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Research paper

Comparison of Forwarding Mechanism Between IPv4 and Named Data Networking (NDN) Case Study: Network Congestion

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Abstract

A routing mechanism which is used by Internet Protocol version 4 (IPv4) is stateful and adaptive. It updates and chooses the best candidate of several routes based on its routing table information. Nonetheless, its forwarding mechanism is stateless, because it just forwards packets to router's neighborhood based on information in its routing table called as Routing Information Base (RIB). Indeed, if there is a network congestion, and the RIB is still not update, its forwarding mechanism cannot find an alternate link. There is a different mechanism, namely Named Data Networking (NDN). It is a content-oriented network architecture. Packets which are sent only bring Name of data exchanged and do not include their IP addresses. A consumer is going to request in the form of Interest packets to a nearest node. The neighborhood router can manage several Interest packets if their status are still pending. This status management is part of NDN forwarding mechanism and provides an advantage which NDN based router can measure performance of multiple paths and also can use alternative ones if there is a network congestion, although its RIB has still not been updated. This mechanism can be achieved by comparing an arrival time of Interest packet with an arrival time of Data packet (Satisfied Interest). Yet, the change from IP network architecture into NDN network architecture requires substantial requirements. Upgrading hardware and software can be very expensive, but it is not necessarily provides a clear advantage. Surely, it is too risky. To reduce that risk, simulations are created to compare a performance of both network architectures. This research describes how NDN forwarding mechanism can find alternate paths and also uses a multipath forwarding mechanism when a network congestion happened compared with IP based forwarding mechanism. This research is based on network simulations and gives an explanation that NDN network architecture, especially its forwarding mechanism gives more advantages than the other one.

Keywords: *NDN, IPv4, forwarding mechanism, multipath forwarding, network congestion*

1. Introduction

A network architecture design determines the shape of its packets forwarding mechanism. Delivering packets using a router based on IP architecture is done in two phases.

First, each Routing Information Based (RIB) of routers is going to exchange its updated routing table information, thus constructing a new routing table for choosing the best route candidate (Black, 2000). Second, Forwarding Information Based (FIB) are going to follow the best route determined by the RIB. Routing in Internet Protocol (IP) is adaptive and stateful, because it can update and choose the best route adaptively based on its RIB. Even so, its forwarding mechanism is stateless, because just follow the information from the RIB to forward its packet (Black, 2000).

In NDN architecture, the packets are going to be identified by its Name of content (Arjunwadkar, 2014). The identifier is not recognized by source or destination address (Yi, Afanasyev, Moiseenko, Wang, Zhang, & Zhang, 2013). NDN forwarding mechanism is not the same as host centric or IP architecture (Arjunwadkar, 2014). In the NDN, a consumer as a node which requests data is going to send a request packet called Interest packet to the nearest router. Then the router is going to forward it to the neighborhood node and saves the packet status if there is pending Interest packet. Actually, this Interest maintenance is a mechanism to track Data from the consumer back to a producer. This mechanism makes NDN router can measure the performance of lines, such as to detect network failure and to find alternate paths, including to do multipath mechanism (Yi et al., 2013).

In this research, simulations to compare forwarding mechanisms between both of those architectures are going to be created. The simulations use a network congestion case. The simulations use a network background traffic which is generated by a packet traffic generator for making network resources become overload. The goal is to determine the extent of treatment which is made by both of forwarding mechanisms for addressing a network congestion.

2. Related Works

Host to host still becomes a popular network protocol for communication which its determination is made by the IP protocol. Each packet which is transmitted to the network is labeled with the source address and the destination address. For routing, Routing Information Base (RIB) is going to periodically update its routing information and select the best candidate from several routes to construct an IP routing table. On the other side, Forwarding Information Base (FIB) maintains maximum next-hop address information based on information from the IP routing table. So it can be said FIB policy just follows the routing table information (RIB) to choose the best path that is going to be passed the packet. The routing mechanism in IP is stateful and adaptive. However, the IP forwarding mechanism is stateless and is not adaptive because only follows the information based on the routing table to forward the packet to a next node (Black, 2000).

Basically, FIB function of the IP router or the NDN router has the same function, which forwards the packet to the next-hop. The difference is the FIB function of the IP router generally only contains information about a next-hop which is the best. FIB function of NDN router has an ability to measure and find alternate route. It makes FIB function of NDN router is adaptive (Yi et al., 2013).

The NDN router has three main components, namely Content Store (CS), Forwarding Information Based (FIB), and Pending Interest Table (PIT) (Zhang, Estrin, Burke, Jacobson, Thornton, Smetters, Zhang, Tsudik, claffy, Krioukov, Massey, Papadopoulos, Abdelzaher, Wang, & Crowley, 2010; “Named Data Networking: Motivation & Details,” n.d).

The CS function is similar with a buffer memory of the IP router, but it has different characteristic. Content in the IP router buffer is going to be automatically deleted when the packets are delivered. The buffer of the NDN router is reusable, so that each packet which is stored in the cache has to be potentially used by many consumer (Zhang et al., 2010).

The FIB is used to transmit Interest packet to the node which has an appropriate Data. The FIB function of the NDN router is almost similar to The FIB of the IP router. The difference is the FIB of the NDN router allows data comes from many sources and can process all of them in parallel, while the FIB of IP router only receives information from a single-hop neighbor (router) (Yi et al., 2013).

The PIT keeps track of Interest packet which is sent from a requester by leaving trails (bread crumbs), hence Data packet from the producer can be returned to the requester in a way trace back through the paths that has been made. When the Data packet is found, then the Data packet is going to be sent to the requester in a manner directly trace back and is going to remove the bread crumbs (“Named Data Networking: Motivation & Details,” n.d). Thus, by removing of bread crumbs, the NDN router only knows that there is the requester which requests Data packet, but does not know about information of the requester, including what address which is used, because labeling on the Data packet does not use IP address (Arjunwadkar, 2014).

The FIB entry of the NDN router owns multiple interfaces information which has been ranked (based on routing preference, RTT, status, and rate limit) to be able to support adaptive forwarding (Yi et al., 2013).

The FIB of the NDN router is going to maintain RTT when Data packet is received at each interface. RTT estimation is used to configure a retry-timer. Information of the retry-timer is used to hold information of Interest packet which carries the same Name and already recorded in the PIT. Thus, the information is not stored directly in the FIB (Yi et al., 2013).

3. Problem Definition

To implement NDN network requires substantial changes on the routers. For example, upgrading hardware and software are required to be able to support packet transmission based on name labeling, including new mechanism of data caching (Psaras, Clegg, Landa, Chai, & Pavlou, 2011).

To upgrade hardware and software can be very expensive and its risk can be very high. To reduce that risk, simulations can be made for comparing a performance of both network architectures.

Simulations are conducted to determine the link utilization of both network architectures in the form of a network congestion. The simulations are done by comparing the forwarding mechanism between NDN based network and IP based network. As mention above, the forwarding mechanism based on IP routing table is constructed by RIB. Indeed, when the IP routing table has not been updated, and a congestion is happened in a path, then the IP forwarding mechanism is not going to move packet transmission from one path to another, including to use multipath mechanism. Meanwhile, the NDN forwarding mechanism can be adaptive. There is the ranked mechanism for each interface based on estimated RTT. If the RTT value rises, then the NDN router is going to find an alternative path which is available, including to use multipath mechanism (Yi et al., 2013; (Carofiglio, Gallo, Muscariello, & Papali, 2013).

The NDN packet is not given the identity of the source and the destination address, but the packet is sent to search the name of the content itself. In addition, the Content Store could help the distribution of content on the network. The effective caching function of NDN router based on the Content Store can increase the rate of cache hits (Yuan, & Crowley, 2013; Li, Wu, Liu, Lu, Wang, Wang, Zhang, & Dong, 2012).

In this study, a comparison of forwarding mechanism, both in terms of IP and NDN are created by taking a network congestion case. The IP network simulation is created by using NS-3, while the NDN network simulation is made by using NDN Simulator (ndnSIM) based on NS-3. Both simulations use the same protocol, namely the Open Short Path First (OSPF) (Zhang et al., 2010).

4. Proposed Solution

This study is going to analyze the link utilization, either on IP based network and NDN based network. The forwarding mechanism is going to be chosen and analyzed for both typical networks. The reason is there is a fundamental difference between the IP forwarding mechanism and the NDN forwarding mechanism. To determine an adaptive capability of those forwarding mechanisms, the network congestion case is going to be selected in this study.

The network topology which uses 13 nodes is selected for both simulations. The topology has a Client Provider (router) which is connected to R1, R4, and R7 (routers). The routers are going to prioritize the data flow through the top links (Client-CP-R1-R2-R3-SP-Server).

The simulation applies 10 Mbps link bandwidth between the client and the Client Provider (CP). It is the same as the link bandwidth between the server and the Server Provider (SP). The capacity of link bandwidth which is implemented on paths that connect Provider 1 and Provider 2 is 1 Mbps. The OSPF protocol is taken as a routing protocol for the simulation.

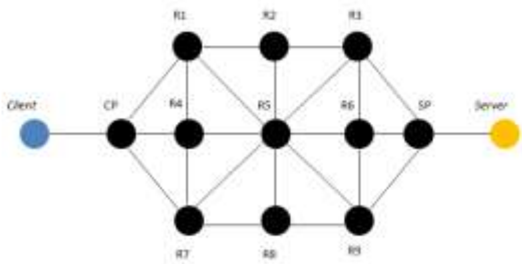

Fig. 1: The simulation topology which uses 13 nodes.

Traffic generator which runs on the simulations is different between IP network and NDN network, but they have the same goal to overwhelm routers with a background traffic so they are going to create a network congestion. The application which is going to be used on the NDN simulation is adapted by one of delivery mechanisms. It is TCP packet which is used in IP protocol (sliding-window). So that, it can be said both simulations (NDN and IP simulations) run the same protocol (TCP).

The IP network simulation is going to use BulkSendApplication class, namely to the class for creating a client application which sends data packets as soon as possible to make the router buffer becomes overload. Only TCP socket is going to be used for this class ("NS-3. A Discrete-Event Network Simulator," n.d.).

The NDN simulation is going to be used ConsumerWindow class, namely class for consumer to generate Interest traffic which is rates change dynamically. These class implements a simple sliding-windows mechanism ("NS-3 based Named Data Networking (NDN) simulator," n.d.). By using this sliding-window mechanism, the sender can send all packets without waiting for ACK of each packet from the receiver. When there is a packet that failed to be received by the receiver, then the receiver is not going to send ACK. However, it is going to wait until the timer of the packet which is failed to be a time out, then the sender is going to retransmit that packet ("NS-3 based Named Data Networking (NDN) simulator," n.d.).

In the NDN simulation, the ConsumerWindow class is going to send an Interest packet ("NS-3 based Named Data Networking (NDN) simulator." n.d.).

5. Results and Discussion

These are the results and analysis of the simulations which describe how IP routers or NDN routers use or switch transfer paths when there is a network congestion on their forwarding mechanism, including link utilization both of the IP network and NDN network simulation.

In the simulation of IP network topology, the packets are going to be sent by client to the Client Provider (CP). Then the delivery arrangement of packets transmission becomes R1-R2- R3-SP-Server.

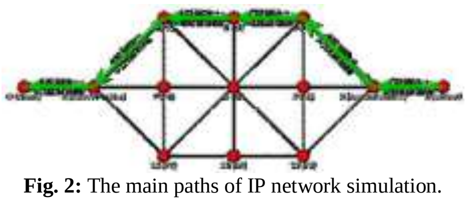

Fig. 2: The main paths of IP network simulation.

Basically, figure 4 is also represents the starting of TCP packets transmission by the client for NDN network simulation. The delivery paths of packets which is used are Client-CP-Provider 1-SP-Server.

Figure 5 represents more packets in the main paths resulting a network congestion in the IP network simulation. Forwarding mechanism in IP network does not perform the change of paths during its routing table has not been updated. As the result, there is no change mechanism for the main paths, including the use of multipath even though the link is experiencing saturation. Drop packets are happened in SP as a mechanism to make buffer becomes empty.

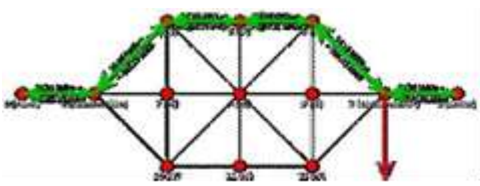

Fig. 3: The network congestion is happened in the IP network simulation.

In the IP network simulation, there is no an adaptive mechanism for its packets forwarding, as a reaction to face a network congestion by switching its transfer lines.

In contrast to the NDN network simulation, its forwarding mechanism makes a response as the increase of RTT value. Because when there is a congestion, the estimated value of the RTT in all routers are going to go up, and the interfaces ranking in all routers in the bottom paths becomes down. So that, an alternate route is expected to restore the data packets with the estimated value of RTT is small (through above paths). It can be seen in the followed figure below:

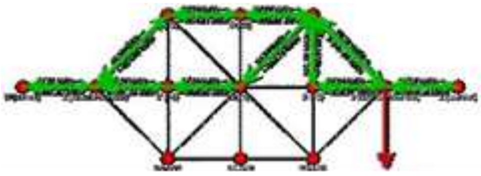

Fig. 4: The network congestion is happened in the NDN network simulation.

The use of multipath is described in figure 6. It occurs in the NDN network simulation as the result of the interface ranking which has the same value after the change of the main paths repeatedly while forwarding mechanism happens. NDN network simulation.

Figure 7 shows link utilization of the NDN network is faster than the IP network which takes 61.01 kbps of bandwidth in 2 seconds, while the forwarding mechanism simulation of the IP network takes 59.39 kbps of bandwidth in 3 seconds. The average bandwidth usage of the NDN network is 31.64 kbps, and 40.23 kbps for the IP network.

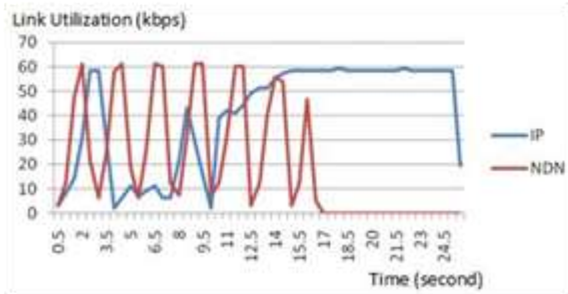

Fig. 5: The link utilization for the main paths

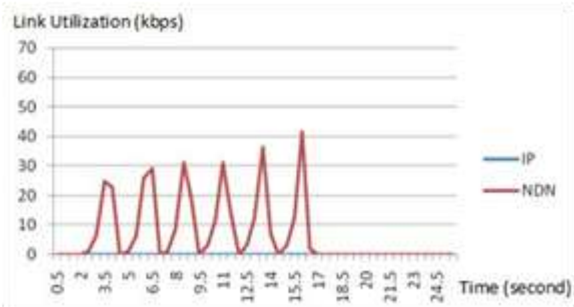

Fig. 6: The link utilization for the middle paths (CP-R4).

By using the multipath mechanism, the NDN network can deliver packets sooner than the IP network. The NDN network can complete the packets delivery in 16.5 seconds, while the IP network completes it in 25.5 seconds.

6. Conclusion

There is no an adaptive mechanism for the IP packets forwarding mechanism, as a response to face the network congestion. It differs with the NDN packets forwarding mechanism, it can make a response as the increase of RTT value as a result of the network congestion. Based on this mechanism, the NDN routers can change their paths to another, including to use multipath mechanism. It can be seen that based on the simulations that the NDN forwarding mechanism can gain more advantage than the IP forwarding mechanism. The NDN network can use the link bandwidth faster than the IP network, including make the usage of the bandwidth more efficient.

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