ICN-LoWPAN: Header Compression for the Constrained IoT

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ABSTRACT

This paper introduces stateless and stateful header compression to support small MTUs typical for low-power link layers in the Internet of Things. We evaluate our proposals on the multi-hop IoT-Lab testbed and show significant overhead reductions for NDN.

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 Internet of Things (IoT) has been identified as a promising deployment area for Information Centric Networks (ICN), because infrastructureless access to content, resilient forwarding, and in-network data replication have shown noteable advantages over the traditional host-to-host approach on the Internet. Recent studies [5] have shown that appropriate link layer mappings provide large benefits for the practical performance of ICN. This will be more relevant in the IoT context where nodes communicate via low-power and lossy wireless links. In this document, we present ICN-LoWPAN [3] as an adaptation layer between constrained link layer technologies and the ICN flavors NDN [4] as well as CCNx.

ICN-LoWPAN integrates into the 6LoWPAN [6] framework by providing dispatch fields for (un-)compressed Interest and data messages. This enables ICN-LoWPAN to use protocol (de-)multiplexing and the 6LoWPAN link fragmentation. NDN / CCNx messages can thus coexist with 6LoWPAN and are not limited to small MTUs of constrained link layers (e.g., 127 octets for IEEE 802.15.4). ICN-LoWPAN contributes stateless and stateful header compression mechanisms for efficiently reducing packet header overhead.

2 ICN-LOWPAN

2.1 Stateless Header Compression

Interest and data messages of NDN and CCNx mainly consist of `Type-Length-Value (TLV)` fields. `TLVs` provide a generic and extensible approach to structure messages. However, they also introduce header verbosity which is inappropriate in constrained environments. ICN-LoWPAN employs a stateless header compression scheme that efficiently removes `TLV` structures and encodes header values in condensed bitfield representations (see [3] for details). The corresponding dispatch octets indicate whether a received message requires decompression prior to parsing.

2.2 Stateful Header Compression

LoWPAN-local State. Context Identifiers (`CIDs`) are used by the ICN-LoWPAN layer to replace common information, such as name prefixes or suffixes, as well as meta information in messages, such as Interest lifetimes. `CIDs` are configured prior to network deployment on each LoWPAN device, or may be distributed dynamically during network bootstrapping. They append to the last dispatch octet (see Figure 1) and consist of 8 bits with the most significant bit indicating another, subsequent `CID` or termination.

During transmission, the packet is deflated at the ICN-LoWPAN layer by replacing information with preconfigured `CIDs`. On packet reception, `CIDs` are resolved, so that the actual uncompressed packet is passed to the NDN network stack.

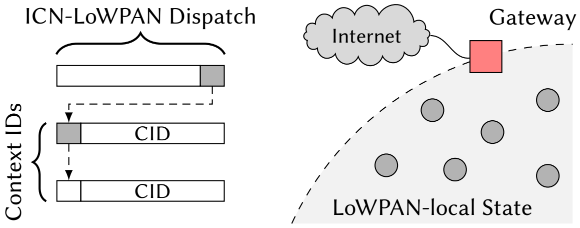

Figure 1: Header compression using LoWPAN-local state

En-Route State. In the typical NDN or CCNx operation, Interest as well as data messages contain Name TLVs to identify the requested content. Name TLVs are stored hop-wise in the PIT during a request to build a reverse path for response messages.

In this hop-by-hop compression scheme, 1) the PIT lookup strategy is adjusted to match against ephemeral, 1-octet wide lookup identifiers (`HopIDs`) instead of Name TLVs, 2) `HopIDs` are included

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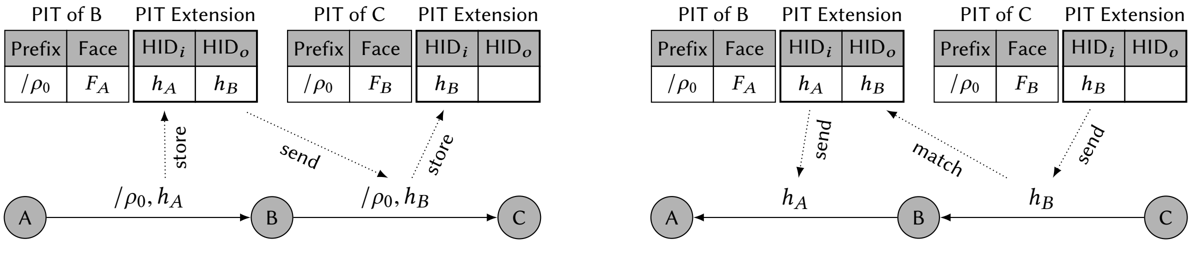

(a) Collecting compression state en-route (Interest) **(b) Eliding Name TLVs using en-route state (data)**

Figure 2: Header compression using en-route state

into Interest messages and 3) returning Name TLVs in data messages are replaced with `HopIDs`. Inbound and outbound `HopIDs` are stored using two new columns in the PIT: $\mathtt{HID}_i$ and $\mathtt{HID}_o$.

Figure 2 illustrates this compression scheme in a setup, where `(A)` requests content, `(B)` forwards the Interest, and `(C)` sends a response on the reverse path. In Figure 2a, `(A)` sends an Interest message with a Name TLV $/\rho_0$ and further includes the `HopID` h_A. On reception, `(B)` extracts h_A and stores it in $\mathtt{HID}_i$. `(B)` then forwards the Interest and includes a new `HopID` (h_B), which is stored in $\mathtt{HID}_o$. `(C)` extracts h_B from the Interest and stores it in $\mathtt{HID}_i$.

Figure 2b depicts the reponse from `(C)` to `(A)`. Instead of providing a Name TLV $/\rho_0$ in the resulting data message, `(C)` includes the previously obtained `HopID` h_B from the $\mathtt{HID}_i$ column. `(B)` extracts h_B from the incoming data message and looks up the correct PIT entry using $\mathtt{HID}_o$. On match, `(B)` forwards the data message using h_A from $\mathtt{HID}_i$ instead of a Name TLV. `(A)` then matches the incoming `HopID` (h_A) with a PIT entry and delivers the data message to an application.

3 EVALUATION & RESULTS

Theoretical Evaluation. We calculate the reduction in size for Interest and data messages with name `/ACM/ICN/Bosten/18/Temp` and content `21°C` in Figure 3. The Interest solely consists of the outermost MessageType TLV, Name TLV, and the Nonce TLV. It is compressed using stateless compression and LoWPAN-local state (to elide prefix `/ACM/ICN`) by 15 octets. Correspondingly, the data consists of the outermost MessageType TLV, Name TLV and a Content TLV. Its size is reduced by 27 octets (71 %) using stateless compression and en-route state (to elide the Name TLV). For brevity, we omit the data packet signature.

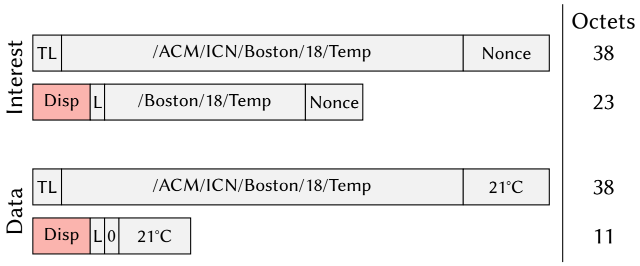

Figure 3: Header compression for Interest / data messages

Experimental Evaluation. We conduct the evaluation of our approach in the FIT IoT-Lab testbed on typical class 2 devices [2] featuring an ARM Cortex-M3 MCU with 64 kB of RAM and 512 kB of ROM. On the IoT devices, we use CCN-lite with the RIOT [1] operating system. The two-hop topology of Figure 2 is constructed in the testbed. The producer `(C)` generates 1000 content items with a naming scheme of `/ACM/ICN/Boston/18/Temp/`**`counter`**, where **counter** ranges from 0 to 999. The consumer `(A)` requests each content in intervals of 500 ms. Table 1 illustrates the total number of transmitted Interest and data octets for 1000 requests. It is apparent that stateless compression together with en-route compression reduces the number of Interest octets by ≈ 36 %, while the number of data octets is largely reduced by ≈ 72 % due to Name TLV elision.

uncompressed		compressed	
Interest octets	data octets	Interest octets	data octets
88000	106000	56000	30000

Table 1: Total number of transmitted octets for 1000 requests

4 OUTLOOK

In future work, we want to elaborate this approach to become a full-fledged protocol extension of CCNx and NDN. As the LoRa radio technology gains more and more momentum for the IoT, we plan to extend our compression mechanisms to it.

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