Demo: Experimental Feasibility Study of CCN-lite on Contiki Motes for IoT Data Streams

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ABSTRACT

Many IoT applications are inherently information-centric, making it advantageous to use ICN transport. We demonstrate CCN-lite ported to run on Contiki sensor motes with limited processing and storage resources. We show a method for mapping streams of sensor data to a stream of immutable CCN named data objects, and an adaptive probing method to find the newest value. We also demonstrate interoperation between MQTT and CCN via a gateway. A higher level goal is to use ICN as an open interface for accessing IoT data.

Keywords

Information-centric networks, Internet-of-Things, sensor networks

CCS Concepts

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

1. INTRODUCTION

Many applications and services of the Internet-of-things (IoT) involve collection and distribution of data from and to devices and users. This communication need often fits the named data communication model of information-centric networking (ICN) [1] where data consumers are decoupled from data publishers. Several existing low-level communication protocols in the IoT domain already have some degree of information-centric-ness, for example, the MQTT protocol providing a topic-based publish/subscribe service, and the COAP protocol providing access to named resources.

We explore ICN as the basis for the network infrastructure of open IoT systems for public authorities in the GreenIoT project[1]. An overall objective is to provide open interfaces to low-level as well as processed IoT data with the goals to maximise innovation in third-party IoT services, and to avoid vendor lock-in. Both goals are important to motivate using public funding for investing in IoT infrastructure, for example, for realising the vision of the 'smart city'.

In this demo, we show our work on adapting the CCN-lite implementation[2] to run on constrained devices with the Contiki operating system [3]. We chose CCN-lite as the starting point since it already had a very small footprint with no library dependencies. Contiki was chosen as the sensor operating system by the GreenIoT project for other reasons and was therefore a given for our work.

Using this platform, we demonstrate the viability of using ICN as a low-level interface to IoT data from sensor devices. We show the feasibility and scalability of some of the ideas by Lindgren *et al* [5], for example, representing a stream of sensor data as a stream of immutable CCN named data objects and adaptive probing to find the newest value. We also demonstrate relaying between IPv4 and IPv6 using CCN, and gatewaying data from MQTT-speaking sensors to ICN.

Previous work has described some advantages and inconveniences of using an ICN for the IoT architecture in order to find the right tradeoffs and explored how to represent and model IoT on top of existing ICN solutions, without requiring IoT specific functionality in the ICN [5]. Other work have looked at how limited aspects of an ICN architecture function for the IoT [6, 4] and have run some initial tests [2]. The research community within the IRTF ICNRG have also focused recent efforts in the same direction [7] to drive the discussion forward and reach standardization and best practice recommendations.

2. SCENARIO

Figure 1 shows the larger GreenIoT project scenario that the demo intends to illustrate. Sensors for environmental sensing, for example, particulates and carbon monoxide, are deployed in Uppsala city. One goal is to provide sensor data via ICN transport for storage and processing in the cloud, but also directly to applications/services, enabling unrestricted third-party service development, possibly in combination with other open data sources.

Sensor devices directly publish their sensor data as a stream of immutable CCN named data objects. Clients can probe or search the sequence number space of the stream to get the most current data, or the data from a particular point in time. CCN router caches close to the sensors take up the load from a potentially very large number of clients.

An MQTT-to-CCN gateway enables non-CCN-capable devices to publish data to the ICN infrastructure. Sensors publish readings to an MQTT broker. The gateway subscribes to selected topics of the broker, creates a CCN name based on the MQTT topic and

[1]https://www.sics.se/projects/greeniot-an-energy-efficient-iot-platform-for-open-data-and-sustainable-development

[2]http://www.ccn-lite.net/

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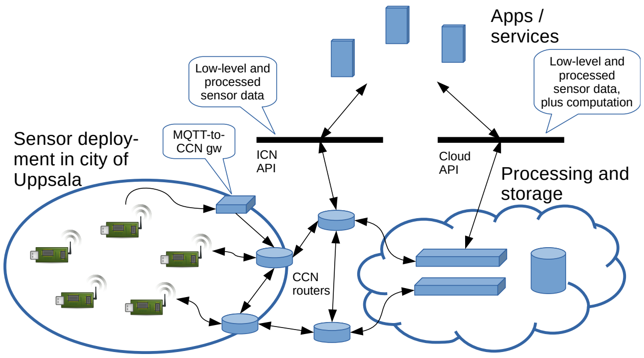

Figure 1: Uppsala city IoT testbed with ICN transport

a serial number, and then republishes the data as an CCN object. The CCN routers close to the sensor devices relays CCN messages between IPv6, used in the sensor network, and the IPv4 Internet, making other IPv4-IPv6 relaying techniques not needed.

3. IMPLEMENTATION

The main implementation work concerned adapting the CCN-lite prototype to run on constrained sensor motes with the Contiki [3] operating system. We used a sensor mote from UPWIS[3] called ‘U101’ with an ARM Cortex M3 32 MHz processor, 16 KB RAM, 128 KB Flash ROM, and an IEEE 802.15.4 compatible radio, which is quite typical for this kind of devices. The code was not a big issue to fit into the available flash ROM size, as the size of the CCN-lite code was small to start with. Instead, as expected, the main constraint was the limited available RAM. We decided to layer CCN on top of UDP/IPv6/6lowpan in order to make it easy to send packets larger than the maximum link-level packet size. This decision however meant that the Contiki OS with the communication stack required about 11 KB of RAM, leaving less than 5 KB for CCN-lite.

Contiki has two memory-efficient dynamic memory allocator functions, one for fixed size blocks (`memb`), and one fragmentation-free that might move already allocated blocks (`mmem`). Because neither of them is suitable as a drop-in replacement for `malloc()`, they would require substantial re-write of the CCN-lite code. We therefore instead used a `malloc()`-compatible implementation with the price of being less memory efficient. In the end, we were able to keep up to three CCN data packets cached on the U101 mote before running out of RAM.

4. DEMO SETUP

Figure 2 illustrates the overall setup of the demo. There will be at least two sensors, one publishing sensor data with CCN-lite, and one with MQTT, the latter with the purpose to show the MQTT-to-CCN gateway. A Raspberry Pi will be used as the sensor gateway which provides connectivity to the sensors and acts as a CCN-lite relay to route to/from the CCN enabled mote. The MQTT broker and MQTT-to-CCN broker as well as the CCN access router will run on regular laptops. Finally, the client devices will be run on laptops and/or smartphones to generate requests and show the features of the demo.

The clients will request streams of data directly from the CCN-lite enabled mote as well as from the legacy mote via the MQTT-to-CCN gateway. We will demonstrate the adaptive probing of sequence numbers to find the latest value of sensor readings published as streams of immutable CCN objects. We will also show the reduction in communication overhead and the latency tradeoffs associated with accessing the data using CCN as compared to directly using MQTT or via the MQTT gateway.

[3]https://www.upwis.se

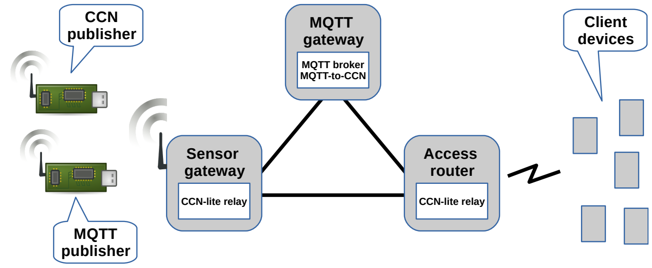

Figure 2: The demonstration setup.

5. CONCLUSIONS AND NEXT STEPS

We have demonstrated the viability of publishing sensor data from constrained IoT devices using CCN. An important purpose is to provide a low-level interface directly to the IoT data in order to maximise third-party service development. We furthermore demonstrate the feasibility of the ideas [5] of mapping a stream of sensor readings as a stream of immutable CCN named data objects, and adaptive probing to find the most current value.

The next steps are to deploy the CCN-lite implementation in the Uppsala GreenIoT testbed for evaluation in the context of the larger project scenario, and to develop applications that access IoT data using ICN transport.

6. ACKNOWLEDGMENTS

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