A QoS-Aware Software Defined Mobility Architecture for Named Data Networking

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***Abstract*—Named Data Networking (NDN) is a future architecture for the internet and is an inventive model to provide content-based services. The unique properties of NDN, like naming schemes for network packets and approaches for in-network caching, makes it more reasonable for content distribution. However, extreme changes are required in the existing network infrastructure in order to implement NDN on it. One of the primary research dimensions for this new internet architecture is mobility. Although some research work has been done to address mobility concerns, there are still mobility issues like maintaining the connection establishment by frequently changing the position of users, loss of interest and data packets, interest and data packet transmission and re-transmission without any correspondence delay. One of the reasonable approaches is the Software Defined Networking (SDN) technique, which is used to realize mobility management for NDN. The core concept of SDN is the separation of the network control plane from the data plane. The data plane is capable of data forwarding, whereas the control plane is responsible for the entire network's control. The network control plane is decoupled from the data plane, resulting in a more programmable environment and the ability for external software to define a network's behavior. The SDN's main features, such as programmability, flexibility, and centralized control, make it a simple and scalable network. To cope with the issue of NDN mobility, we propose the design of a software-defined mobility architecture for NDN in which the SDN paradigm is extended to support mobility handling in the NDN architecture. Moreover, the intra-domain and Inter-domain handover handling scenarios in the software-defined mobility architecture for NDN have been described.**

***Index Terms*—Software Defined Networking, Name Data Networking, OpenFlow, Mobility Management, Handover Handling, Internet-of-Things**

I. Introduction

Presenting a new tool towards the Internet of Things (IoT), the current network platform is suffering from effective content distribution because of IP base routing, host to host data sharing in nature and location dependent on IP. This causes an increase in the complexity of the overall internet architecture. To overcome these difficulties, a new future internet architecture known as Information Centric Networking (ICN) has been introduced. The basic idea behind the ICN architecture is the separation of data (service) from the actual devices storing (providing) it through location independent naming [1], [2], [3]. ICN provides an opportunity to use name-based routing instead of IP-based, which is location independent and equipped with a cache for storing the content in order to provide better content distribution for consumers. The ICN intends to move the present Internet replica from a difficult one to a straightforward and standard one. The essential networking unit is no longer the distinguished node (servers, switches, terminals).

All activities of the network are performed on the basis of name content objectives in ICN. In ICN architecture, when a user shows their interest in specific content, the content would be searched in the router. If it is found, the content would be delivered to the user. So, there are different features of ICN like name-based routing, location-independent naming, local multicast, self secured content, and so on [4]. Several ICN architectures have been proposed, including Data Oriented Network Architecture (DONA), Content Centric Networking (CCN), Publish Subscribe Internet Routing Paradigm (PSIRP), Network of Information (NetInf), and Named Data Networking (NDN) [5]. NDN is a future architecture for the internet that has become known as an alternative architecture to the traditional IP-based networking using name for routing instead of IP and storing the data in a cache for the purpose of content distribution such as video streaming, audio, and Peer to Peer (P2P) data sharing services in an efficient manner [6], [7], [8]. The interest packet keeps some information like the name of the requesting content and the data packet, which consists of some information like digital signature, signed information, etc. NDN also supports consumer mobility. There are several issues occurring in consumer mobility, like connection establishment, data packet forwarding, and correspondence delay.

A. Contributions of our proposed framework

In this paper, our main contribution is the integration of the SDN architecture into the NDN to provide better mobility:

- The design of software-defined mobility architecture for NDN is presented in which the SDN controllers keep the network topology and link information in order to send the updated routes during the handover scenario.
- If the content resources move from one point to another, it makes sure that the content name space is not replaced in that case.
- To maintain routing stability in the presence of provider mobility.
- To efficiently determine provider mobility and request stuffiness issues, and
- To reduce loss of interest and data packet hand-off delay.

The structure of this paper is categorized as follows. Section II consists of literature review that provides an overview of NDN and SDN architecture. Also provides the literature review about NDN mobility models, and Section III consists of motivation and convergence of SDN in NDN. In Section IV, the proposed scheme design architecture for NDN mobility is discussed. Finally, Section V comprises the conclusion of the paper.

II. Literature review

We have offered a complete literature review in the following parts, such as NDN, its interest and data forwarding mechanism, SDN, its architecture model and review of NDN Mobility.

A. Overview of Named Data Networking (NDN)

NDN is a future architecture for the internet that has become known as an alternative architecture to the traditional IP-based networking using name for routing instead of IP and storing the data in a cache for the purpose of content distribution such as video streaming, audio, and P2P data sharing services in an efficient manner [6], [7], [8]. There are two types of packets in NDN: interest packets and data packets. The interest packet keeps some information like the name of the requesting content and the data packet, which consists of some information like digital signature, signed information, etc. The NDN node consists of three tables: Content Store (CS), Pending Interest Table (PIT), and Forwarding Information Base (FIB). Each table serves a specific purpose; the CS is used to store data locally, while the PIT is used to maintain the interface between the consumer and the FIB as well as the forwarding strategy which is shown in Fig.1. When an interested party arrives at the router for content orientation, the router checks the content data with his name in the CS. If the data is not found in the CS, then the router looks for it in the PIT, which consists of an interests list waiting for data. If the process in the look up table was successful, then it is forwarded to the consumer, otherwise it is checked with PIT for forwarding the interest packet to the provider. The PIT stores all of the interests that a router has sent but has not satisfied yet. If there is no concern entity found, they know that the router neither contains the content nor knows how to provide it from where it comes from, so in this case, the interest packet is discarded. The FIB maintains the forwarding strategy and decides when and where the interest is forwarded [9].

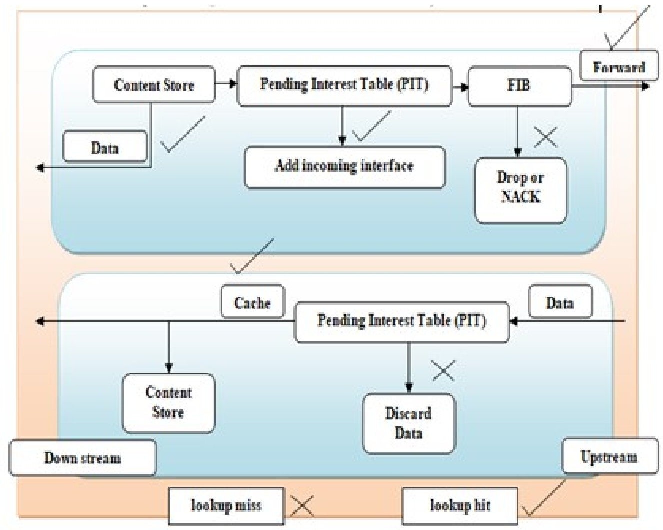

Fig. 1. Interest and Data processing mechanism in NDN [10]

B. Software Defined Networking Architecture Model

The basic idea behind SDN is the separation of the network control plane from the data plane. There are three layers in SDN architectures, i.e., the infrastructure layer, control layer, and application layer. On traditional networks, the traffic will be forwarded in a distributed manner, which means that they will have no global view of the entire network. On the other hand, the SDN controller will have a global view of the network because they have logically centralized control.

C. Infrastructure Layer

There are several network devices, such as switches or routers, in the infrastructure layer that can communicate with each other and share information. Two functions are performed by these devices: collecting information for network status, storing it temporally, and sending it to the controller. Moreover, the second is to process the packet under the specific rules that are applied to the packets by the controller [11].

D. Control Layer

The control layer is responsible for handling the network traffic. It is the middle layer of SDN, which is connected to both the infrastructure and application layers [12].

E. Application Layer

In this layer, different APIs are designed for various purposes and are implemented on devices by the use of north bound interfaces [12].

F. Review of NDN Mobility

In [5], the author presented a new networking paradigm known as ICN. Through this survey, they examine different key perspectives, for example, methods for naming and routing, in network caching approaches, and features that define the advantage of actualizing ICN, open research problems, and new attractions in this area. An NDN communication model for user mobility was described by the author in [13], in which the interest packet and data packet are sent as a single transaction unit. In order to create the link for transactions, this study presented a Mobility Link Service (MLS) that operates in NDN. The key benefit of MLS is that it reuses the current connection for a transaction rather than making a new connection since users' locations constantly shift. The current connection is damaged and partial data reception is caused by handover if a consumer moves away from the neighbor's node or changes its location. Therefore, in this instance, the connection is restored rather than establishing a new connection, and then a new interest is requested for content from the new NAR. So, the old NAR transmitted the data to the NDN producer, and the NDN producer provided data to the new NAR that the user requested for the remaining content [13]. The transaction is done through an IP-based architecture, which is described in scheme [14], which creates a simulation environment for the NDN architecture to examine the performance when a mobile consumer is moving from one point to another in order to check the generation rate of the interest packet using ndnSIM in the NS3 simulator. Initially, when a mobile consumer generates an interest packet, it is encapsulated with an IP header and transmitted to the NDN node by means of the associated AP. When it reaches an NDN node, it removes the IP header from the packet to de encapsulate it, and thus the packet is forwarded on the NDN layer. Moreover, the NDN node returned data packets in encapsulated form along with an IP header and transferred them to mobile customers [14].

SDN is a developing technology that may be used in a variety of fields, including VANET, IoT, WSN, cloud computing and ICN. In [15], the author introduced a system called SDN-RMbw. In [16], the author describes SDN functions that have been included into the NDN architecture to simplify communication between nodes, switches, and controllers. They investigated the impact of the SDN approach on the ICN network. In more detail of the SDN environment when using Open-Flow, the process will be described as in [17] where a strategy is suggested which depends on hashing content names in the IP packet's address field. To actualize this strategy, the User Datagram Protocol (UDP) and Open Flow 1.0 are utilized. The NDN packets are encapsulated into a payload that is part of the UDP packet. There are two different port numbers which are devoted to interest and data packets. This makes the routers ready to recognize these two NDN packets and furthermore perceive IP packets from NDN packets; consequently, the switches can work with both NDN and IP structures. The NDN routers must have the capacity to perform Longest Prefix Matching (LPM) on packet names; there is no standard in the Open Flow protocol for coordinating packet payloads. Accordingly, the names are hashed and put into the IP field of the packet header.

III. Motivation

The whole idea behind ICN is to take care of the limitations of IP networks by name base routing using in network caching in order to save bandwidth utilization and be location independent to access the content for forwarding it to multi path as well as mobility management. The basic idea behind the current internet architecture is that communication is done through client and server conversations and the exchange of information from one point to another. NDN changes the attention of networking from locations (origins and destinations) to the information itself through special routers that are equipped with cache, and these routers consist of three tables that are CS, PIT, and FIB through which the data can be accessed, and the network will not suffer from connecting to a server by requesting information itself [18].

A. Convergence of SDN to NDN

NDN is a future internet architecture that has attracted a lot of research in recent years. NDN is known as an alternative architecture to the traditional IP-based networking using names for routing instead of IP and storing the data in cache for the purpose of content distribution such as video streaming, audio, and P2P data sharing services in an efficient manner [4], [5], [6]. But the current architecture of NDN has been facing many difficulties, like less flexibility, less programmability, less security, and less scalability in the deployment of services on a large scale. The convergence of SDN and NDN can play an important role in addressing these challenges. The distinguishing features of SDN, such as its flexibility, programmability, and dynamic network resource allocation, can help to fulfil the performance and management requirements of NDN. In NDN, we mean that the data has multiple locations and the SDN decides the location for the data through which the data is forwarded to complete the user request in order to maintain the information flow and network stability. In more detail, if the data already exists in the router cache, the SDN can discover the routes for data transmission. SDN routing not only improves efficiency, scalability, flexibility, and security, but it can also put everyone in a good position to transition to a new network architecture in a simple and easy way [18].

IV. Proposed Scheme

This paper presented the design of a software defined mobility architecture that adds to the QoS in mobility management by introducing the concept of SDN technology.

A. Proposed Software Defined Mobility Architecture for NDN

We will proceed towards an SDN based NDN design after a thorough evaluation of the literature and a thorough understanding of these two networking developments (NDN and SDN). Because of their features and real world applications, these two developing technologies (NDN and SDN) are currently being considered and developed. As a result, designing an effective mobility strategy for SDN based NDN architecture is critical. To address this, we create a design of a software defined mobility architecture for NDN that is both efficient and effective. The suggested software defined routing mobility and network model are explained further down.

B. Network Model

The proposed SDN architecture consists of three planes, i.e., the management plane, the control plane, and the data plane. The management plane consists of different APIs designed for various purposes and implemented on devices by the use of north bound interfaces, while the control plane controls all the router actions that are applied to receive and disseminate traffic to handle the network performance, and the data plane consists of forwarding devices that forward the packets, including interest and data packets. A mobility management application is required for the integration of these controllers to cooperate with each other in the control plane. The communication between the mobility management application and the SDN controller is done through north bound interfaces. Communication between the SDN controllers is done on an east-west bound interface in order to enable the work distribution of mobility management applications. However, for the interaction of the control and data plane, a southbound interface is used through which the controller has a clear scope of the state of the Mobile Consumers (MCs) as well as the devices to forward the packets to and from the MCs. In our designed architecture, there are three network components, which are: user (MC), NDN router, which consists of an NDN Access Router (NAR) as well as an NDN producer, and the SDN controller.

A. User

User must be able to push or pull the data to or from NDN. In case, if a user wants to publish the new content into network, can easily publishes it, and if a user wants to access data from the network it will send an interest to the NDN containing name.

B. NDN Router

NDN router is responsible for packet forwarding and caching the name data. Every NDN router contains three major data structures: the FIB, the Content Store (buffer memory), and the PIT. The PIT keeps track of all interests and maps them to network interfaces where relevant requests are received. Using this state, data is then routed back via the reverse request path. NDN enables on path caching, which means that a content object may be cached such that subsequent requests for the same item can be answered from the cache (CS). The memory capacity required for a given traffic reduction is determined by the size and popularity distribution of the object population [19].

C. Communication Process

NDN routers can interact directly with the controller (for example, by sending report messages) or via a neighbors (Open Flow) OF-switch, which sends reports conveyed in a packet-in (the OF switches send unknown packets to controller). All of these methods leverage the Open Flow channel as well as Open Flow protocol and control messages, such as traffic control messages [19].

D. SDN Controller

The SDN controller has the clear scope of the state of the MC. So, the SDN controller identifies the parameter for routing, about the user mobility concerning the launch of a specific protocol.

C. Overview of Proposed Software Defined Mobility Model for NDN

The notion of SDN technology was used in this section to describe the software defined routing mobility for NDN.

D. Initialization phase

When the first time an MC is attached to an edge router, which is connected to the NAR that is programmed by the network controller to support NDN transactions, The NDN node consists of CS, PIT, and FIB. When an interest arrives in the router from a mobile consumer for content orientation, the router checks the content data with his name in the CS. If you find the requested data in CS, send it to the consumer. If the data is not found in the CS, then the router looks for it in the Pending Interest Table (PIT), which consists of an interest list waiting for data. If the process in the lookup table was successful, then it is forwarded to the consumer, otherwise it is checked with PIT for forwarding the interest packet to the provider. If there is no concern entity found, we know that the router neither contains the content nor knows how to provide it from where it comes from, so in this case, the interest packet is discarded. The FIB maintains the forwarding strategy and decides when and where the interest is forwarded. Actually, the edge router is an IP router that is connected to the NAR. How it works: Initially, when a mobile consumer generates an interest packet, it is encapsulated with an IP header and transmitted to the NDN node by means of the associated AP. When it reaches an NDN node, it decapsulates the packet by removing the IP header, and the packet is then forwarded to the NDN layer. Then, again, at the NDN node, the returned data packets are encapsulated with an IP header and transferred to the mobile customers [20]. There are two types of handovers: intradomain handover and inter-domain handover.

E. Single SDN controller scenario

If a MC moves from NAR-1 to another NAR-2 within the range of a single SDN controller or if the content source and MC belong to single controllers, we say the single SDN controller scenario case in inter-domain handover handling. In order to be aware of this movement with the help of notifications, The SDN controller then modifies the routing table, which contains the ID of MC, its content name, and interface, and sends new flow entries to the NDN Access Router (NAR). The NAR updates the routing table, and the packets are forwarded to MC as shown in Fig.2.

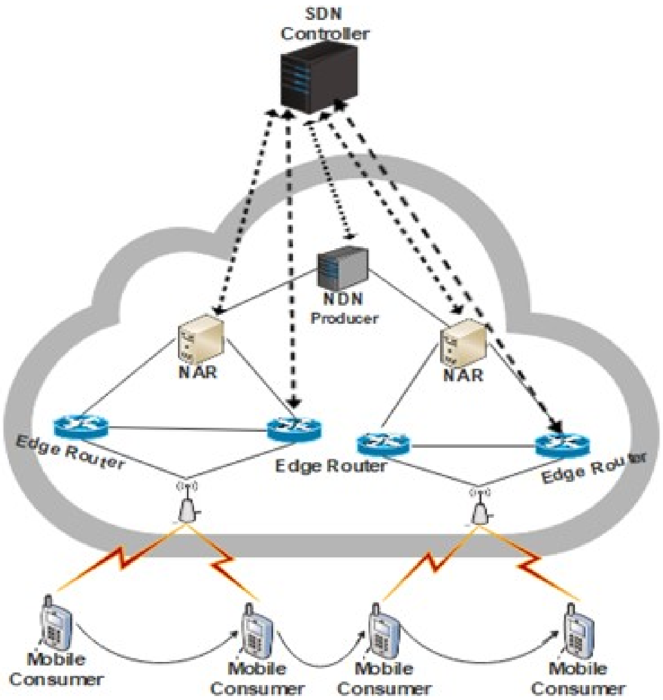

Fig. 2. Single SDN controller Scenario

F. Intra Domain Handover Handling Scenario

When MC moves from one NAR-1 to another NAR-2, the following process is required:

1. First, it sends a handover initiation message to NAR-1.

2. When NAR-1 receives the handover message from MC, it is forwarded to the SDN controller. So, the SDN has a clear scope of the state of the entire movement.

3. When MC comes within range of NAR-2, it sets up the connection with NAR-2 and sends a handover completion message to NAR-2.

4. When NAR-2 receives the handover message from MC, it is forwarded to the SDN controller.

5. So, the SDN controller decides on the flow entry, and a new routing table is sent to the NARs. So, in this order, the packet is forwarded to a new attachment point, which is NAR-2 from NAR-1 as shown in Fig.3.

G. A Multi SDN Controller Scenario

If an MC moves from one SDN controller to another, or if the content source and MC belong to different controllers, the different controllers are engaged for system initialization and handover handling.

H. Inter Domain Handover Handling Scenario

If a consumer changes its position, which is part of a different node, i.e., changes its domain and enters into the area of another domain, the inter-SDN controller communication is required to handle the movement of MC. Fig.4 shows an inter-domain handover handling scenario in which the MC moves from source NAR-2 to source NAR-3 and from source NAR-3

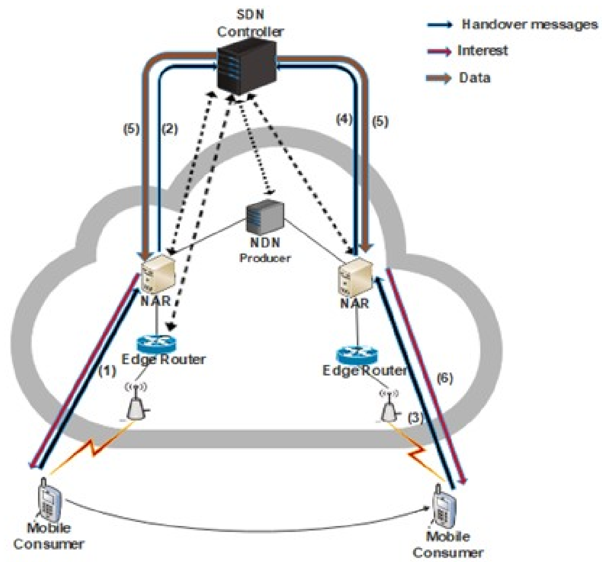

Fig. 3. Intra domain handover handling scenario

to source NAR-4 that belong to different SDN controllers. The following steps are required:

1. First, it sends a handover initiation message to NAR-1.

2. When NAR-1 receives the handover message from MC, it is forwarded to SDN controller-1. So, the SDN has a clear scope of the state of the entire movement.

3. When MC comes within range of NAR-2, it sets up the connection with NAR-2 and sends a handover completion message to NAR-2.

4. When NAR-2 receives the handover message from MC, it is forwarded to SDN controller-2.

5. If an MC changes its domain and enters the area of another domain, inter-SDN controller communication is required to handle the movement of the MC. In this case, it enters into the area of another domain and connects to NAR-3, which is located in the area of SDN controller-2.

6. When NAR-3 receives the handover message from MC, it is forwarded to SDN controller-2.

7. For instance, a method is applied, i.e., first of all, the SDN controller-2 makes a query for the previous controller, SDN controller-1, to notify them of the MC's movement and also route information with the help of an update routing table through which the packets are forwarded to the new attachment point, which is NAR-3. So, for this instance, the process is continuing for SDN controller-3 until the new attachment point, which is NAR-4 [21-23].

V. Conclusion

In this paper, we have designed a software defined mobility architecture for NDN in which the SDN controllers keep the network topology information in order to send the updated routes during the handover scenario. Consumer mobility sends a handover initiation message to the NDN router for the first time when the user is connected for a transaction. The router receives the handover message and forwards it to the SDN

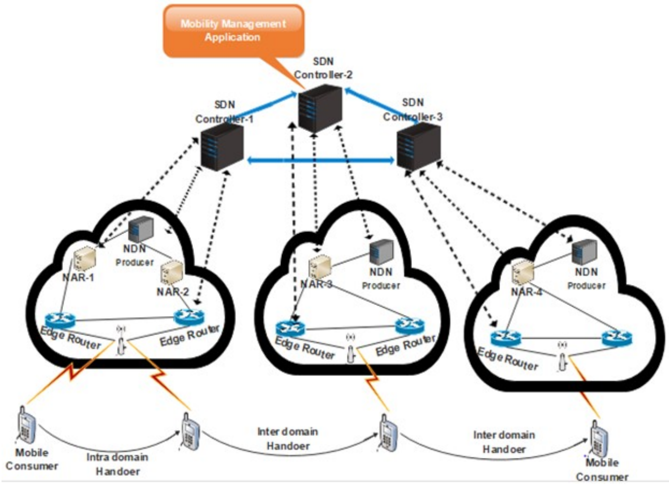

Fig. 4. Inter domain handover handling scenario

controller. When a user comes into range of another router, it sets up a connection to that router and sends a handover completion message to that router. When a router receives the handover message from a user, it is forwarded to the SDN controller. So, the SDN controller decides on the flow entry, and a new routing table is sent to the NDN routers. In this order, the packet is forwarded to the new attachment point. This architecture addresses the issues like connection corruption due to handover, data not being received completely, packet transmission delay, etc. and can take care of advantages like scalability, flexibility, programmability, centralized control, and dynamic network resource allocation. It can help to fulfil the performance and mobility management requirements for NDN. The future works include demonstrating the scenarios in Mininet and Opnet with improvements for security [24-25].

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