LOCATION DEPENDENT DATA RETRIEVAL FOR NDN-BASED IOT

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Abstract

Recently, the Internet of things (IoT) has shifted from using specialized hardware and proprietary protocols toward widespread adoption of open standard technologies that are based on IP paradigm. Besides, the increasing demands for smarter yet more efficient indoor space further shift IoT toward advanced technologies and architectures, such as Named Data Networking (NDN), for better integration with the physical world. However, large-scale deployment, such as location-aware service, of IoT face challenges of IP complexity and packet overhead, reliance on the middleware for simple communication and security, especially for resource-constraint devices of IoT. NDN, future networking paradigm, is a new promising approach that addresses the scalability issues in IP-paradigm and provides a hierarchal content naming scheme, flexible content retrieval and in-network caching. In this research, a location-aware service is proposed based on the basic communication principle of NDN. The proposed design aims to improve content naming and delivery, addressing, data aggregation and mobility, by using contents and management distribution, and at the same time provide location estimation for the user. It also provides an efficient content delivery mechanism of the searched information within a search diameter by dividing the environment area into squares.

1 INTRODUCTION

The topic of Internet of things has emerged due to the need for proper content distribution and retrieval. The things in IoT are heterogeneous devices, each could be tiny with limited CPU, memory or power capacities. Currently, IoT systems use various proposed open IP-based standards and suite of protocols, such as 6LoWPAN of the IETF working group [1], to interact coherently with another type of networks and Internet and to enhance the overall performance of IoT. Nevertheless, IoT contents are typically small and transient, unlike Internet contents distinguished by usually large files, that do not adhere to time. The sensors, in IoT systems, may constantly generate new information subject to environmental changes which makes the current IP-based paradigm not suitable for these distinct peculiarities of IoT systems on a large scale, especially, systems with stringent requirements of their constrained-components (e.g. low memory, power efficiency, and scalability robustness) or host-centric systems, which inherit the communication overhead of the current IP leading to excessing network traffic [2].

A new emerging protocol, called Named Data Networking (NDN), exemplifies the proposal of Jacobson et. al., Content-Centric Networking (CCN) [3], designed for future Internet architecture, provides robust and simple communication methodology. It explicitly names content instead of physical locations, hosts with IP addresses, and transforms content into a first-class entity, which makes it selfidentifying and self-authenticating when digitally signed by the producer. Both NDN and CCN support automatic in-network caching of data to optimize bandwidth use. As a consequence, any node in the network may provide the data when requested despite its actual producer, and there is no need for the consumer to know the content location. Besides these features, NDN offers lightweight configuration, multicast capability and scalable naming which makes it a promising solution for IoT challenges.

The importance and benefits of incorporating NDN to IoT have been highlight by several previous works. The work in [4] has started addressing the fundamental aspect of such incorporation, identified advantage of named data on Wireless Sensor Network (WSN) and demonstrated an architecture build around the attribute-named data to enable data aggregation, in-network caching. Concurrently, the research community addresses the IoT challenges and help to achieve the IoT visions [5] and deliberates how NDN can be applied to achieve IoT framework functionality such as bootstrapping, access control, service discovery, schematizing trust, data aggregation, synchronization, and Internet integration.

Different research works have conducted the incorporation of NDN to divers IoT applications and at same tackled particular challenges of NDN-based IoT. The work of [6] [7] address the service registration and discovery to achieve efficient coordination and prioritized routing for wireless sensor and actor network and provides transparent access to and from the cloud. The authors of [8] [9] developed secure frameworks for Building and Management System ensuring security and ownership over contents, authentication over Interest commands, encrypted access control for actuation and bootstrapping for devices.

Although NDN natively supports in-network caching for the Internet, it is not well suited for wireless IoT environment, due to the stringent requirements of the resource-constrained devices and information freshness. Some researches considered caching management and introduce alternative NDN caching strategies for wireless IoT environment, [10] discussed how caching impact the network bandwidth and energy efficiency. Those researches use a different methodology for their proposed caching strategy. For example, [11] proposes a device driven caching scheme based on task mapping; [12] [13] uses a freshness parameter to cache contents on devices; TCCN [14] uses tags to categorizes the caching contents; Popularity-aware caching [15] which calculates popularity values and use it to ranks the caching content; [2] proposed caching time model to estimate the content caching time on the neighbor node and use it to limit the multicast forwarding.

The aforementioned works show that NDN names can directly address heterogenous IoT contents and services such as home services and environmental data, due to its content-centric nature. It proves that NDN matches a wide set of IoT applications that are content-centric in nature since they target content regardless of the identity of the producer which originate or stores the data. However, although NDN names are location-independent of content or service producers, which facilitates the delivery operation in the presence of nodes' mobility, it is still a key challenge for some scenarios where the nodes' identity is needed [5]. The V2V work [16] has addressed this issue and proposed a location-based naming scheme for the geographical locations of the vehicular information network, which support mobility management, traffic control and schedule, and emergency broadcast. However, it emphasizes the need for another naming scheme, device-based naming, to address the content coming from the devices in the vehicles. Navigo [17], a V2V system for VANET, uses geolocation-based forwarding for location-dependent data. However, the consumer should bind the content name with geographical area otherwise Interest flooding is required to learn contents' geographical area.

While the above proposals try to couple the content name and its location, most of the entities require the knowledge of all the content names, which is not scalable. Moreover, most of the aforementioned implementations did not consider the energy consumption or broadcast nature in wireless resource-constrained networks. On the other hand, many of the provider-aware schemes use a centralized management for configuration and lack a reliable discovery mechanism for services and devices in the network. Therefore, this study proposes a location-aware system for NDN-based wireless IoT networks that provides a reliable distribution of contents.

2 PROPOSED WORK

In this section, the initial design of an NDN-based location-aware system (NDN-LAS) that estimates the user's position and looks-up for information surrounding the user's current location. NDN-LAS design consists of four main components, see fig. 1, the first component is the Location-aware Service (LAS) which in turn consist of two other sub-services; Location Estimation Service (LES) used to estimates the users position based on the RSSI signals of the network devices surrounding the area and Geolocation Information Lookup Service (GIL) used to search for items available in the area covered by the router. Both sub-services can also be requested directly by the user without the need to LAS request. LAS consist also of two other components, command broker and location-based information filter (LIF), which used to parse the received interest and to filter the search result based on the user's search diameter respectively. The second component is the peer discovery algorithm which is used to auto-register/config the user device to the network devices. The last is the data aggregation component which is used to aggregate the requested data results from multiple sources using one interest request of services.

A. *Naming Scheme*

The designed scheme follows building convention for data naming of the IoT devices to reflect their physical location, thus the remaining namespace is constructed based on the hierarchy in the building structure. The designed scheme divides the environment area into square sections, each section falls under and covered by an NDN router. Each section or router can be reached by the sub-namespace */ndn/mall.my/area-x*, where *x* is the section/area number. In IoT environment, it is common to

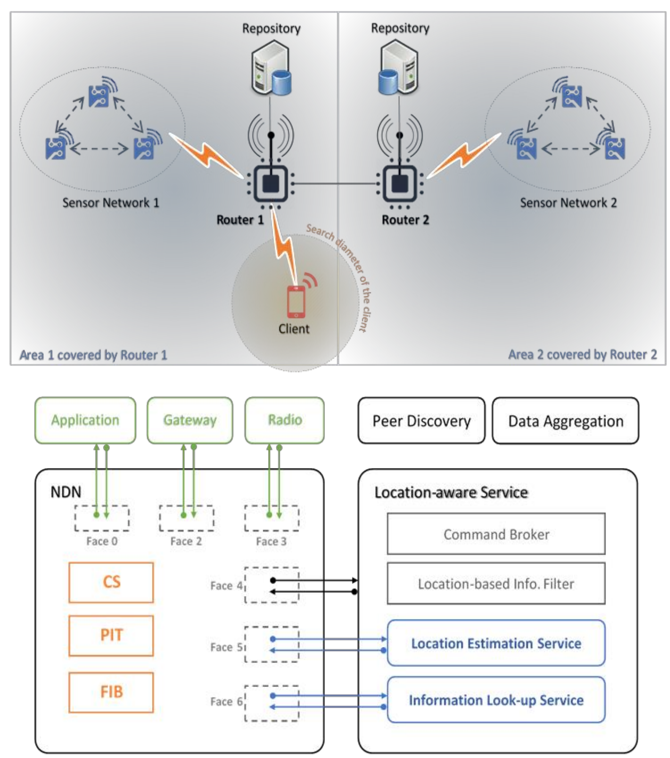

Figure 1. The proposed design and the major components of NDN-based Location-aware architecture

name the IoT devices to reflect their physical location in a building. For example, the building may have multiple floors, identified by floor number, and each partitioned into rooms or shops, identified by room number. The users in the other hand are directly represented under the root with the sub-namespace */ndn/mall.my/user/userMAC*, where *userMAC* is the unique hardware identification of the user device.

B. NDN-based Location-aware Service

The proposed location-aware service, as in fig. 1, consists of two basic entities, command broker and location-based information filter, and two sub-services, NDN-based geolocation Information-lookup and the positioning estimation. The routers in the square areas employed with the LAS service and handle its request from the user devices. The user device that needs to use the LAS service should first scan the surrounding area for the Received Signal Strength (RSS) and then send an Interest message using the predefined prefix name *(/ndn/locate*) along with the search key and RSS signals, for example */ndn/locate~54~60~70~laptop~100* where the last two parameters are the search key and the search diameter respectively and the remaining is the collected RSS signals.

C. Command Broker and Location Estimation

As you can see in fig. 1, the mobile user first broadcast the LAS request to the nearest node in the area after the completing the peer discovery. Any sensor node receives the interest will forward the interest to the nearest router in charge of the square area. The router receives the interest of the service request will parses (using command broker) the name component and issues interest requests for location estimation service (LES) attached with the RSS readings, read from previous Interest, through the NDN face of the requested service. The broker waits for the service replay and when the estimated user coordinates received, it lists the areas intersected with the search diameter of the user's device, with respect to the user's estimated location, and other square areas. After that, the broker sends multicast interest, to the routers of the intersected areas, and requests for service of the geolocation information look-up attached with the search keyword.

D. Data Aggregation

The proposed data aggregation is used to collect all the found results from the routers that their areas intersect with the search diameter. In other words, it collects the found results from the routers who receives the GIS requests and performs the search process. After that, the aggregated results are passed to the Location Information Filter (LIF) to filter only the results under the search diameters.

References

[1] Z. Sheng, S. Yang, Y. Yu, A. Vasilakos, J. Mccann, and K. Leung, "A survey on the ietf protocol suite for the internet of things: standards, challenges, and opportunities," *IEEE Wirel. Commun.*, vol. 20, no. 6, pp. 91–98, Dec. 2013.

[2] Z. Zhang, H. Ma, and L. Liu, "Cache-aware named-data forwarding in internet of things," *2015 IEEE Glob. Commun. Conf. GLOBECOM 2015*, 2016.

[3] L. Zhang *et al.*, "Named data networking," *ACM SIGCOMM Comput. Commun. Rev.*, vol. 44, no. 3, pp. 66–73, 2014.

[4] J. Heidemann, F. Silva, C. Intanagonwiwat, R. Govindan, D. Estrin, and D. Ganesan, "Building efficient wireless sensor networks with low-level naming," *ACM SIGOPS Oper. Syst. Rev.*, vol. 35, no. 5, p. 146, 2001.

[5] D. Corujo, R. L. Aguiar, I. Vidal, J. Garcia-Reinoso, and K. Pentikousis, "Research challenges towards a managed information-centric network of things," *EuCNC 2014 -*

Eur. Conf. Networks Commun., 2014.

[6] N. T. Dinh and Y. Kim, "Potential of information-centric wireless sensor and actor networking," *2013 Int. Conf. Comput. Manag. Telecommun. ComManTel 2013*, pp. 163–168, 2013.

[7] H. Hellbr??ck, T. Teubler, and S. Fischer, "Name-centric service architecture for cyber-physical systems," *Proc. - IEEE 6th Int. Conf. Serv. Comput. Appl. SOCA 2013*, pp. 77–82, 2013.

[8] J. Burke, P. Gasti, N. Nathan, and G. Tsudik, "Securing Instrumented Environments over Content-Centric Networking: the Case of Lighting Control," *IEEE INFOCOM Work.*, no. 1, pp. 394–398, 2013.

[9] W. Shang, Q. Ding, A. Marianantoni, J. Burke, and L. Zhang, "Securing Building Management Systems Using Named Data Networking," no. June, pp. 50–56, 2014.

[10] J. Quevedo, D. Corujo, and R. Aguiar, "A case for ICN usage in IoT environments," *2014 IEEE Glob. Commun. Conf. GLOBECOM 2014*, pp. 2770–2775, 2014.

[11] Y. Song, H. Ma, and L. Liu, "Content-centric internetworking for resource-constrained devices in the internet of things," *IEEE Int. Conf. Commun.*, pp. 1742–1747, 2013.

[12] J. Quevedo, D. Corujo, and R. Aguiar, "Consumer driven information freshness approach for content centric networking," *Proc. - IEEE INFOCOM*, pp. 482–487, 2014.

[13] M. A. Hail, M. Amadeo, A. Molinaro, and S. Fischer, "Caching in Named Data Networking for the Wireless Internet of Things," *2015 Int. Conf. Recent Adv. Internet Things Singapore, 7-9 April 2015 Caching*, no. April, pp. 1–6, 2015.

[14] Y. Song, H. Ma, and L. Liu, "TCCN: Tag-assisted Content Centric Networking for Internet of Things," *Proc. WoWMoM 2015 A World Wirel. Mob. Multimed. Networks*, 2015.

[15] Z. Liu, M. Dong, B. Gu, C. Zhang, Y. Ji, and Y. Tanaka, "Inter-domain popularity-aware video caching in future Internet architectures," *Proc. 11th EAI Int. Conf. Heterog. Netw. Qual. Reliab. Secur. Robustness, QSHINE 2015*, no. Qshine 2015, pp. 404–409, 2015.

[16] Z. Yan, S. Zeadally, and Y. Park, "A Novel Vehicular Information Network Architecture Based on Named Data Networking (NDN)," *Internet Things Journal, IEEE*, vol. 1, no. 6, pp. 525–532, 2014.

[17] G. Grassi, D. Pesavento, G. Pau, L. Zhang, and S. Fdida, "Navigo: Interest forwarding by geolocations in vehicular Named Data Networking," *Proc. WoWMoM 2015 A World Wirel. Mob. Multimed. Networks*, no. 1, 2015.