Integrating Named Data Networking in Internet of Things Architecture

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Abstract— **The Internet of Things (IoT) is different than the traditional Internet due to factors including (i) massive number of resource constrained devices, (ii) huge volume of small data exchange among physical things, (iii) autonomous configuration and management aspects and (iv) support for mobility. Named Data Networking (NDN) supports them natively and provides excellent mechanism for content retrieval in IoT ecosystems addressing their sustainability issue over a long term. This paper explores the advantages of NDN over traditional Internet paradigm for IoT and examines how NDN can be integrated into an IoT architecture. We explain the utilization of NDN mechanism for disseminating high level knowledge derived from raw sensor data to interested consumers through operational phases of the architecture.**

Keywords— Content Centric Networking; Internet of Things Architecture; Named Data Networking.

I. INTRODUCTION

The Internet of Things has been receiving a lot of attention from academia, industry and standard development organizations (SDO) around the world. IETF working groups have proposed open source, low power communication protocols (e.g. CoAP) allowing resource constrained devices to easily connect to the Internet. The advantages of using the Internet Protocol (IP) are manifold and identified in [4]. Utilizing host-centric IP as a backbone communication of IoT ecosystem gives rise to two key issues – (i) need of DNS and (ii) no support for mobility. Also, HTTP was not designed for resource constrained devices or support mobility. Therefore, exchanging high volume of short messages over HTTP (or even CoAP) would prove to be expensive in terms of power. As an alternative, the research community is examining content centric networking (CCN) aspects where content is the primary focus. In that paradigm, Named Data Networking (NDN) [1] [2] promises to mitigate the mentioned issues through simple communication, in-network caching, multicasting, security elements and native support for mobility. In addition, NDN does not require name resolution and provides automatic configuration management of participating nodes, scalability and sustainability. NDN is especially beneficial for content retrieval by consumer devices. This paper advocates for utilization of NDN in IoT ecosystems. Towards that goal, we provide a background understanding of NDN and integration of its elements into the IoT architecture. This is the main contribution of the paper. Rest of the paper is organized as follows. Section II summarizes the NDN and Section III explains the integration of NDN in IoT architecture. Finally, Section IV concludes the paper.

II. NDN BACKGROUND

The technology was introduced by Jacobson et. al. [2]. Current literature describes that the CCN paradigm has data at its core and is able to solve issues related to host-centric IP paradigm. NDN is a type of CCN and defines two types of packets – (i) interest and (ii) data. The interest packets contain names of the desired contents and a cryptographic nonce. A unique identification is derived from their combination. The names in these packets are used to search for desired content at the participating nodes in NDN domain. The reply to that request contains the data packet. It has four fields – (i) content name identical to that of the interest packet, (ii) cryptographic signature (e.g. hash function or digest), (iii) signed information (e.g. a publisher key) and (iv) desired data corresponding to the content. Figure 1 highlights the mentioned structures.

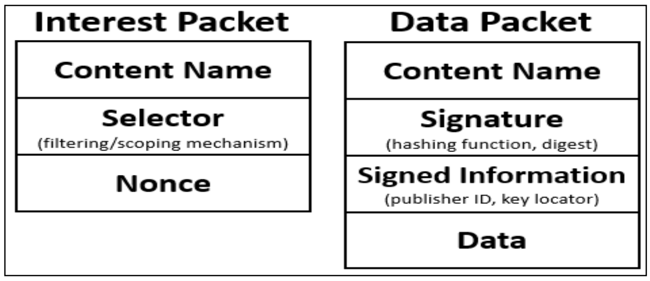

Fig. 1. Interest and data packets structures in NDN.

The participating nodes in NDN paradigm must have forwarding mechanisms for the interest packets. The processing of these packets make use of three key elements – (i) content store (CS) that caches the data corresponding to an interest, (ii) pending interest table (PIT) that keeps track of the previously forwarded interests and (iii) forwarding information base (FIB) that is populated using a routing protocol and is used to route interest packets towards the data source.

III. NDN INTEGRATION INTO IOT ARCHITECTURE

We have previously presented IoT architectures for smart home [4], personalized healthcare [5], discovery [8] and consumer centric application development [6]. An evolution of these works and the benefits that NDN can bring to the IoT ecosystem lead us to integrate the NDN building blocks into the IoT architecture. It is depicted in Figure 2. Its elements are categorized into several subsystems namely generation, network, processing and storage, consumer and actuation. Their building blocks, requirements and functionalities are described in [5]. This work introduces several additional elements into the subsystems.

- **Naming of Interest (URI)**: The consumer subsystem must have a software element that can generate URIs corresponding to the consumer interest. Based on the NDN principle, the URI must be forwarded to an NDN router.
- **NDN Router**: This element can be deployed at a cloud or edge server depending on the use cases. The router forwards

the incoming interest to a processing and storage subsystem that contains the corresponding data.

- **NDN Element:** The NDN element resides into the processing and storage subsystem. The data processing element derives high level knowledge from raw sensor data and that is stored at the local storages. This element uses the naming mechanisms to index the stored information. Upon receiving the interest, it looks up and sends the corresponding data. The data is cached in the NDN router before being forwarded to the "consume data" element to the consumer subsystem.

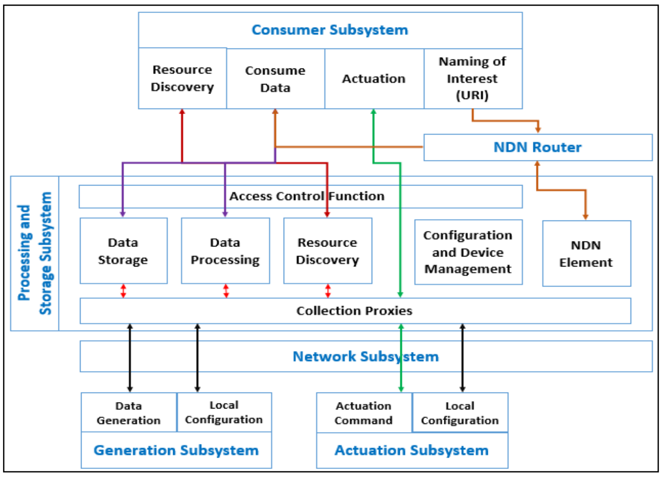

Fig. 2. Integration of NDN elements into IoT architecture.

The operational phases of the proposed architecture are explained with the help of Figure 2. The processing and storage subsystem initiates resource discovery that searches for available sensors and tag that belong to the generation subsystem. This corresponds to the discovery phase. Depending on the consumer application logic, a sensor type and its domain of application are selected during the provisioning phase. To enable raw sensor data processing using semantic web technologies, the architecture makes use of the Machine-to-Machine Measurement (M3) Framework [7]. It is deployed at a Google cloud platform. Depending on the combination of sensor type and domain, the M3 Framework generates an IoT application development template which contains the ontologies, rules and datasets required by a semantic engine. It transforms the raw sensor data into high level knowledge using the template at the convert, reason and query phase. After that the result are parsed and named according to the NDN mechanism and then stored at a local database. The next phase corresponds to data dissemination in which the consumer subsystem generates an URI for the interest. The interest is then communicated to an NDN router that forwards it to the processing and storage unit having the data which travels back in the same way. The router in between the subsystems caches the data. The consumer upon receiving the intended data can send a command to an actuator triggering the actuation phase. That completes the IoT data cycle from generation to processing, storage, dissemination and actuation. The novel aspect lies in the fact that NDN is being utilized for data dissemination instead of HTTP GET or PUT methods.

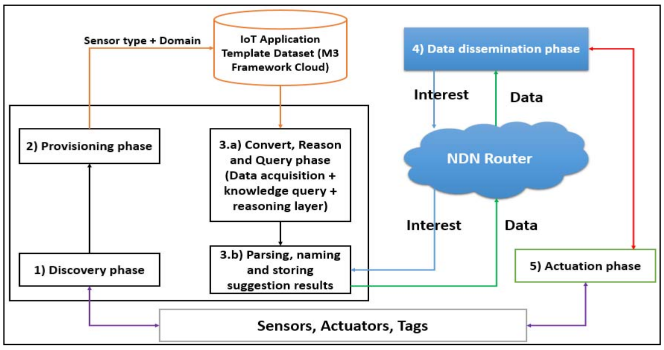

Fig. 3. Operational phases of the NDN enabled IoT architecture.

IV. CONCLUSION

In a nutshell, the paper highlights the benefits of Named Data Networking for IoT. NDN's native support for mobility, automatic configuration management, scalability, huge volume of short data exchange and in-network caching is proving to be highly advantageous for IoT ecosystems. The main contribution of the paper is to integrate the NDN mechanism into a standard IoT architecture. Finally, it is shown that the high level knowledge derived from raw sensor data can be disseminated to interested consumers efficiently through NDN technology. We are currently working on a prototype of the NDN enabled IoT architecture and integrating NDN in a consumer mobile phone [7].

ACKNOWLEDGMENT

The authors thank Dr. Amelie Gyrard for her immense efforts on design and development of the M3 Framework. This work is supported by French research project DataTweet (ANR-13-INFR-0008).

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