

Named Data Networking Based Smart Home Lighting

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1. INTRODUCTION

The current momentum gained by the Internet of Things (IoT) is encouraging the scientific community and industry to evolve the current silo-based IoT platform models towards a globally unified IoT platform—a platform capable of efficiently supporting 50-100 billions networked objects. To meet the challenge, several proposals have emerged, such as building a unified host-centric IoT platform overlaid on top of today's host-centric Internet [3]. Alternatively, the networking community suggests the use of Information Centric Networks (ICNs), such as NDN (Named Data Networking), to face the challenge. NDN uses name-based routing to deliver data packets in a simple stateful forwarding plane [2]. It offers developers great flexibility in naming, security, caching and inherent multicast support. It avoids dependencies on separate protocols and various middleware used in IoT networks.

In this paper, we use NDN to provide an initial evaluation of a home smart lighting system and demonstrate some of the advantages of using the ICN paradigm to meet the IoT challenge. We developed a prototype and benchmarked it against the IP cloud based approach.

2. NDN SMART LIGHTING SOLUTION

NDN implements a request/response architecture based on a stateful forwarding plane using two types of packets: *Interest* and *Data*, both provided with URI-like names. Multicast delivery is inherently supported and based on name-based forwarding of Interest packets with subsequent aggregation and replication of correspond-

ing Data packets. Data packets are self-described and self-secured which enables them to be cached and reused. Decoupling data retrieval from data location enables a decentralised, efficient, scalable and secure content distribution model.

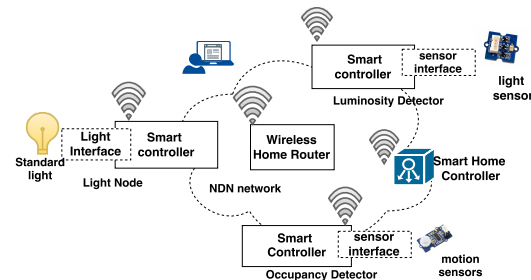


Figure 1: System architecture

Our architecture is shown in Figure 1. *Home Router*: A wireless router that connects all IoT devices. *Smart Controller*: An IoT platform (e.g., Raspberry Pi) with a wireless interface (802.11g). *Light Node*: A conventional light bulb, connected to a smart controller via an actuator that can switch the bulb ON/OFF remotely. *Occupancy Detector*: A Motion sensor that tracks persons' movements in/out to/from the room. *Luminosity Detector*: A light sensor for measuring light level in lux. *Smart Home Controller*: A smart home application running on a smart controller to control lights based on room occupancy and daylight. We configured the raspberry Pis and the home router with Raspbian Wheezy and OpenWrt 12.09, respectively. NDN Forwarding Daemon¹ binaries were used to enable NDN functionalities. We developed the end applications in Python with the PyNDN client library.

NDN Push-based communication: NDN inherently supports pull-based communication. However, in some applications like our smart lighting, push-based data dissemination is more appropriate. The occupancy detector uses push to send data about detected movements and to disseminate measured light levels. The

¹<http://named-data.net/doc/NFD/current/>

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data is a 20 byte string directly sent by appending it to Interest packets. This method is known as Interest notification [1]. Figure 2 shows an example of message flow between luminosity detectors and luminosity monitor with name-based routing. The luminosity detector measures the light level every five seconds and pushes (i.e, sends) Interest notifications that include the light level value and time stamp to the smart controller, which registers the name prefix with the home router through static routing to receive such notifications.

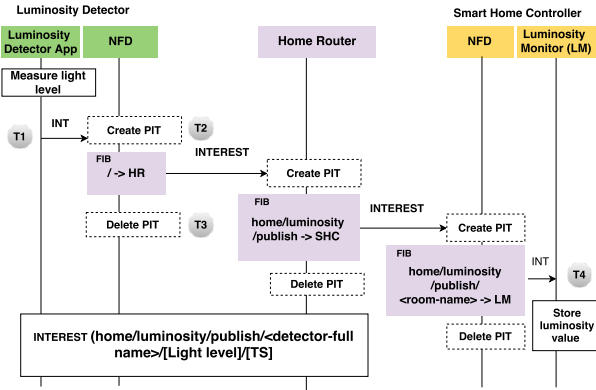


Figure 2: Data dissemination from luminosity detectors via Interest notification

Name-based Multicast: Our solution benefits from the inherent multicast communication of NDN by using an aggregated namespace. A single Interest packet is enough to command tasks to multiple devices. For instance, the Interest packet named /home/light/floor1/off will be received by every node published with the same name on floor1 and switch off.

FIB optimization: NDN uses a data structure called Forwarding Interest Base (FIB) as a routing table that records matching of outgoing interface(s) to names. To scale up, we optimize FIB by applying *Interest filtering* in the local forwarder to filter matching Interests to their NDN names internally. The effect is that a single FIB entry is enough for nodes to capture Interests with multiple matching hierarchy.

3. PRELIMINARY RESULTS

We compared our system with NetPie, a local cloud platform² with its own instant messaging system that supports the MQTT protocol and the HTTP RESTful API. To connect our platform to NetPie, we implemented client modules for each device and registered them with the NetPie server. We configured the modules with the matching identities and application id (home), so that they can authenticate and publish the data under URI-like topic names. We focus the evaluation on message delivery delay: the time spent to deliver a message from producer to consumer. Figure 3 shows

²NetPie is one of the most popular IoT cloud platforms in Thailand, currently running more than 800 applications, connecting around 6000 things. (<https://netpie.io>)

the CDF of message delivery delays between the luminosity detector and smart home controller under the NDN and cloud approaches. With the cloud, we separately measured Internet Transmission Overhead Delay (ITOD) by pinging the cloud server from the home router and estimated it to be approximately 70 ms. We deducted this overhead from the message transmission delay to model a locally operated cloud.

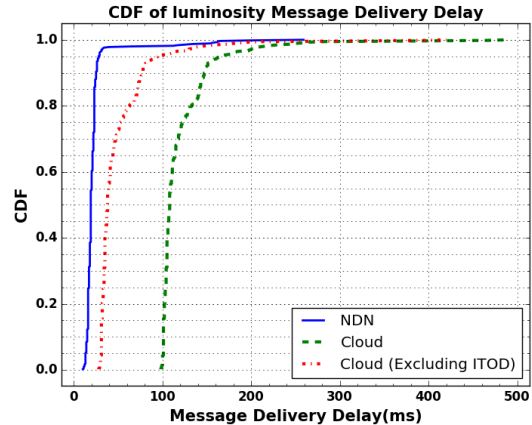


Figure 3: Luminosity message delivery delay

The plot shows that 85% of the messages are transmitted with delays of less than 23 ms and 142 ms in the NDN and cloud respectively. When the Internet transmission overhead is deducted from the cloud approach, 85% of the messages are transmitted in less than 72 ms. This indicates that even if the cloud is hosted locally, the delay is still higher than in NDN due to processing overhead and its protocol stack. Delay reduction is important in applications like smart lighting to ensure real time response and simultaneous control sets of lights. With the cloud, multiple consumers can receive luminosity messages by subscribing to related topics whereas under NDN, multiple consumers can subscribe to luminosity Interests notification, by registering to the related name prefix in the FIB of the home router. Thanks to the multicast forwarding capability of NDN, all the consumers can receive Interests notification simultaneously. Comparatively, NDN offers a higher performance and greater flexibility than cloud based platforms. This is especially useful when traffic is local.

4. ACKNOWLEDGMENTS

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