Interworking of NDN with IoT Architecture Elements: Challenges and Solutions

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***Abstract*—The Internet of Things (IoT) ecosystem can immensely benefit from the Named Data Networking (NDN) paradigm. But interworking between the two paradigms is often challenged due to their intrinsic features. This paper attempts to identify the challenges, proposes their solutions to highlight the interworking of NDN with previously developed DataTweet IoT architecture elements. Our main contribution is in proposing a naming convention to create the interest packets in NDN from consumer systems. A prototype of the overall system is developed which is deployed in a real test bed. The performance evaluation strongly supports the proposed interworking.**

Keywords—DataTweet; Discovery; Internet of Things; Named Data Networking.

I. Introduction

The Internet of Things (IoT) bring numerous consumer benefits in home automation, health & fitness monitoring, smart manufacturing, intelligent transportation system and more domains. But using the traditional Internet for IoT – (i) makes it dependent on DNS mechanism and (ii) provides no native support for mobility (needed for connected vehicles) [1]. At the same time, the HTTP protocol was not designed to run on devices with limited resources. Named Data Networking (NDN) [2] effectively addresses these issues as well as introducing additional features like in-networking caching and security mechanisms. Having studied the advantages of NDN, we have integrated it into our previously developed IoT architecture [3]. The evolved framework of the architecture includes three additional elements namely – (i) Naming of interest packet (described using URI and resides in a consumer device), (ii) NDN router (a part of the core network) and (iii) NDN element (in charge of matching interest with data and resides in a computing device like cloud or edge platform) [1]. In this paper, we address the interworking of the two elements except the NDN router with rest of the IoT architecture. The interworking is mainly challenged due to the opposite nature of the two paradigms of Internet and NDN. The interworking will also demonstrate seamless interoperability among the two paradigms. The main contributions of the paper are mentioned below.

- Identifying the issues challenging the interworking of NDN and IoT architecture elements.
- Proposing mechanisms to solve the above challenge using a specific convention for naming the interests through URI and its corresponding data.
- Demonstrating seamless interoperability among the NDN and IoT architectural elements through a prototype.

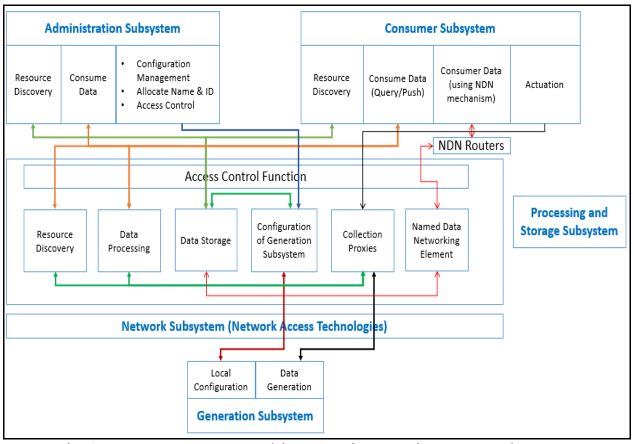

Fig.1. DataTweet IoT architecture integrating NDN elements.

The rest of the paper is organized as follows. Section II identifies the challenges and proposes solutions for the interworking. Section III describes a prototype for interoperation of NDN and IoT elements. Finally, Section IV summarizes the contributions and concludes with some future directions.

II. Challenges and Solutions for Interworking

A closer study of the above architecture reveals that the consumer subsystem includes an element to consume data using NDN mechanism. Naming of interest packet takes place in the consumer subsystem. On the other hand, the processing and storage subsystem has another NDN element which interacts with the local data storage to map the interest with data. From this premise, we have identified following challenges.

A. Challenges

- **Naming of interests**: The main challenges is in naming of interests from the consumer devices. In NDN paradigm the interests are expressed using URIs. But there is no uniform or recommended mechanism to create a structured URI. The scheme, URI parameters are not defined. Resource discovery is necessary to construct the URI. This requires interoperation among NDN element in the consumer device with resource discovery element from the processing and storage subsystem in IoT paradigm.
- **Uniform mapping of interest and data**: For the NDN mechanism to function, the processing and storage subsystem must map the data to interests. This means the subsystem should follow the same principle of naming of interests as that of the consumer devices. This involves interworking between data storage element of IoT paradigm and NDN element.

- **Dissemination of both raw data and high level intelligence**: The NDN mechanism is basically used for data dissemination phase in the DataTweet IoT architecture. As a part of that, both raw data and high level intelligence derived at the processing and storage subsystem must be mapped to respective consumer interests. This requires interoperation between data processing and data storage from IoT paradigm and NDN element.

The three challenges must be solved to form the stepping stone for interworking among NDN and IoT architecture elements. The solutions are described below.

B. Maintaining the Integrity of the Specifications

In this work, we are using the CCNx implementation from Xerox PARC. Following their guideline, we use the 'ccnx' as default scheme to construct the URI. We define two steps to mitigate the above challenges.

- **Uniform naming of interest:** Resource discovery mechanism [4] allows any IoT system to understand the thing descriptions including information about its name, ID, type, supported protocols. From these information, we create an URI using the naming convention below –

scheme://host/thing_type/thing_id

The convention is followed in both the consumer and processing and storage subsystems. Note that "thing_id" is unique to each thing (e.g. sensor, actuator). To add further granularity and distinguishing between raw data and derived high level intelligence, we finalized the following two URIs for the interests –

scheme://host/thing_type/thing_id/raw for requesting raw sensor data and

scheme://host/thing_type/thing_id/derived for requesting derived high level intelligence.

- **Mapping of raw data:** Before mapping of raw data, the NDN element of the processing and storage unit creates the interest using the above convention. Then for each unique sensor, the raw measurement value and its unit is mapped to the interest. This is done as soon as the sensor data reaches the subsystem. An internal service is developed which extracts the sensor measurement and its unit from the SenML metadata [5] and then completes the mapping.

- **Mapping of derived high level intelligence:** The of mapping is the same as that of the raw data. The only difference is the involvement of the data processing element of processing and storage unit. The element acts upon the raw sensor data to derive high level intelligence using semantic web technologies [6].

III. Prototyping and Performance Evaluation

We have created a prototype of the architecture depicted in Figure 1. The generation subsystem is a wearable device with temperature sensor. It communicates SenML based sensor metadata to a storage and processing unit deployed in a Raspberry Pi. The NDN route in deployed in a laptop computer. Another Raspberry Pi acts as the consumer device in this case. Details of the software elements for the IoT paradigm are described in [3]. Following the proposed convention, the system created an interest – ccnx://datatweet/tempSensor/qazxsw21. It shows that 'ccnx' is used as the scheme, 'datatweet' is host, 'tempSensor' is the type of sensor and 'qazxsw21' is the sensor ID. The type and ID of the temperature sensor is found following the discovery process. Then following mapping of interest and raw data is created in a local storage -

ccnx://datatweet/tempSensor/qazxsw21/raw - 42 degrees Celsius

The data processing elements determines that the person wearing the wearable sensor has fever which is treated as the derived high level knowledge. The mapping in this case is –

ccnx://datatweet/tempSensor/qazxsw21/derived – fever

Our early performance evaluation found that the time required for the exchange of consumer interest and corresponding data is 1-2 seconds. The memory footprint of the NDN stack and additional elements amount to 10MB showing the implementations are lightweight. Finally solving the interworking challenges also demonstrates the seamless interoperability of NDN elements with that of DataTweet IoT architecture.

IV. Conclusion

In a nutshell, the paper is an evolution of our work described in [1] and [3]. We have identified three main issues challenging for interworking of NDN and IoT elements. We have proposed mechanisms to create uniform naming of interests and mapping of both raw data and derived high level intelligence to interests. These are the main contributions of the paper. Our prototyping experience validates the premise and the performance evaluation results are promising.

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