Internet traffic. This allows targeted in-network caching strategies to maximize caching gains.

3. C-DAX: ICN FOR SMART GRID

C-DAX [6] follows a topic-based publish-subscribe model, sharing some similarities with ICN projects such as PSIRP [7] and COMET [8], whereby data producers and consumers are decoupled in time and space. A topic represents a group-based communication session for data distribution and replication. C-DAX consists of control and data planes (see Figure 1).

Data Plane – Data publishers stream (real-time) data under a given topic to an entity called data broker (DB) which acts as a rendezvous point. The DB forwards received data to legitimate subscribers of the topic. This dispenses the need for explicit handling of communication. Multiplicity of DBs under a common topic is allowed for purposes such as scalability and resilience (especially for larger grids). The use of DBs enables the semantic grouping of clients in terms of management and configuration (e.g., PMUs in a certain feeder may be configured collectively). DBs may cache data for further usage and also adapt data rates toward subscribers with heterogeneous requirements.

Control plane – The topic resolver (RS) entity facilitates clients to join and leave a topic by resolving a topic join

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request to the relevant DB(s). Depending on the size of the grid, there may be a set of RSes forming a hierarchy for robust and efficient resolution. Once a request is resolved, the RS configures the DB(s) involved as well as the (optional) designated node (DN). DNs are introduced for scenarios where a large number of clients is expected, and their purpose is to handle/aggregate all signalling (e.g., topic join/leave requests) that originated from attached clients. Taking a proxy role, each DN is also responsible for performing local authentication of publishers / subscribers in the grid. Such operations require a dedicated security server (SecServ) in the control plane to carry out the access control and client authentication operations.

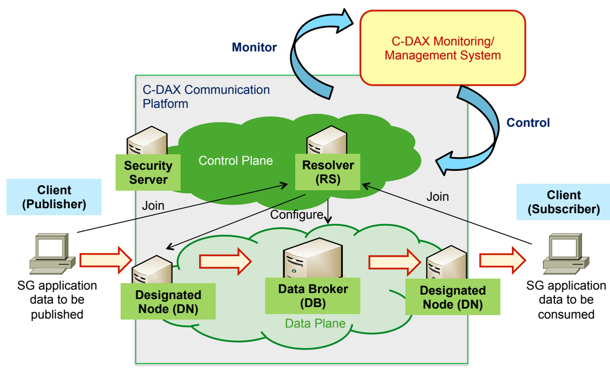

Figure 1: C-DAX architecture

4. DEMONSTRATION OUTLINE

Although C-DAX is designed to support in general all SG applications, we choose to demonstrate its functionality for near real-time PMU data delivery as it represents the most time-critical application to date (see [3] for the analysis of the requirements). Our demo consists of two parts: a lab setup where the publishers are emulated by replaying pre-recorded synchrophasor data to show the ICN-based C-DAX communication functionalities, and a live view on a field trial in a real distribution grid in the Netherlands.

Lab-based Demo. The lab-based demo will show the flexible setup, and fast and reliable transmission of data between a number of publishers (i.e., PMUs) and a few consumers (e.g., phasor data concentrators (PDCs)).

Figure 2 shows the setup of the lab demo for which will use the iMinds Virtual Wall facility[4], a testbed for emulating real communication networks. During the demo, we will show the following aspects of the C-DAX platform:

- Creation and configuration of a topic for PMU data.
- Seamless topic migration e.g., in case of maintenance.
- The resilience feature redirecting traffic to a secondary DB upon a failure, with negligible data interruption.
- Addition and configuration of new data consumers.
- The filtering feature of the DB by only forwarding a subset of the PMU data to another power application.
- A management system to create, configure, start, stop, migrate, etc. different C-DAX nodes. It also provides monitoring information on resource usage and network performance statistics.

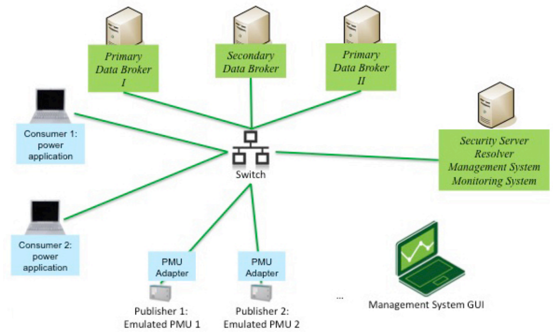

Figure 2: Lab-based Demo setup

Live Field Trial. We also demonstrate C-DAX in a live field trial, hosted in a medium-voltage (10kV) feeder that supplies electricity to the city of Huissen, the Netherlands. The feeder is equipped with 10 PMUs connected through a 4G link, to a PDC that monitors the status of the grid every 20ms and with latencies in the range of 100ms.

During the demonstration, a direct link to the server hosting the PDC will be established to show real-time measurements of the grid status with the live assessment of the latencies of the measurement chain, including C-DAX.

5. ACKNOWLEDGEMENT

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