HoPP: Publish–Subscribe for the Constrained IoT

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ABSTRACT

In this demo, we showcase our NDN based Publish–Subscribe scheme HoPP in a multi-hop low-power and lossy IoT deployment using constrained devices that operate RIOT. These devices publish temperature sensor readings and subscribe to fan control commands. We manually induce network disruptions to illustrate a seamless publisher and subscriber mobility with HoPP. A web-based dashboard highlights the network resilience and visualizes topology maintenance as well as traffic flows.

CCS CONCEPTS

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

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1 INTRODUCTION

The emerging Internet of Things (IoT) aims to connect numerous heterogeneous devices on a global scale. To cope with challenges resulting from mainly constrained devices in low-power and lossy networks (LLNs), the IETF puts forth an effort to design a protocol suite that meets such demanding requirements.

Research indicates that rethinking the networking paradigm to focus on a loose coupling may be rewarding for networked devices that operate in LLNs. Information-Centric Networking (ICN) is a candidate that gains momentum and decouples content provisioning and data producers. Especially Named Data Networking (NDN) [5] was positively evaluated for its suitability in the IoT [3].

We showcase our NDN based Publish–Subscribe scheme HoP-and-Pull (HoPP) [4] that adds a decoupling in time and synchronization. It leverages the stateful forwarding and in-network caching properties of NDN to allow for energy conservation and a robust communication.

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2 HOP AND PULL: LIGHTWEIGHT PUB–SUB

Overview. HoPP is a lightweight Pub–Sub scheme based on NDN. It decreases control-plane chattiness in stable networks to reduce excessive media access and has minimal memory demands to support large-scale IoT deployments. Nonetheless, HoPP remains highly reactive during routing anomalies and ensures a rapid convergence.

HoPP focuses on deployments, where constrained devices connect to powerful gateways with upstream connectivity. One or several gateways act as Content Proxies (CPs) and take the role of data caches. IoT nodes publish sensor readings to CPs, so that content requests are handled by proxy nodes instead. This approach adds a decoupling in time and synchronization. In the normal NDN operation, requests traverse a multi-hop network until a cache is hit, thereby interrupting intermediary nodes. In the HoPP operation, content is published to a CP, so that it serves requests as a proxy to reduce the load on the IoT network (see Figure 1).

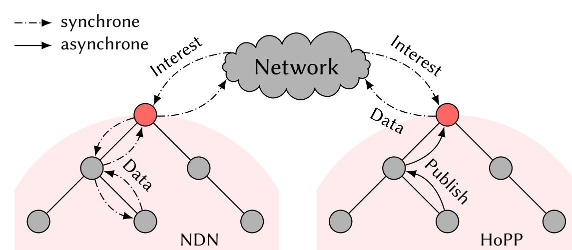
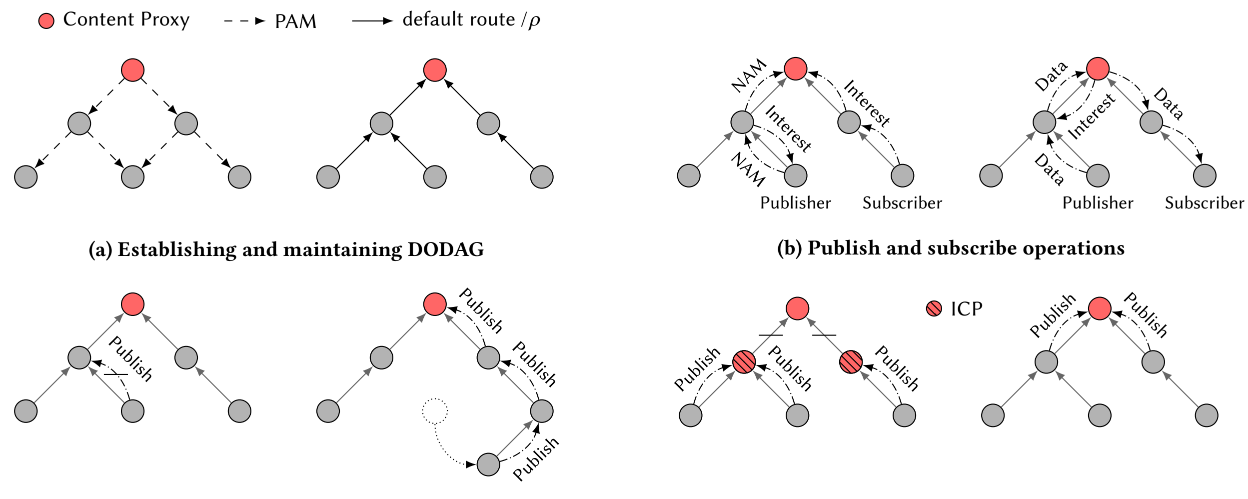


Figure 1: Communication flow with standard NDN (left) and Pub–Sub approach HoPP (right)

HoPP consists of three primitives: (i) establishing and maintaining a routing system that reactively detects anomalies, (ii) providing a publish operation and (iii) providing a subscribe operation.

Route Maintenance. HoPP establishes a routing system with minimal memory requirements. A prefix-specific Destination-Oriented Directed Acyclic Graph (DODAG) is rooted at a CP and each node stores a prefix-specific default route to the immediate parent node.

Figure 2a illustrates the DODAG building. A CP node announces Prefix Advertisement Messages (PAMs) into the broadcast domain. PAMs include a name prefix to set up default routes and a distance number starting with 0. Nodes in the vicinity adjust their forwarding table and rebroadcast PAMs with an incremented distance number, until the DODAG converges. The periodicity of PAM transmissions rapidly slows down in stable networks and is only reset on routing inconsistencies to ensure a faster convergence.



(a) Establishing and maintaining DODAG

(b) Publish and subscribe operations

(c) Rejoining the DODAG on publisher mobility

(d) Intermediate content proxies in partitioned networks

Figure 2: Protocol operations

Publish & Subscribe Operations. The publish operation is depicted in Figure 2b and consists of two steps: (i) a content name is announced on the control-plane to the parent node using a Name Advertisement Message (NAM), and (ii) in return, the parent requests this content on the data-plane using a normal NDN request. This process is repeated hop-wise until the content reaches a CP.

A subscription to a name prefix consists of a normal NDN request. It is forwarded along the default route to the CP and is reissued by the subscriber on a PIT timeout or on Interest consumption.

Publish Recovery. A publish operation may fail due to publisher mobility, intermittent connectivity, or even a complete network partitioning. A failure is detected, when content requests of parents in response to several NAM retries are absent. As a result, a publisher rejoins the DODAG using another parent (see Figure 2c). A publisher that fails to rejoin the DODAG due to network partitioning takes the role of an intermediate content proxy (ICP) (see Figure 2d). ICPs delay received publishes until they reconnect. In this case, all delayed publishes are resumed towards the CP.

3 DEMO SETUP & DESCRIPTION

We locally deploy 3 battery-operated *Class 2* [2] devices that feature an ARM Cortex-M4 MCU with 32 kB of RAM and 256 kB of ROM as well as a Raspberry Pi that acts as the CP. Our constrained devices operate RIOT [1] and make use of its integrated NDN network stack CCN-lite [6], while the CP node runs Raspbian Stretch. HoPP runs in a separate thread and controls the CCN-lite forwarder.

The CP announces /ACM/ICN in PAMs to build a prefix-specific DODAG. We enforce a multi-hop topology in the confined demo space using a MAC address whitelisting for nodes (A), (B) and (C), such that (A) and (C) attach to CP, and (B) attaches to (A). (B) periodically generates temperature readings and publishes them under /ACM/ICN/temp/**seq**, where **seq** is an increasing sequence number. On threshold excitation, (B) publishes ON/OFF commands under /ACM/ICN/fan/**seq**. (C) subscribes to these fan commands and controls a locally attached fan. We manipulate the temperature by applying body heat to (B). The publish recovery features of Figure 2c and Figure 2d are illustrated by manually blacklisting links to enforce connectivity loss and network partitionings. A second Raspberry Pi is used as a sniffer that feeds a live packet trace to a web-based dashboard. This dashboard visualizes the topology building and maintenance as well as traffic flows.

4 FUTURE WORK

In future work, we will improve our implementation to seamlessly handle multi-CP setups and we will extend HoPP to support traffic prioritization as well as more elaborate routing metrics. Additionally, we will work on an analytic model to enhance our understanding of the different protocol control loops.

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