Abstract—The Internet has become a major need of the world community leading to a new era of sophisticated communication strategies. This is to provide services to develop the architecture and improve the content widely. The main obstacle to the TCP/IP protocol for retrieving data or using a service is the consumer who wants to know the endpoint (IP address) that provides the desired object or service. Another problem is the efficient use of network power available. The last problem that motivates the paradigm shift in the network is the inherent problem in IP. Neither the integrity of the IP packet nor its authenticity can be accessed by the recipient or by the network forwarding entity.

Named Data Networking (NDN) offers an alternative solution as the next generation internet architecture. Named Data Networking (NDN) is a theory that has been used based on progress in data-driven processes. In this thesis, we have studied the strategy of Forwarding Replica Routing (NRR) to some forwarding strategies in NDN by analyzing their performance against triple-play services (data, voice and video). Ideal Nearest Replica Routing (NRR) is a strategy implemented on the CCnS IM simulator where this forwarding strategy looks for the nearest cache and selects the shortest path accordingly. Experiments were performed using NS3 and ndnSIM 2.0 on Ubuntu 14.04.5 with different forwarding strategies and increasing the number of consumers.

The experimental results show that the Nearest Replica Routing (NRR) strategy provides the total data sent / total overhead cost more efficiently by 20% to 58% compared to other forwarding strategies in terms of data transfer. And the total cost per kilobyte is better by 18% to 45% compared to other forwarding strategies.

Keywords—Performance Evaluation, Quality of Service; Simulation; NS3; ndnSIM; Named Data Networking; Forwarding Strategies

I. INTRODUCTION

Nowadays, in our real-life information provided on Internet can be used at anytime. Connection to the centre of information can be provided because internet used a set of distributed point-to-point communication known as Internet Protocol (TCP/IP).

Today, the fast growth of content led to a new era of sophisticated communication strategy. Point-to-point communication such as the Internet Protocol has a few drawbacks. Named Data Networking (NDN) came to fulfill this situation. Named Data Networking (NDN) is a simple model of Content Centric Networking (CCN) or Information Centric Networking (ICN). NDN exploits the TCP/IP in which NDN boost the transferring function of Named content aspect.

In obtain data, information supply in NDN must comply a particular communication standard. Information encompassed in the Named data include but not limited to lag-tolerant and current condition. Some forwarding strategy have been reviewed in [3-6] that carry out adaptive forwarding concept which led to a unique output with sort of load balancing, optimized throughput, and reduced delay.

Posch, et al. [1] studied the FTP as an example of data forwarding application. Their results indicated that Stochastic Adaptive Forwarding (SAF) serves the requirement well. The comparison of performance and the quality of service of several forwarding strategies against HTTP as the data transfer protocol have been performed since FTP is not a popular data transfer protocol. The result show that is SAF is the best forwarding strategy.

This paper focuses on exploring the ideal Nearest Replica Routing (NRR) [2] proposed by Rossini, et al. The forwarding strategies examined is based on several
categories of IP based user applications, such as Voice, Video Streaming, and Data Transfer Protocol.

This paper is systematized as follow: In Section II we presented the literature review of NDN, some NDN Forwarding Strategies, and ndnSIM as the simulator used. The simulation’s configuration specification and the scenario’s illustration are illustrated in section III. The effectiveness analysis of this research is presented in IV. As a final point, we provided the conclusion in Section V.

II. LITERATURE REVIEW

A. Named Data Networking (NDN)

Named Data Networking (NDN) is a theory that has been recommended based on the progress in an activity compelled by data (data-driven). Interest and Data are the bottom line of NDN components. Three key players on NDN are Producer, Consumer, and Router. A collection of Names that formalized information which become the embodiment of needs from Producer by Consumer are interest. Usually, NDN router contains three core modules:

(i) Content Store (CS): Retained data packets that has been forwarded by the router and it took a spot in NDN router

(ii) Forwarding Information Base (FIB): A list which is fulfilled by the routing information consisting of the name components and the correlated interface

(iii) Pending Interest Table (PIT): a place that enrol Interest forwarding information both by reciprocal interfaces and content name.

The NDN's works starts when an Interest packet requested by consumer through the network. In the initial step, a router will look up into the CS to verify the existence of the content when the Interest arrived at the first upstream router in networks. If the content exists at CS, by using the original path, the data packet will go back to the consumer. Moreover, the next upstream router will have received information from the router by confirming the next information of destination router at PIT. In this condition, there are three circumstance that lead the PIT to decide the next action as follows:

(i) A router will add an interface through the PIT and will pulled out the Interest when an entry has a different interface but the same content name;

(ii) If content name and interfaces are similar, the Interest will be removed instantly by the router; and

(iii) Since FIB stored many prefixes information with appropriate routes, the router will refer to FIB.

The router will employ an information from PIT to forward the data to suitable Consumer and store the information at CS while the Producer forward a data to the router.

B. NDN Forwarding Strategies

NDN implements the forwarding strategies by concatenating multi-lanes delivery. From the forwarding plane's point of view, the context awareness is the primary key for effective interest forwarding. Some of the preeminent NDN forwarding strategies are as follow [6]:

- Broadcast only examined the information provided by the FIB and ignored the information related to context.
- BestRoute is a forwarding strategy which is equipped with a set of function to calculate the hop count and the results in the lowest-cost of routing for data forwarding. This is claimed as its main advantage.
- NCC is a forwarding strategy that has been ported to the Network Forwarding Daemon (NFD) from PARC's CCNx version 0.7.2 [13]. On PARC's CCNx this strategy is a default forwarding strategy. In NCC, a minimum delay for getting data packets plays an important role to decide on which faces those Interests will be transmitted. NCC is equipped with a set of function that helps out to collect and cultivate the latency’s statistics freely.
- Request Forwarding Algorithm (RFA) [10] is constructed by the multi-commodity flow problem as its forwarding strategy. An optimal dynamic multi-lane congestion control protocols approach is known as a part of RFA.
- On-demand Multi-Path Interest Forwarding (OMPIF) [7] comes with a method that has been targeted as node-disjoint paths. This method came from the main idea that one face are mapped to only one network and only on specific path the forwarding of interest will be implemented.
• Stochastic Adaptive Forwarding (SAF) [2] determined the probability of distribution by using data packet as an input and to evade congestion. SAF adopted virtual dropping face technique. This forwarding strategy is influenced by auto-balancing on water pipe system. This strategy grants a privilege to the operator to enforce specific context-aware deliberation.

• Ideal Nearest Replica Routing (NRR) is implemented on ccnSIM simulator which is proposed by Rossini et al [2]. This forwarding strategy is looking for the nearest cache and choose the shortest corresponding face rather than delivering the Interest to the content genesis. According to the author, NRR concept is complex to be realized in real. Suppose the issue related to the individual content chunks in cache can be settled, NRR forwarding strategy become the competitor of Stochastic Adaptive Forwarding strategy [2] in the future.

C. ndnSIM

To run this simulation, we utilize ndnSIM module that has been developed under NS-3. ndnSIM act as a new network-layer protocol model to simulate the NDN architecture. Thus any available link-layer protocol can run above the NDN architecture. Moreover, it is possible to run numerous schemas.

The development of ndnSIM simulator is made to be compatible and run above the NS-3 simulator engine. ndnSIM contains a numerous essential traffic generator. Part of abstraction for ndnSIM consist of [16]:

(i) ndn::L3Protocol: NDN main protocol for inter-communication. Data packet come from Face and Interest are gathered by this part;

(ii) ndn::Face: Organize alternative pluggable module with information that came from ndn::AppFace ndn::NetDeviceFace;

(iii) ndn::ContentStore: A repositories that place in network that save data packet either for temporary or for life time.

(iv) ndn::Pit: Face are keep on this area by its prefix of Interests for collection and dissemination;

(v) ndn::Fib: Interest transmitting are handled by the forwarding strategy by employed this part;

(vi) ndn::ForwardingStrategy: nucleus implementation strategy for transmitting Data and Interest by finding related information at ContentStore, PIT and FIB. Subsequently ships the corresponding data packets to PIT.

III. SIMULATION CONFIGURATION AND SCENARIO

A. Simulation Scenario

In order to measure the Quality of Service, we simulated some scenarios which used a method on ndnSIM over NS-3 [5]. We experiment with scenarios and parameters used in [17], and executed those scenarios. We segregated the network topology in two areas as follows:

(i) Client area. This is supported by voice, video, and data application and used the interconnection from the ISP.

(ii) Cloud area. This provides a cloud environment as a service provider

SVC-DASH dataset [4] for video content, and Dynamic Adaptive Streaming Principles [11-12] have been used for simulating the traffic of video streaming on client. We evaluated the Signal to Noise Ratio (SNR) extensibility as a value to measure the Quality of Service (QoS) by the slice period of 2 second. The base content layer is enriched by two augmentation layers called by L1 and L2, in which L1 has the adjacency bitrate of 355 Kbps and L2 has the adjacency bitrate of 407 Kbps.

To simulate the IP-based VoIP over NDN, we adopted the fixed jitter assumption proposed by Posch et al. in [1]. NDNS's namespace hierarchical order proposed by Jacobson et al. in [14], and audio codec rule G.711 in [15]. Each client requests a big file with a bandwidth capacity of 3 Mbps from server.

B. Evaluation Method

We assessed and studied multiple forwarding strategies by evaluating their performance against triple-play service, i.e. voice and data using evaluation method as follows:
1) Simplified E-Model for VoIP

L. Sun et. al. in [8] proposed this representative model. To work with this model, information related with delay disruption and packet loss are needed. Model and the selected parameter were introduced by the ITU Standard of G.107, G.711, G.113. This model allows us to calculate the Mean Opinion Score or R-value in Equation below:

\[ R = 93.2 - I_d - I_e - I_{eff} \]  

(1)

From the Equation 1, we need the value of \( I_d, I_e - I_{eff} \). \( I_d \) which mean the prevailing disruption from one-way interruption \( I_e - I_{eff} \) which demonstrated the codec disruption. To determine the \( I_d \) and \( I_e - I_{eff} \) rules we used Equation 2, 3, and 4.

\[ MOS = \begin{cases} 
1 & \text{if } R \leq 0, \\
(1 + 0.035 R + R_0) & \text{if } 0 < R < 100, \\
4.5 & \text{if } R > 100 
\end{cases} \]  

(2)

\[ I_d = \begin{cases} 
0.024d & \text{if } d < 1733.3, \\
0.024d + 0.11(d - 1773.3) & \text{if } d \geq 1773.3 
\end{cases} \]  

(3)

\[ I_{e-eff} = I_e + (95 - I_e) \cdot \frac{p_{pl}}{p_{burst}} \frac{p_{pl}}{p_{burst}} \]  

(4)

2) Download Bitrate for FTP Clients

In order to evaluate the data transfer performance, we used the download bitrate as the measurement parameter.

IV. SIMULATION RESULTS & PERFORMANCE ANALYSIS

The results obtained from the simulation for the required Cost value per transmitted kilobyte with the number of 9 consumers can be seen in Figure 4. Cost required for NRR is worth 1 which is the smallest value of any other strategy forwarding. This indicates that NRR is the most efficient forwarding strategy in using resources. The highest cost value is in the RFA forwarding simulation result, which indicates that the forwarding strategy is not good in choosing the route

![Fig. 3. Topology of Experiment.](image)

![Fig. 4. Cost per transmitted Kilobyte 9 consumers.](image)

![Fig. 5. FTP Download Rate 9 consumers.](image)

![Fig. 6. Total Traffic of 9 consumers.](image)
The results obtained from the simulation for Mean Opinion Score (MOS) value with the 9 consumers can be seen in Figure 7. The MOS NRR, Broadcast, NCC and Best Route values have the same value of 1. This indicates that those strategies are poorly used for voice transmission.OMPIF strategy has the highest MOS value, which shows this forwarding is best in voice transmission than any other forwarding strategy.

The results obtained from the simulation for Video Segment Bitrate value with 9 consumers can be seen in Figure 8. High bitrate is generated from strategy RFA, SAF and SAF_CAA. This shows that the forwarding strategy is better at delivering the video. The low bitrate values are in the Bestroute and the NRR forwarding simulation results, which indicates this forwarding is slower in sending the video.

The results obtained from the simulation for the FTP download rate of the number of 9 consumers can be seen in Figure 5. The highest download rate is generated from the RFA forwarding simulation which denotes that this forwarding is best for sending data transmit with 9 consumers. The lowest value is generated from the Broadcast forwarding simulation. It indicates that this forwarding is not good enough to transmit data.

The total traffic transmitted will raised as the number of consumers increases. This applies to all strategies. The addition of consumer is not significant compared to the traffic with fewer consumers. The lowest total NRR traffic indicates that the most efficient use of the network. In our experiments, the ideal Nearest Replica Routing strategy provide good performance in terms of total data transmitted and unit costs. However NRR does not perform as that good when transmitting Voice. In the future work we would like to extend our work on Named Data Networking with different new NDN forwarding strategies such as Density-Aware Delay-Tolerant (DADT) and Strategy for Interest Forwarding and Aggregation with Hop-Counts (SIFAH) forwarding strategy.

V. CONCLUSION

In this study, we studied different forwarding strategies in NDN network. We incorporated a forwarding strategies called NRR into the performance evaluation. Nearest Replica Routing (NRR) shows good results for data transmission, but less good for voice and video packet delivery than other forwarding strategies. Cost per kilobyte of data transmitted through NRR does not change with the increasing number of consumers. This is different from other forwarding strategies where Cost increases with the addition of the number consumers.

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