

Information-Centric Networking for the Industrial IoT

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ABSTRACT

The wireless Internet of Things interconnects numerous constrained devices such as sensors and actuators not only with each other, but also with cloud services. We demonstrate a low power and lossy Information-Centric Network interworking with a cloud in an industrial application. Our approach includes a lightweight publish-subscribe system for NDN and an ICN-to-MQTT gateway which translates between NDN names and MQTT topics. This demo is based on RIOT and CCN-lite.

CCS CONCEPTS

• **Networks** → **Network design principles; Sensor networks; Naming and addressing;** • **Computer systems organization** → **Embedded and cyber-physical systems;**

KEYWORDS

ICN; Industrial IoT; Publish-Subscribe; Constrained Environment

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1 INTRODUCTION

Sensors and actuators often pose communication requirements in industrial applications that are critical for business and safety. Both stationary and mobile devices have to be integrated in supra-regional control and monitoring systems and exchange data in a timely and fault tolerant manner. These control and monitoring systems are often provided by means of cloud services.

Information-Centric Networking (ICN) has the potential to solve the problems and challenges of the Industrial Internet on the network layer. The *ICN for the Industrial Internet (I3)* project explores ICN as local access technology for industrial applications in harsh environments. With the industrial partner MSA Safety, the project considers industrial process plants in its scenarios. Workers in these facilities perform maintenance tasks in safety-critical environments. Dangerous events may occur any time and include exposure to toxic or combustible gases, oxygen depletion in confined spaces, gas leaks or sudden outbursts of fire. Workers have to wear low power battery-operated gas detectors to monitor gas levels and to alert workers locally in case of danger. MSA's portable gas detectors typically probe gases such as H₂S, NO₂, O₂ or SO₂. Each gas detector has a wireless network interface and sends events to other devices and to the cloud over a border gateway router (BGR).

The request-driven nature of Named Data Networking (NDN) [6] prevents unsolicited signaling originating from a gas detector. Furthermore, typical gas detector networks are subject to producer mobility and loss of upstream connectivity. Since cloud services rely on traditional IP technology, a mapping of NDN semantics to application protocols of cloud services is required.

Ahlgren et. al. [2] introduced an MQTT-to-CCN gateway with cloud connectivity, which translates between MQTT topics and CCN names. However, this approach relies on periodic content requests and is unsuitable for alerting scenarios. In [5] the authors mapped publish and subscribe originating from an IP infrastructure to Interest and Data messages for an enhanced IoT cloud scalability. The authors defined a naming scheme to address the correct NDN broker in a broker overlay structure. However, the approach does not cover publish-subscribe from an NDN node.

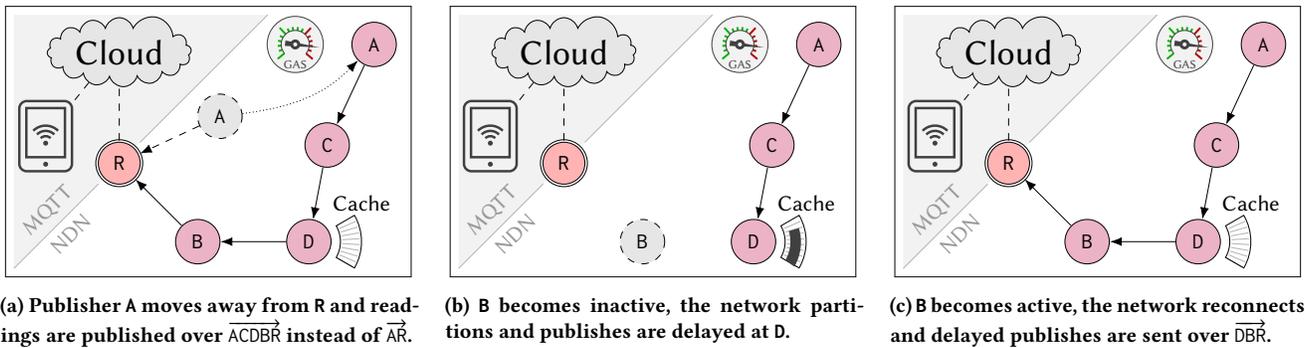
In this demo, we present a publish-subscribe system which enables unsolicited publish from an NDN IoT device to a cloud service. Furthermore, subscriptions from cloud-connected clients are presented.

2 CONTRIBUTIONS

Publish-Subscribe Scheme for NDN. The proposed publish-subscribe scheme for NDN focuses on low power and lossy networks with quasi-stationary infrastructure [4]. With converge cast (many-to-one) being the prevalent communication pattern in IoT, the protocol adopts the approach of PANINI [7] to build and maintain a

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spanning tree rooted at a BGR with prefix-specific default routes. Data is published hop-wise towards the BGR for an enhanced resilience and producer mobility support.

The publish operation is split into two steps: (i) Names of Named Data Objects (NDOs) are advertised on the control plane using unicast link-local signaling to the upstream neighbor in the sink tree. Our content naming scheme follows the form $/prefix/topic/uid$. (ii) As a result of receiving unsolicited name advertisements, content is requested on the data plane with standard NDN Interests from the downstream neighbor. Devices repeat this process iteratively until the published content is replicated to the BGR. Accomplishing replication on the data plane preserves the flow balance of NDN.

A subscription to a name is dispatched with an Interest, where the Interest timeout allows for a configurable trade-off between soft states in the network vs. refreshes needed to keep the subscription active. Each requested Data requires a subscription renewal.

ICN2MQTT. We provide a gateway that translates between NDN packets and MQTT messages. When content is published via our publish-subscribe scheme, the NDN component of the BGR notifies the translator to send an Interest for this NDO. If the gateway receives a reply, it publishes the data to MQTT under a topic equivalent to the $/topic/$ component of the content name. Likewise, if an ICN IoT node sends an Interest, the gateway translates it into a MQTT subscription message with a topic corresponding to the $/topic/$ component of the requested name. When data is published under that topic, it is sent to the ICN node in reply to the Interest.

Reproducibility. The source code and documentation of our contributions as well as a demo description is publicly available¹.

3 DEMO SETUP & DESCRIPTION

We conduct the demo on a network of typical resource-constrained IoT devices, equipped with an ARM Cortex-M4 MCU, 32 kB of RAM, 256 kB of ROM, and an IEEE 802.15.4 radio. Our implementation uses RIOT [3] and CCN-lite [1] including the contributed publish-subscribe option. To enforce a multi-hop topology on site, we make use of the link layer black/white list module in RIOT.

The BGR runs on a Raspberry Pi equipped with an IEEE 802.15.4 transceiver. We implemented the ICN2MQTT-translator in Python using Eclipse Paho. On the NDN side we use the Linux version of CCN-lite with our publish-subscribe extension that connects to the gateway via a socket-based interface.

¹https://github.com/5G-I3/ACM-ICN-17_Demo

In our initial setup (Fig. 1a), a producer node (A) periodically publishes gas sensor readings to the BGR (R) via \overrightarrow{AR} . After content dissemination, (R) publishes data to the cloud and MQTT subscribers get notified. To showcase the robustness gain and publisher mobility of our approach, we move (A) away from (R). As we observe, an alternative path is established and content dissemination is continued through \overrightarrow{ACDBR} . Further, we fully disrupt the network by deactivating node (B). During network disruption, hop-wise publishes are delayed in the reachable upstream router (D) (Fig. 1b). After enabling network connectivity by reactivating node (B), the replication of delayed publishes resumes via \overrightarrow{DBR} and new gas sensor readings are published via \overrightarrow{ACDBR} (Fig. 1c).

4 FUTURE WORK

In future work, we will extend our showcase with respect to resilience and disruption tolerance. Furthermore, we will augment our proposed scheme with a group alerting component and add a more elaborate control logic on the BGR to enable a flexible coupling of sensors and actuators. We will evaluate our scenario in our I3 wireless testbed at MSA.

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