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Investigation of Internet of Things Handover Process for Information Centric Networking and Proxy Mobile Internet Protocol

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ABSTRACT

IoT (Internet of Things) technically connects billions of entities to the Internet. The IoT is divided between the technology and the service itself. As a result, great efforts are needed to join data from many contexts and services. This reason has motivated proposals to develop solutions that can overcome existing issues of limitations for mobility, security, reliability and scalability of IoT. These billions of devices are interconnected to each other either using unicast, multicast or broadcast communications, and mixture of static and mobile communications. This paper aims to investigate the parameters of mobility performance in handover process for mobile multicast IoT environment. Investigation is done quantitatively by evaluating the parameters of handover process for IoT in two networking protocols that are possible to support acceptable mobility performance for IoT. The protocols are ICN (Information Centric Networking) and Proxy Mobile Internet Protocol. The evaluation parameters include packet loss and service recovery time. The metrics are extracted from the handover process flow for each network protocol topology. The service recovery time parameter is assumed as the time duration for each message to travel from sender to receiver, while packet loss parameter depends on the packet arrival rate and service recovery time. The results show that the ICN performs better than Proxy Mobile Internet Protocol.

Key Words: Handover, Information Centric Networking, Proxy Mobile Internet Protocol, Packet Loss, Service Recovery Time.

1. INTRODUCTION

The IoT is also known as Industrial Internet, stated as a global network of machines and devices capable of interacting with each other [1]. In recent years, the current Internet has become incompetent in supporting rapidly evolving technologies of billions of IoT devices, applications and connections [2-3]. As a result, ICN [4] has been recommended as a future Internet strategy to overcome the existing network environment inefficiencies [5].

PMIPv6 is an extension of MIPv6 (Mobile IPv6) [6-8], a unicast network oriented mobility arrangement that enables IP (Internet Protocol) movement for a host without demanding any mobility associated messages

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[9-10]. Two network objects named as MAGs (Mobile Access Gateways) and LMAs (Local Mobility Anchors) are introduced from the old MIPv6 [11-12]. The main task of these two objects is to manage IP movement for the receiver known as MN (Mobile Node). PMIPv6 supports multicast communication technologies using approaches such as deploying proxy functions at MAGs [13], deploying multicast routing functions at LMAs [14] and deploying selective route optimization. However, such approaches incompletely provide multicast data services [15]. Despite all these solutions, it is still inefficient to manage the heterogonous multicast communication of objects and services connections of IoT.

ICN is an approach that directly supports data objects as a network service. ICN compromises numerous features comprising data networking, mobility, network caching, data security, and scalability. These features allow better data distribution policy to support various IoT technologies. Communication becomes self-governing regardless of application, location and storage, permitting global network caching and mobility [16]. It is estimated to improve security, efficiency, scalability and stronger network performance in current challenging communication situations. In summary, ICN is the promising Internet architecture that models data with different services, different properties and higher performance.

The paper is arranged as follows: section 2 delivers current problem statement and section 3 research background. Section 4 describes the infrastructure and handover process for PMIPv6 and ICN as well as the mathematical equations and parameters. Section 5 is the acknowledgment. Finally, section 6 is the conclusion.

2. PROBLEM STATEMENT

Mobility in the IoT architecture consists of data producer mobility, data requestor mobility, IoT Network mobility, and disconnection between data source and destination pair. It is necessary to deliver the IoT data below an application's acceptable delay constraint. It is sometimes necessary to negotiate different connectivity or security constraints specific to each mobile context. Considering the variety of IoT applications mobility handling, information delivery in the corresponding infrastructure are very challenging. ICN architectures are generally able to handle requestor and producer mobility compared to the existing network architecture [16]. During a network communication, either the data producer or the requestor is mobile. Thus there is a need to handle the mobility to avoid information loss and fast recovery if the connection is lost.

3. RESEARCH BACKGROUND

The main idea of ICN is that the Internet infrastructure supports information distribution directly. It is a communication model for a network that delivers retrieving data as a service. ICN provides distinctively termed data as a central Internet principle. Each data object represents bytes of information. Data object is independent of location, storage, application and transportation. This enhances security, in-network caching, scalability, multicast and mobility. This facility is achieved by relocating or retooling relevant protocol stacks. There are two main entities in ICN namely requestor and publisher [4]. Requestor is an object that requests data (named data objects) from the network. It retrieves data potentially from one or multiple data sources and thereafter determines the completion of a retrieval process. Publisher is an object that publishes data to the network. A publisher delivers the facility of accommodating data for the actual creators [5]. Recent work in ICN involves either implementation of ICN on other based network or improvement on quality of services.

In a recent work done by Figueiredo et. al. [17], ICN architecture is applied in 5G (Fifth Generation) network. This work was aimed to optimize mobility, security and storage performance. It highlighted three major components which are content as an object, name based routing and transport enhancements. The services are delivered using a new communication model that addresses mobility, removes exclusive mobility overlays, data security integrity and dynamic network storage. Azgin et. al. [18] investigate producer mobility procedures to detect device mobility in a network by enabling path requests of the destination. This work claimed to provide low handover latency and low number of mobility signalling. Paul [19] introduced a caching scheme by utilizing in resource pooling, node locating and content storing. This work claimed to provide better packet loss probability and possible number of data clusters.

Maroua, et. al. [20] Fei, et. al. [21] and Zhang et. al. [22] proposed to build an integrated IoT architecture. Chen, et. al. [14] implemented the ICN at the middlwareIoT services or administrative services. Liu et. al. [23] built the unified IoT platform leveraging the main feats of ICN architectures. Specifically, the work explored two ICN architectures namely Mobility First and NDN (Name Data Networking) to support IoT. Sobia et. al. [24] studied the ICN specifically NDN as the future internet basis. This work proposed NDN striking features like data self-security, data forwarding, mobility and network caching for use in smart campus. The aimed was to enable communication among smart devices and to combine all Internet-based smart applications under one roof.

4. HANDOVER PROCESS FOR ICN AND PMIPV6

The basic infrastructure of PMIPv6 involved three main entities which are the LMA, the MAG and the MN, while basic ICN infrastructure involved two main entities which are the publisher and the requestor. The infrastructure for both is illustrated in Fig. 1. The basic multicast communication handover process flows for both environments are shown in Fig. 2. The performance metrics for PMIPv6 are router solicitation, router acknowledge, binding update, binding acknowledge, MLD query and MLD report. While for ICN the performance metrics are requestor interest message and publisher data send.

5. QUANTITATIVE ANALYSIS

The quantitative evaluations for both protocols are derived from the handover signaling flow shown in Fig. 2. The parameters are service recovery time [25] and packet loss cost [26]. It is assumed that the service recovery time is the time needed to resume the service to the normal state after mobility [25]. It is assumed that general average duration for packet delivery is 10ms from one node to another node for both environments, however this general average duration is different in case of real network environments depending on the real infrastructure. Table 1 describes the parameters used.

The total service recovery time is denoted as μ. Therefore, the service recovery time [24] for PMIPv6 is denoted as μ_{pmipv6} described in Equation (1). As for ICN, the total service recovery time is represented μ_{icn} described in Equation (2).

$$\mu_{pmipv6}=\beta_{pmipv1}+\beta_{pmipv2}+\beta_{pmipv3}+\beta_{pmipv4}+\beta_{pmipv5}+\beta_{pmipv6}+\beta_{pmipv7} \quad (1)$$

$$\mu_{icn} = \beta_{icn1} + \beta_{icn2} \quad (2)$$

Figs. 3-4 show the service recovery time for both ICN and PMIPv6. It is illustrated in Fig. 3 that the service recovery time for ICN is 20 ms while the service recovery time for

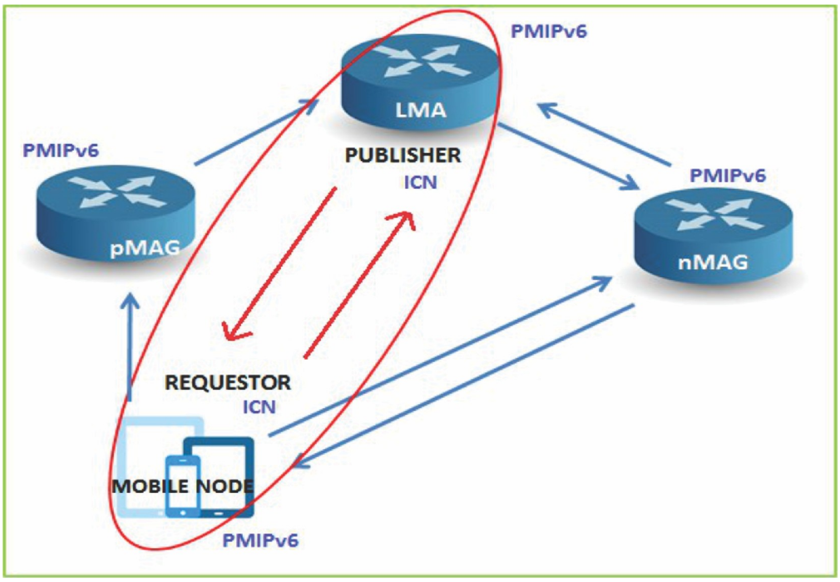

FIG. 1. BASIC NETWORK MODEL FOR PMIPV6 AND ICN

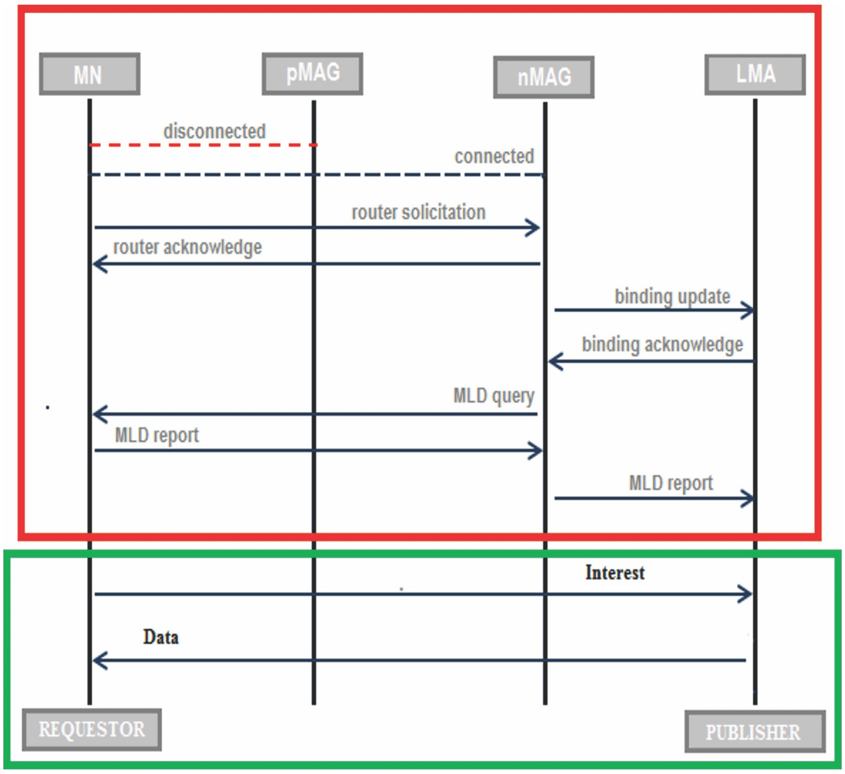

FIG. 2. MN HANDOVER SIGNALING FLOW

PMIPv6 is 70 ms for a multicast communication. Fig. 4 depicts the effect of increasing the number of forwarding nodes. In this paper the forwarding node for PMIPv6 is the MAG node, while for ICN is the publisher node. It is clearly observed that ICN has lower service recovery time compared to PMIPv6. However, the service recovery time increases as the number of forwarding nodes increases which is normal in network performance as each node has its own time duration.

TABLE 1. SERVICE RECOVERY TIME PERFORMANCE METRICS

Parameter	Description
β_{pmipv1}	time taken to send the Router Solicitation message from MN to nMAG
β_{pmipv2}	time taken to send the Router Acknowledgement message from nMAG to MN
β_{pmipv3}	time taken to send the Binding Update message from nMAG to LMA
β_{pmipv4}	time taken to send the Binding Acknowledge message from LMA to nMAG
β_{pmipv5}	time taken to send the MLD query message from nMAG to MN
β_{pmipv7}	time taken to send the MLD report message from nMAG to LMA
β_{icn1}	time taken to send the request message from Requestor to Publisher
β_{icn2}	time taken to send the data message from Publisher to Requestor

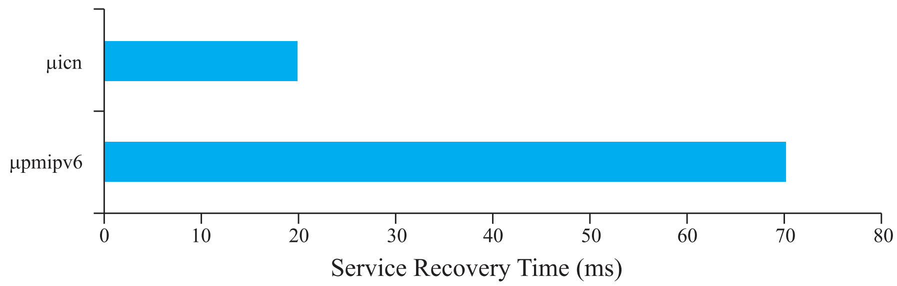

FIG. 3. SERVICE RECOVERY TIME FOR ICN AND PMIPV6

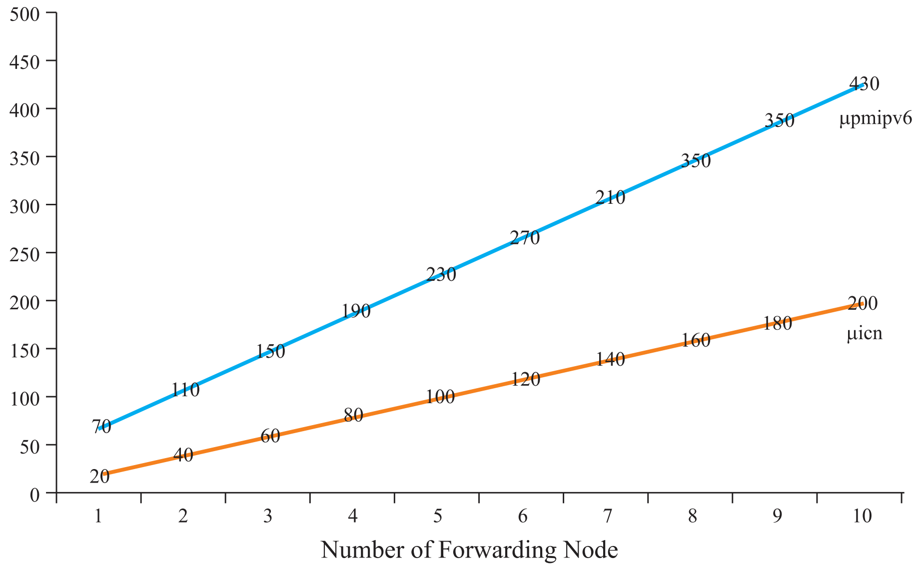

FIG. 4. SERVICE RECOVERY TIME FOR ICN AND PMIPV6 VERSUS NUMBER OF FORWARDING NODE

In this paper the packet loss cost [26] is calculated from the packet arrival rate and service recovery time of Figs. 3-4. Table 2 describes the packet loss cost performance metrics used.

The packet loss cost is noted as α. While the packet loss cost for PMIPv6 is denoted as α_{pmipv6} described in Equation (3) and further derived in Equation (4). However, in case of ICN, the packet loss cost is denoted as α_{icn} described in Equation (5) and further derived in Equation (6).

$$\alpha_{pmipv6} = \delta_t (\mu_{pmipv6}) \tag{3}$$

$$\delta_t(\mu_{pmipv6}) = \delta_t(\beta_{pmipv1} + \beta_{pmipv2} + \beta_{pmipv3} + \beta_{pmipv4} + \beta_{pmipv5} + \beta_{pmipv6} + \beta_{pmipv7}) \tag{4}$$

$$\alpha_{icn} = \delta_t (\mu_{icn}) \tag{5}$$

$$\delta_t (\mu_{icn}) = \delta_t (\beta_{icn1} + \beta_{icn2}) \tag{6}$$

Fig. 5 shows the packet loss cost for both ICN and PMIPv6 where the effect of increasing packets arrival rate is investigated. ICN has a lower packet loss cost compared to PMIPv6. The packet loss cost for PMIPv6 increases substantially as the packet arrival rate increases.

The results confirm that the ICN network simplify the handover process for IoT mobility. The ICN leads to reduction in the service recovery time and low packet loss cost. The multicast packets of PMIPv6 however require the packets to go through many paths which eventually lead to more service recovery time and higher packet loss cost. In IoT mobility multicast traffics, especially for the real-time video applications the multicast session must remain continuous in order to provide good service. Hence ICN has the promising capability to provide better performance for IoT Mobility.

TABLE 2. PACKET LOSS COST PERFORMANCE METRICS

Parameter	Description	Value
δ_t	Packet arrival rate	10 -100 packets/sec
μ_{pmipv6}	Service recovery time PMIPv6	70 ms
μ_{icn}	Service recovery time ICN	20 ms

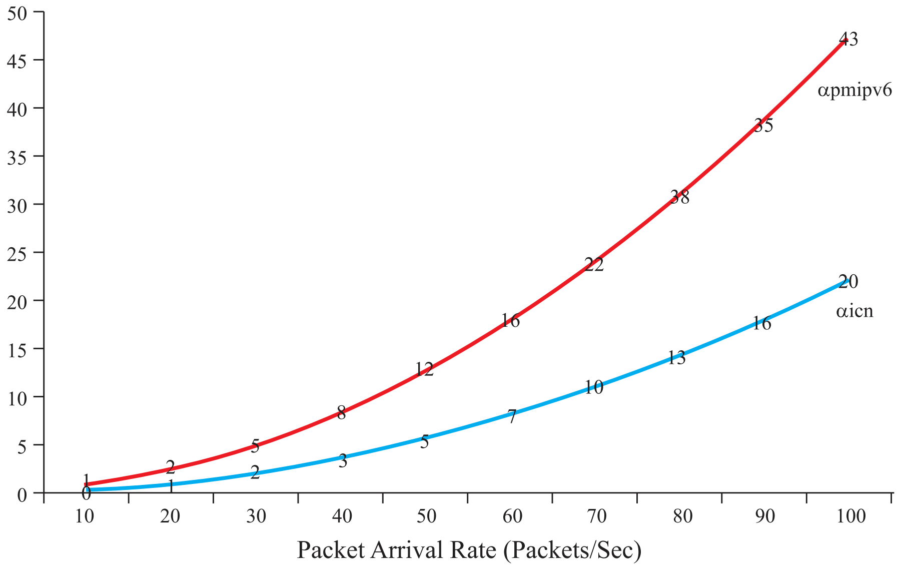

FIG. 5. PACKET LOSS COST FOR ICN AND PMIPV6 VERSUS PACKET ARRIVAL RATE

6. CONCLUSION

This paper qualitatively measures the handover proses of IoT in two different networking approaches namely the ICN and the PMIPv6. The crucial parameters which are packet loss and service recovery time are generated from the handover process flow. The results revealed that ICN is a very promising research infrastructure as it showed the best performance in handover process for IoT. ICN provide lower packet loss rate and service recovery time. It can be concluded that ICN is proficient in handling IoT mobility. However, the limitation of this research is the absence of simulation evaluation, and infrastructure scalability and security. Therefore, further research will be done via simulation and will cater scalability as well as security issues. In addition, recommendations and suggestions to improve the existing research will be proposed.

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