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Supporting Seamless Mobility for Real-Time Applications in Named Data Networking

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Abstract

Named Data Networking architecture originally provided consumer mobility by design, however content or producer mobility was left unspecified. Since then a number of producer mobility support schemes have been proposed. In this paper, we provide a survey on the most relevant proposed techniques to support mobility in NDN. We classify these mobility support techniques into categories based on their underlying mechanisms of explicit notification, routing, indirection, mapping, and proactive caching. We discuss their strengths and weaknesses, and investigate their appropriateness to accommodate real time requirements necessitated by most of today traffic.

Keywords: Named Data Networking, Content Centric Networking, Producer Mobility, Consumer Mobility, Mobility management

1. Introduction

Since its inception back in the sixties, the Internet has undergone a host of development and innovations to cope with the progress in communication technologies as well as to accommodate different user behaviors and traffic types. The current Internet is facing many challenges, the most crucial of which are device mobility and data content. Research in industry and academia are focusing on how to efficiently design the next-generation Internet, how to overcome the current vulnerabilities and weakeness, and how to achieve sustainable emergence [1].

User mobility support is one of the main concerns urgently needed to be addressed [2]. Recent statistics issued by Cisco [3], estimated the Internet traffic to have an annual global traffic surpassing the zettabyte (ZB) threshold in 2016, and the 2.3 ZB threshold in 2020. The Internet video traffic will attain 82% of all Internet traffic by 2020. The mobile traffic is estimated to increase eightfold between 2015 and 2020, and the global mobile data traffic is estimated to grow three times faster than the fixed IP traffic. These predictions have motivated the development of Information-Centric Networking (ICN) [4].

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The ICN paradigm is shaping the future Internet architecture by focusing on the data itself rather than its hosting location. This represents a radical shift from a host-centric communication model to a content-centric model that supports among others unique and location-independent content names, in-network caching and name-based routing. Some of the well-known ICN approaches that have been recently explored are Named Data Networking (NDN) and its predecessor the Content-Centric Networking (CCN)[5 6], DONA[7], MobilityFirst[8]. Among those NDN stands out as the most promising candidate[9], and as such, we restrict our attention in this paper to NDN.

NDN can use IP services such as inter-domain routing policies and Domain Name Service (DNS) because its basic design is based on the Internet. With little modification, the IP routing protocols such as Open Shortest Path First (OSPF) and Border Gateway Protocol (BGP) can be borrowed to the NDN. However, NDN has its own enhanced features. First, the data packets do not have source and destination addresses, but instead each data packet has a content name, and therfore it is independent from its source and destination. Contents are signed by their producers and verified by their consumers. Multi-path forwarding is also supported in NDN, thus the request can be forwarded at the same time to multiple interfaces. In-network caching plays a central role in NDN so that contents may be obtained from nearby caches rather than from distant hosting locations. NDN inherently supports consumer mobility. However for scalability purposes, the separation between location and identity is partial in NDN[4]. As such supporting the host (or producer) mobility remains a real challenge. With the constantly growing proliferation of mobile devices, it becomes essential to find efficient ways to support mobility. Standard protocols were developed for the Internet, such as Mobile IP (MIP)[10] and Proxy Mobile IP (PMIP)[11]. The underlying ideas of these standards are also borrowed into the NDN, and most of the NDN solutions to support mobility are more or less derived from these protocols. In this paper, we review the most relevant proposed techniques to support seamless mobility in NDN, and identify their strengths and weaknesses. Besides, we classify the proposed techniques into some useful categories based on their operational mechanisms of explicit notification, routing, indirection, mapping, and proactive caching The paper is organized as follows. Section 2 describes the NDN communication model and the way it supports producer and consumer mobility. Section 3 gives an overview about different approaches proposed in the literature to support the seamless mobility in NDN. We qualitatively compare these approaches in section 4, present and discuss their advantages and weaknesses. Finally, we conclude the paper in section 5.

2. NDN Communication Model

NDN adopts a simple communication model using two types of packets: Interest packet and Data packet. The communication is initiated by the consumer device by broadcasting an Interest packet about a named content over all available network faces. The Interest will be forwarded in the network hop-by-hop until reaching the content provider or a node storing (caching) the content, which will reply with the Data. The Data packet retraces back the path followed by of the Interest packet to be delivered to the consumer(s). To maintain a strict flow balance, the Interest and Data packets are one-for-one, so data is transmitted only in response to an Interest. Each NDN node maintains three data structures: 1) Content Store (CS), 2) Pending Interest Table (PIT), and 3) Forwarding Information Base (FIB). The CS is used as a cache to store recent retrieved data contents. The PIT serves to keep track of the Interests requesting faces. The FIB is the routing engine which provides the next hop face(s).

It is quite simple to support consumer mobility in NDN. When a consumer moves, it can re-send the Interest packet from the new location for any unsatisfied Interest. This can be done seamlessly because no registration is required[12]. The new request for the content will be satisfied by the first common router between the old and new routers. It has been already shown that the NDN can satisfy up to 97% of the consumer interests during high mobility situations[13]. However, it is a challenging task to support provider mobility because it necessitates the updating of the FIBs pointing to this provider. This requires from the routing protocol to advertise the new content prefix which would amount to a high overhead under high-mobility situations. Changes in topology forces the provider device to be inaccessible during the hand-off. The inherently support of ''multi-sourcin'' (e.g. multiple caches) mitigates this problem[12]. However, still a long delay is encountered under high mobility scenarios, since the ratio between the capacity of the cache and the number of the contents in the network should be around (10^{-5}) according to[2]. To sum up, NDN still can not satisfy the requirements of real-time applications[14,15].

For scalability purposes, the separation between the location-identity is only partial in NDN[4]. Although the content name is decoupled from the location, this does not mean that the content name is completely separated from its