Performance Comparison of Named Data and IP-based Network—Case Study on the Indonesia Higher Education Network

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Abstract**—**Internet Protocol (IP) has been a universal network layer which implements all the functionality necessary for global interconnectivity, but its point-to-point communication nature is not beneficial to the recent trends which Internet is primarily being used as a distribution network, delivering contents all over the network. Named Data Networking (NDN) is an entirely new architecture aimed to focus on the contents itself instead of the path to get the contents. This research is conducted to compare the performance of NDN to IP-based network in three parameters: throughput, packet drop, and delay. The results show in general, NDN results in lower delay because of the existence of content store. NDN can also outperforms IP in term of throughput, while in some nodes it can also gain same results with IP. Meanwhile, packet loss results in zero loss due to bandwidth channel unfully loaded.

Index Terms— NDN, IP, QoS.

I. Introduction

Internet Protocol (IP) has been a universal network layer which implements all the functionality necessary for global interconnectivity. IP network was designed to create a communication network, connecting endpoints therefore the only entities that can be named in its packets are communication endpoints.

The new mechanism called Named Data Networking (NDN) is a fundamental paradigm shift from the current IP-based Internet architecture. Instead of carrying the destination IP address in each packet, NDN puts a data name in each packet; a data consumer sends out an Interest packet whose name identifies the desired data, and the response is a Data packet containing the name, the data, and a signature by the original data producer.

Considering the nature of IP-based network which is more suitable for point-to-point communication, we are certain that NDN will have its advantage compared to IP in the environment of high demand of large content such as video streaming and downloading. Caching mechanism that exists in NDN node will also play an important role in reducing what was constraints in IP. In this research, we are to prove that NDN performs better than IP in terms of throughput, packet drop, and delay.

The Named Data Networking (NDN) architecture is a fundamental paradigm shift from the current IP-based Internet architecture. Instead of carrying the destination IP address in each packet, NDN puts a data name in each packet; a data consumer sends out an Interest packet whose name identifies the desired data, and the response is a Data packet containing the name, the data, and a signature by the original data producer. By explicitly naming and signing data, NDN enables features such as in-network caching, multipath forwarding, multicast data delivery and data authenticity [1]-[3].

Internet Protocol (IP) has been a universal network layer which implements all the functionality necessary for global interconnectivity. IP network was designed to create a communication network, connecting endpoints therefore the only entities that can be named in its packets are communication endpoints. Recent growth in e-commerce, digital media, social networking, and smartphone applications has resulted in the Internet primarily being used as a distribution network. Distribution networks are fundamentally more general than communication networks, and solving distribution problems via a point-to-point communication protocol is complex and error prone. (Fig. 1)

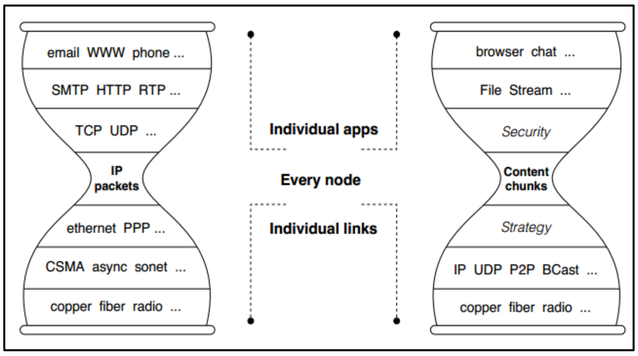

Fig. 1. Internet hourglass architecture [2]

NDN retains the Internet's hourglass architecture but evolves the thin waist to enable the creation of completely general distribution networks. The core element of this evolution is removing the restriction that packets can only name communication endpoints.

II. Methodology and Scenarios

A. Methodology

The steps taken in conducting this research is presented in Fig. 2. The first steps include familiarizing with the

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tools and the way NDN works. After done with first steps, the work continued on gathering information on the parameters by running a simulation both in NDN and IP-based networks.

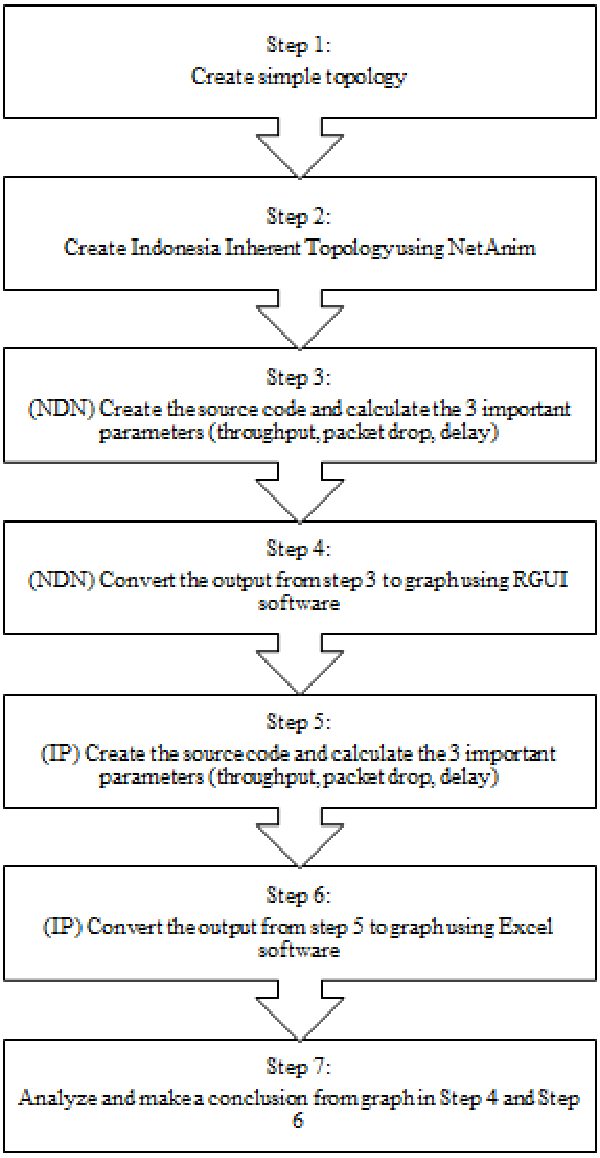

Figure 2. Methodology flowchart

B. *Indonesia Inherent Topology*

Indonesia Inherent Topology is a program initiated by Ministry of Research, Technology and Higher Education of the Republic of Indonesia containing 33 cities in Indonesia which are connected to each other by network links, i.e. fiber optics or satellite, as shown in Fig. 3 which aims to provide higher education institutions with high speed internet. The nodes and their characteristics, including link bandwidth and coordinate, in this topology is used in this research as a reference in the simulation described in the next section.

For the simulations, Network Simulator 3 (NS3) is used as the base simulator to call that topology txt files and run it on ndnSIM. The topology of Indonesia Inherent obtained is shown in Fig. 4. It is formerly realised by using python visualizer module but then presented in NetAnim for a better view.

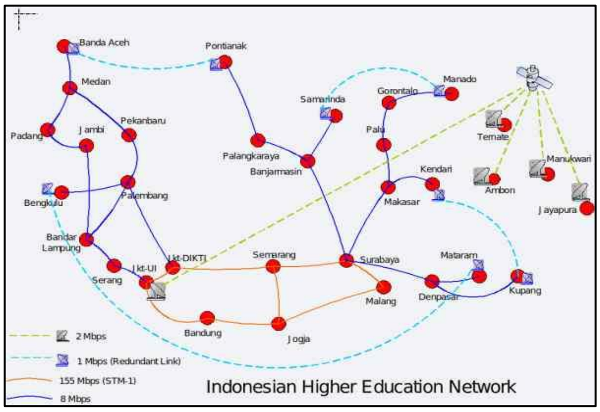

Fig. 3. Indonesia higher education network (Inherent) topology [5]

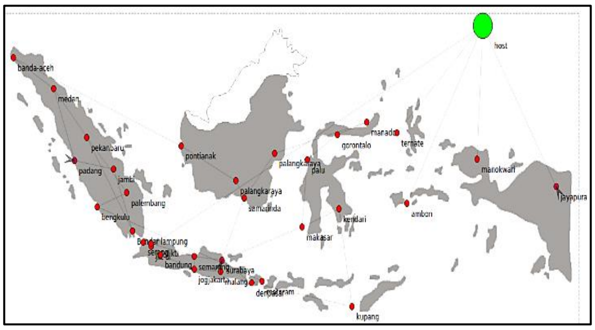

Fig. 4. Inherent topology visualized in NS3 using NetAnim

In NDN scenario, 100 interest packet per second with 1024 payload size and 1000 content store is used. There are 2 producer nodes, i.e. Banda Aceh and Manado, and 4 consumer nodes, ie, Padang, Jkt-UI, Surabaya and Kupang, which we think are representative enough to depict the overall topology because the nodes selected are quite separated to each other. The routing policy used is best route, which, from our observation, is based on calculation of cost (the distance vector algorithm). Among all nodes, only those nodes mentioned before are simulated. The simulation time is 20 seconds.

To obtain same treatment and environment to NDN in IP scenario, we create a programming script for IP and run it over ndnSIM software, similar to what is done in NDN scenario. Through this script, we simulate and calculate 3 important parameters, i.e. throughput, packet loss, and delay, like those we have calculated in NDN, and then compare their performance metrics.

In IP scenario, we use RIP routing, which is similar to best route mechanism in NDN, both of them are using distance vector algorithm. Because the behavior of the routing mechanism is similar in both scenario, we can focus on comparing the performance of IP and NDN.

III. Simulation Results

1) *Throughput*

Throughput is defined as the number of bits, excluding control bits, succesfully transmitted in a time slot [6]. For

NDN scenario, we calculate the throughput for each node using ndn::L3RateTracer class. The output can be seen in rate-trace.txt. To visualize the text, we use RGui to convert from text to graph. Another way to present the throughput value is by using Microsoft Excel, as shown in comparison of NDN and IP graph presented in Fig. 5. Highest throughput is acquired by Jkt-UI, followed by Kupang. This can happen because they are in strategic area where traffic from a node to the destination may go through. Low throughput may occur because the later three nodes are in less strategic area where traffic may pass.

But there is one thing to keep in mind about NDN, which is the existence of content store. The content store is possibly the cause of low throughput in some nodes because nodes that formerly needs information from them no longer need to go straight to the destination because the information has been cached by nearby nodes.

As for the IP scenario, the amount of throughput in each nodes are relatively similar and all of them are lower than those in NDN. It can be because in IP, every information needs to be obtained from its original destination.

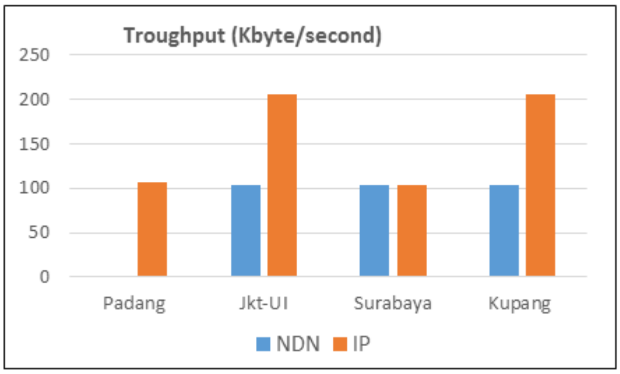

Figure 5. Throughput comparison of NDN and IP

2) *Delay*

Delay can be defined in several ways: the period required to build services, and the period for receiving or sending information [7]. For NDN scenario, we calculate the delay using ndn::AppDelayTracer class.

The output of the tracer is a .txt file which consists of delay parameter and characteristics. Some of the characteristics are the type of delay, i.e. full delay and last delay. From our understanding, full delay is the time required for a packet to arrive from sender to destination by also calculating the length of the packet itself, resulting in a greater delay. Last delay is the time required for a packet to arrive from sender to destination without considering its length, therefore resulting in a smaller delay. We believe that last delay is more representative because it does not involve the packet, but only the path it crosses. Therefore, we use last delay in our measurement.

In IP, highest delay is in node Kupang, Surabaya, Jkt UI, and Padang respectively. This is standard case for IP: the farther the destination, the greater the delay. Delay in each of four nodes, both for NDN and IP are presented in Fig. 6.

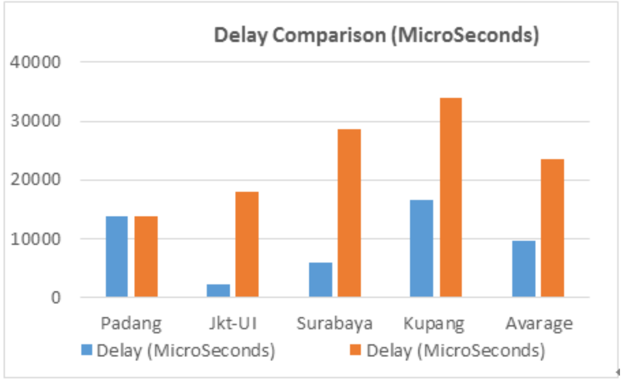

Fig. 6. Delay comparison of NDN and IP

3) *Packet Loss*

Packet drop or packet loss refers to the percentage of packets that are not delivered to their destination. For NDN scenario, we calculate the packet drop rates for each node using L2Tracer class. The result can be seen in file drop-trace.txt. For IP scenario, packet loss is obtained by using Wireshark software, which is equipped with a packet loss counter. To visualize the text, we can use RGui to convert from text to graph or just use Microsoft Excel for ease of use.

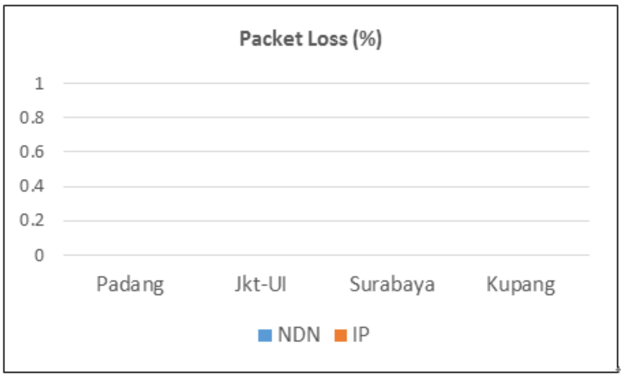

Figure 7. Packet loss comparison of NDN and IP

No packet loss is shown in both NDN and IP, as shown in Fig. 7. For NDN, It is not that in NDN there are no packet loss, but it can be caused other factors. For example, too few producers can result in no packet loss. Another possibility is that the bandwidth are still too vacant in this case. For IP, the case is similar. Because of this, we are quite sure that this is because the bandwidth which is still vacant. Therefore, 5 consumers are not sufficient for obtaining the value of packet loss. In other words, in scenario like this, there will be no packet loss.

IV. Evaluation

Comparasion of three essential parameters of NDN and IP based networks from the simulation on the Indonesia Higher Education Network can be summarized on the Table I.

Throughput parameter in NDN are mainly affected by routing policy, content store, and interest packet rate. Routing policy determines the flow of the packets, such as best route, multicast, or set manually. One of the advantages in NDN is content store which resembles caching mechanism. Larger content store size makes less packet traffic in network because the packets with the same content has been requested and delivered to consumer before will be stored in the node they pass through, enabling that particular consumer or other consumers to obtain the data from the nearest node instead of asking the content to the producer again.

TABLE I. COMPARASION PARAMETERS ON NDN AND IP NETWORKS

	Delay (MicroSeconds)		Troughput (Kbyte/sec)		Packet Loss(%)	
	NDN	IP	NDN	IP	NDN	IP
Padang	13728	13781	0	107	0	0
Jkt-UI	2251	17967	103	205	0	0
Surabaya	5890	28507	103	103	0	0
Kupang	16585	33889	103	205	0	0
Avarage	9614	23536	77	155	0	0

On the other hand, to request some content packet, consumer will generate an interest packet. This interest packet will be responded by producer by sending a content packet corresponding to the request. More interest packet asking for various requests result in more content packets sent and can cause overrun in the network.

Packet drop parameter in NDN are mainy affected by bandwidth and content store. For example, in the first simulation, Banda Aceh node as a producer can only be connected with 8 Mbps and 1 Mbps links. Huge amount of traffic can not be well-accomodated due to insufficient bandwidth, causing congestion in network and resulting in occurrence of packet drop. Content store contributes to solve this problem, reducing volume of traffic in the network because the same requested contents are stored in nearest node to consumer.

The main differences in NDN and IP scenario are IP address and content store. IP uses addressing system, which needs a destination source in order to obtain information. For content store, in IP scenario, there is cache system which resembles the one in NDN, but not practically the same because it is not originally embedded in the routing system.

Throughput in NDN and IP are mainly influenced by existence of content store. In IP-based system, there is no content store, therefore the packet will be requested and transferred to and from consumer and producer every single time, regardless of the demand frequency of the packet. In general, throughput in NDN links should be less than in IP links because NDN stores the same requested content to nearest node at consumer side.

The delay of NDN and IP have been calculated with 5 consumers and 1 producer (Banda Aceh). From data simulation above, average delay in NDN is less than delay in IP, concisely. The existence of content store does not need to ask a content to producer that located far away continuously, the same content can be asked from the nearest node, so the high delay might be reduced.

Due to our simulation scope, both of the simulation result in no packet drop. Therefore, it still can not claim that one scenario is better than another scenario. This may be improved by adding more producers and consumers to make the bandwidth used fully, therefore there is a chance of packet loss occured.

The existence of content store also affects packet drop parameter. The huge volume of traffic which flood the links can congest the links. This congestion leads to packet drop. The functionality of content store is to help reducing huge volume of traffic in the links. It can occur because a requested content will be stored in nearest node from consumer for future use. Therefore, the same requested content can be acommodated by adjacent node.

V. COMPARISON WITH PALAPA RING SIMULATION

To review our results, comparasion with the ones obtained in [9], [10] is discussed. For each performance metrics, new graph and table consisting the acquired parameters in Indonesia Inherent and Palapa Ring topology are presented. The measured value is the average for all sampled nodes. Overall, our simulation compares with the result obtained in [10] as follow:

1) Throughput

TABLE II. THROUGHPUT COMPARASION OF THE INHERENT AND PALAPA RING NETWORKS TOPOLOGY

Throughput (Kbytes/s)	Inherent	Palapa Ring
NDN	82	8233
IP	144	23625

Table II shows the throughput acquired in Indonesia Inherent and both scenario of Palapa Ring. In terms of throughput, IP-based networks yield higher throughput for Inherent and Palapa Ring since there are more traffic passing through the network without the existence of contet store.

2) Delay

TABLE II. DELAY COMPARASION OF THE INHERENT AND PALAPA RING NETWORKS TOPOLOGY

Delay (microseconds)	Inherent	Palapa Ring
NDN	14456	2746
IP	25042	19283

In both two networks, NDN yields better delay performance than IP-based, as shown on Table III. As explained in the former section, the ability of NDN to fetch data from content store are highly beneficial to reduce the propagation delay as experienced in IP-based network.

3) Packet Loss

Packet loss does not occur both in the Inherent and the Palapa Ring networks as shown on the Table IV, due to the inefficient bandwidth usage.

TABLE IV. PACKET DROP COMPARASION OF THE INHERENT AND PALAPA RING NETWORKS TOPOLOGY

Packet Loss (%)	Inherent	Palapa Ring 2
NDN	0	0
IP	0	0

Overall, the simulation of NDN implementation in Indonesia Inherent network shows quite similar characteristics with the implementation in Palapa Ring as in [9]. This shows that NDN as a new mechanism to utilize a more content-centric paradigm can be applied in various networks.

VI. CONCLUSION

This paper provides a simulation that compares two mechanisms to deliver packets: a legacy IP mechanism which delivers packets in a point-to-point, source-to-destination fashion, and a newly proposed Named Data Network, which implements name as the identification of the network system and utilizes caching mechanism referred as the content store. In the simulation, NDN and IP scenario use the same type of routing: distance vector mechanism-based routing, i.e. RIP in IP, and best route mechanism in NDN. The final goal is the comparison of 3 important parameters: throughput, packet drop, and delay, between NDN and IP-based network. This goal should be achieved by calculating the parameters in NDN and in IP, comparing the graph in both networks, and then analyzing and discussing the main aspects that influence the parameters.

The result is that we have already calculated the parameters that affects 3 important parameters in NDN and IP. The main aspects that has already been analyzed and discussed are content store, bandwidth, and routing policy. By using the same treatment for IP and NDN scenario, bandwidth and routing policy parameters should not lead to significant difference for both networks. On the other hand, the existence of content store takes part in better outcome of delay and throughput in NDN-based network. This NDN's advantage assists the network to store the content packet in the nearest node from consumer node, so the network will not be burdened.

From the simulation can be concluded that in average delay, NDN results 9.6 ms, lower delay than 23.5 ms in IP. In term of throughput, NDN with 77 Kbps also outperforms IP with 155 Kbps throughput. NDN throughput proved below IP throughput, while some nodes gain same results as IP. Meanwhile, packet loss parameter results in zero loss for both NDN and IP, the explanation is interest or request packet used in this simulation is not big enough compared to bandwidth used, then congestion not occured and no packet loss found. In general, performance NDN better than IP based network. Additionally, our experiment described in this paper are also in line with the work on Palapa Ring NDN simulation.

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