Performance Evaluation of Best Route and Broadcast Strategy for NDN Producer's Mobility

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Abstract: Named Data Networking is a novel concept mainly for the future Internet infrastructure that is centered on routable named data. The NDN infrastructure comprises of a new constituent known as the strategy layer. The layer give access for automatic selection of network routes by considering network pre-conditions such as delay in Interest messages forwarding via a producer. However, expressing appropriate pre-condition in selecting the best possible routes to forward Interest messages remains a challenging factor in NDN, because various parameters and conditions opposes one another when selecting best routes. Besides, it is possible for data in NDN to be retrieved from several sources. Yet, so far preceding research on forwarding strategy techniques that can calculate, from which route accurate NDN data contents content are realized does not regard a network attacker trying to transmit invalid data contents containing same name as accurate data. Therefore, this paper evaluate performance of forwarding strategy using analytical and simulation, and that can be compatible to related network applications such as voice. In analytical, we exploit the use of distribution function for consistency. These are the Probability Density Function (PDF) and Cumulative Distribution Function (CDF). In simulation, each application require its own form of forwarding policy using best route and broadcast. These were exploited to evaluate the total delay in a given interval from 10 through 50 seconds for five times. Similarly in our evaluation, a largescale ring topology was use in the simulation consisting of 30 nodes and 48 links. Link bandwidth is configured as 1Mbps. Numbers of content consumer/producer starts from 1 to 18 so as to achieve our simulations. Both consumers and producers were randomly selected in term of unique content request on the access network. ndnSIM 2.1 is used in simulating the scenarios for several time intervals. Performance results presents best route policy carries significant delay when compared with broadcast policy. Also, in our result, Delay metric is half the value obtained during analytical and simulation processes for NDN producer's best route and broadcast using CDF, as compared to the value realized in our benchmark paper for NDN consumer.

Revised Manuscript Received on September 22, 2019.

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Keywords: Delay, Best route, Broadcast, Bandwidth, Topology, Nodes, Consumer, Producer, ndnSIM

I. INTRODUCTION

The term forwarding strategy is a process of implementing policy centered towards forwarding content towards best destination with respect to time. In information Concentric Networking, the names of application (e.g voice or video) that identifies contents are usually employed for delivering ICN packets between source and destination[1][9]. This makes ICN routers operate routing based on names so as to form their forwarding tables. Recently, routing has undergone a rebirth in the domain of research. This rebirth gave rise to the remarkable and efficient resolutions of most of the routing challenges in computer networking. According to researchers, any routing policy that operates accurately in IP networks should operate well in ICN, particularly in an NDN. This is because the strategy of forwarding in ICN is a severe superset of IP with small limitations. It has a similar semantics that relative to routing. The routing strategy is a hierarchical naming aggregation that has longest matching lookup. Considering content concentric network architecture and named data networking, it has the ability to provide an accurate vehicle for the implementation of routing protocols. The CCN/NDN operates in the stage of pre-topology communication where the identical network elements have no knowledge of their other peers. It is known for CCN with it security essential capabilities and when CCN is used as a routing transport system, it will make the network infrastructure secured dynamically [8]. However, in forwarding using NDN, two most important information are being exchanged by two parties. These are the Interest and Data information [10] [6]. The information is forwarded by the use of unique naming scheme. The consumer sends an Interest for a named content by using a broadcast to all accessible paths. Then an NDN router holds a record of that content in its cache. Then a response will be made using data information. It is noted that the Interest and Data that are in exchange on the network has to hold a unique name for successful routing and forwarding in NDN, every router in NDN manages three crucial data structures [7]. These are; *Pending Interest Table*. The PIT manages the records of content interest that has been received as a query but is yet to be treated as data content by the NDN router. *Forwarding Information Base*. The FIB records the information on where content interest that corresponds to some of the name prefixed should be transferred or forwarded to. *Content Store*.

The CS records the already treated/satisfied data content that have been forwarded to the NDN router. NDN performs its routing and forwarding decisions using names [5]. This removes some of the issues affecting addresses in our traditional IP architecture such as limitation in address allocation and management, and NAT translations.

II. LITERATURE REVIEW

A. NDN Anchor-less Mobility support

This research considers the approach of anchor-less mobility support to enhance network availability and scalability. There are three different forms of managing mobility using this approaches on an NDN network [8],[9]. These are as follows:

i. **Rendezvous based Mobility**: This involves name resolution to their various locations carried out by particular router nodes. This approach supports improved scalability with minimum signal overhead. Also, support content rerouting of some applications and has no issues with frequent content producer relocation.

ii. **Anchor-based**: this is where a static router will maintain the knowledge of every nodes movement by capturing packets to itself. It support content rerouting but cause higher signal overhead because of its single point of failure.

iii. **Anchor-less**: Here, the mobile router will take responsibility of advertising all mobility information and updates within the network.

NDN is believed to be the future internet architecture when it comes to routing scalability, efficient forwarding, network security, content integrity and privacy [5],[6],[7]. The most foremost usage of the current Internet is targeted at content creators, by dissemination and delivery performance.

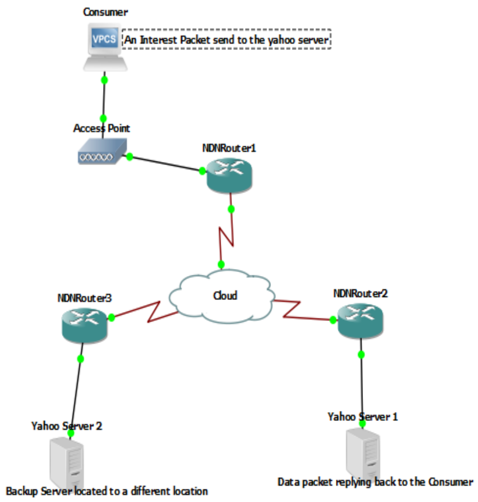

Fig. 1 NDN Mobility Scenario

The architecture of NDN becomes a challenging prototype of computer network communication today. This is because network elements such as the host, server address and other connecting elements only require the content itself based on the naming convention instead of their physical location or assigned IP addresses. NDN will further change the data content to a form of an entity [1],[2]. Communication in the NDN is structured by ends receivers. These are called the data consumer. For a system to receive the data, content consumer needs to send an interest packet and data packets. Those two forms of packets carries a unique name that ascertain the chunk of data which is transmittable as a packet of data. Also, for data content to be delivered, content consumer tag name of the selected data content into an interest packet and transmit it over the network. The producer router will then identify the link of request that comes so as to forward the packet by checking or verifying the names in its FIB and forward the interest to the data producer. [1],[3,5].

B. NDN Forwarding Strategy

The NDN router supports three main functions in its forwarding plane [1]. These are; fast or rapid name look-up, intelligent forwarding strategies and efficient policy of caching. In the routers IOS, the forwarding plane comprises of a CS which has packet data cache, PIT that store the pending interest request and FIB that store all the information on forwarding policies.

The Fast name lookup operation forward content on NDN containing lookup processes that is name centric. This is because, NDN packets has no source and destination information like IP packets. The Intelligent forwarding strategies operation picks several exit interfaces and then choose the highly effective interface. Forwarding policy is decided based on the network situation, either congested or non-congested. The efficient policy of caching is operated with the CS because of the support it offers to the process of content dissemination on the network [10,11,12,13].

Therefore this research is centered on the performance of a network in better forwarding strategy condition. Forwarding strategy on an NDN node is mainly used to pick the appropriate face on FIB table to be used in forwarding packets interest. We then exploit two forwarding strategies. These are best-route and broadcast forwarding strategy.

The best-route strategy forwards every fresh interest with minimal routing cost. In controlling forwarding route, the NDN router filters the content containing similar name. In the downstream route, received content will be transmitted to all interface, from where interest arrived, and by filtering nonce. In a scenario where an interest come from other downstream routes but have similar nonce values, the interest that will be transmitted is only the downstream route that was initially accepted by router. However, when the content has not been received in specified threshold time, then retransmission occurs by picking the lowest-cost next-hop router [1], [4],[5].

In best-route strategy implementation, the class *NFD :: fw :: Best Route Strategy 2* is utilized. Best route strategy comprises of content interest forwarding, retransmission suppression interval, nack generation & processing. The Interest forwarding forwards the new content interest to all upstream having lowest-cost next-hop excluding downstream. When the earlier content interest are forwarded; when multiple content interest carries similar name -similar selector and interface, but different nonce, then suppression occurs at the time of retransmission suppression.

When a content interest is then received after transmission (suppression interval) the content interest will be forwarded to upstream containing lowest next-hop. In addition, retransmission of suppression interval for best-route strategy is mainly used in preventing mischievous contents that gives experience by sending excessive content interest to an end-to-end. Time usage in best-route permits retransmission of a content consumer and periodic retransmission prevents DDoS occurrence. There exist three design possibilities for retransmission suppression timing (interval), these include Fixed Interval, RTT estimation and exponential back-off. Nack generation is important in improving best-route strategy performance. When new content interest meant for forwarding is dropped, the nack will be restored back to the downstream saying no route. When qualified Next-hop receive content interest, it becomes different from the downstream inbound interest. When otherwise, the next-hop will be regarded unqualified, then best-route strategy will automatically reject content interest [1],[6],[7], [8] and [10]

The Broadcast strategy sends content interest to all connecting interfaces upstream. It is designated by FIB entries provided. In broadcast strategy implementation, the class *nfd::Broadcast Strategy* is utilized. Subsequently, when content interest is received for forwarding, the broadcast strategy decides the next-hop that is qualified according to the FIB records. The next-hop face qualified as an upstream is the face that has not been used and never violated its scope. *Pit::entry::can Forward To* is the best form of assessing the policies. The subsequent broadcast strategy will then forward content interest to all qualified upstream otherwise content interest will be rejected.

Table. 1 Summary of Related Work

Author	Contribution	Results Obtained	Research Limitation
[1]	Has applied forwarding strategy for broadcast and best route using distribution function.	Delay metric was high in best route compared to broadcast in simulation.	Applicable to only NDN consumer. Hence, no regard for NDN producer.
[2]	Choosing which forwarding path between several options in NDN is regarded multiple attribute decision making (MADM) challenge and a maximizing deviation based probabilistic forwarding (MDPF) strategy was proposed to choose forwarding interface using probability	Results of Experiments presents MDPF strategy has better responsive and sensitive to NDN network changes. The MDPF can comprehend higher throughput, lower drop rate and as well as better load balancing	Could not present other network metrics particularly the distinctive NDN characteristics that can be blended with MDPF to improve performance.
[3]	Probabilistic binary tree structure concept was proposed for forwarding process as an interface selection process moving from root node to leaf node. It also offers abstract backing for machine learning and minimizes complexity of forwarding process. The strategy is improved to avoid convergence of local optimal solution using simulated annealing.	Results of Experiments presents that the proposed strategy can limit time complexity and offer high throughput, good load balancing and small packet loss compared with existing forwarding strategies. The drop rates were minimized by 60% and 34% respectively using different scenarios as compared to Best Route.	Could not focus on using several modification policies to change to dissimilar application requirements and carry out experiments on real NDN networks.
[5]	Analysis on the process involved in forwarding a protected data from a preceding to reaching access point. Analysis on how to ensure consistency in routing at handoff.	The effective minimization of delay and packet transmission during handoff. Zhou, Z., et al, 2014	However, the paper could not cover the addition of software define networking in their design. Forwarding mechanism is encouraged to be researched on to minimize the quantity of transmission of the interest packets in NDN.

III. SIMULATION

Simulations are carried out using ndnSIM 2.1 which consist of several libraries in NS-3.29. The aim of the simulation is to achieve an efficient forwarding strategy between the producer/subscriber to the consumer within an NDN network and another network.

Our scenario consist of multiple forwarding domains so as to evaluate both mobile producer and consumer at any point on the NDN network. When the scenario is fully implemented, an optimal network performance will be ensured. Our simulation consist of a 25 random consumers and 5 mobile producers so as to run both best-route and broadcast form of forwarding strategy. Intervals of simulation were changed in several iterations such as 10 seconds, 20 seconds, 30 seconds and 40 seconds. The content store carried a value of 150 and rate of each producer's interest was set to 250 to execute adaptation of best-route forwarding strategy. Meanwhile the broadcast strategy was set for 4 times in simulation test as can be depicted in the table I below

Table 2 below presents our Simulation Overview. The value for each mobile producer's interest packets that are sent/received is set to be 250 throughout the simulation time. The number of content store is 150 on each mobile producer node. Using both best route and broadcast strategy form, we obtain the following simulation information.

Table. 2 Simulation Information

Time T(s)	Producer's Interest (PI)	Content Store (CS)	PI/T(s)	CS/T(s)
10.	250	150	25.00	15.00
20.	250	150	12.50	7.50
30.	250	150	8.30	5.00
40	250	150	6.30	3.80

A. The Distribution Function: PDF and CDF

A major parameter that is used in determining statistical probability is the density function for a particular factor present in a sample [1].

Probability Density Function (PDF)

The rate of probability the 0≤ $P(x) \leq 1$ for all events is expressed as $\sum_n P(X = x_n) = 1$. Therefore (∴) a PDF of a simulation for S seconds is by dividing he values into 5. ∴ X = {x_1, x_2, x_3, x_4, x_5}. The preceding divisions are the network delays. And let's assume the values to be $X_1 = 0.02$, $x_2 = 0.04$, $x_3 = 0.06$, $x_4 = 0.08$, and $x_5 = 0.10$. From this presentation it shows that the difference in the shows for the delays (seconds) is 0.02 seconds.

Also, bearing in mind that probability = Number of possible outcome/Number of total outcome. $Probability = \frac{number\ \ of\ possible\ \ outcomes}{number\ \ of\ total\ \ outcome}$

$\sum_n P(x_n) = 1 - \sum(x_n)$

P = $N_{Po} \div N_{To}$ symbolically

∴The above representation is further expressed as

$$\sum_n P(x_n)$$

$\sum x_n = x_1 + x_2 + x_3 + x_4 + x_5$

= 0.02 + 0.04 + 0.06 + 0.08 + 0.10

= 0.030 seconds

Recall $\sum_n P(x_n) = 1 - \sum(x_n)$

$\sum_n P(x_n) = 1 - 0.30 = 0.7$ seconds.

This proves the probability that $\sum_n P(x_n) = 1$ as $0 \leq P(x) \leq 1$

Cumulative Distribution Function (CDF)

This distribution is defined as $(\chi \leq x)$, as $\chi = \{x_1, x_2, x_3, \ldots x_n\}$. Hence there is a possibility of χ= x. Then$P(\chi \leq x_k) = \sum_{i=l}^{k} P(x_i)$. Therefore, considering P = $N_{po} \div N_{To}$.

Then $\Sigma P(x_k)$= $\left\{\frac{0.02}{1} + \frac{0.02}{1} + \cdots \frac{0.02k}{1}\right\}$. Then for delays of 0.02, 0.04, 0.06, 0.08 and 0.10 it is possible to estimate the calculated delays in a sum of 0.30 seconds as$P(x_k)$. Therefore$P(\chi \leq 0.30)$ => signify, this delays as values less than 1 or sometimes equal to 1.

By announcing cumulative distribution function carrying delay in interest with initial simulation time of 10sec means adopting value of initial probability distribution function so as to acquire the proceeding value of cumulative distribution function. Practically, it is done by summing up the whole value of second probability distribution function with the first value of cumulative distribution function. This technique is to be repeated severally until a higher value is obtained as presented in table 3 below.

Table. 3 Simulation Setup

Simulation time (s)	Delay D(s)	PDF	CDF	PDF *D(s)	CDF*D(s)
10	0.16	0.10	0.10	0.02	0.02
20	0.32	0.41	0.51	0.13	0.16
30	0.56	0.43	0.79	0.24	0.44
40	0.72	0.45	1.01	0.32	0.73
50	0.96	0.50	1.80	0.50	1.73

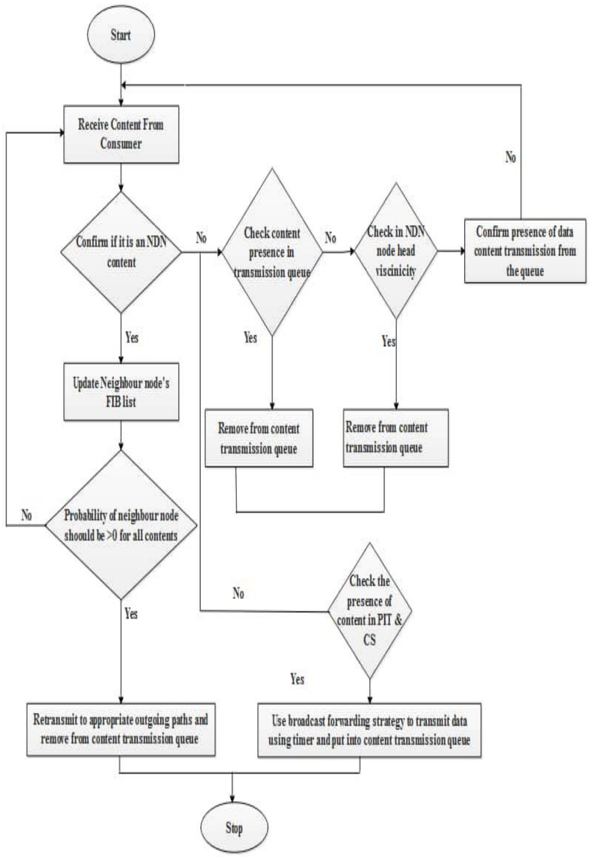

Fig. 2 Proposed Method Flowchart

Figure 2 above present our proposed methodology for content transmission between NDN producer nodes in broadcast form. Each producer node preserves transmission and retransmission queues for both interest and data contents within the NDN network. Each and every time a producer hears an NDN content, it checks and update the queues and later check the Pending Interest Table and Content Store. If in any case a content contains a matching name in pipeline, it then gets dropped because it has been treated satisfactorily. In terms of data content forwarding, timers was set for rebroadcast acceptance by using last hop travel distance. In our simulation, data content retransmission is also implemented which is much related to interest content retransmission.

IV. RESULT

Our simulation results were obtained using ndnSim 2.1 for 10s, 20s, 30s, 40s and 50s which is presented graphically using cumulative distribution function (CDF) delay on each NDN mobile node producers.
The table below present simulation parameters used

Table. 4 Parameters for simulation

Parameters	Value
Simulator	NS3.12.1
Operating system	Linux Ubuntu 12.04
Simulation time	[0-10] sec.
Packet size	1024 bytes
Interest/Data speed	[30, 40] sec
No. of connections per SMR	2
Types of technologies supported by SMR	WiFi and 3G
Pause time	12 millisecond
Strategy	Best route and Broadcast
Delay	10sec
topology	Ring
Link BW	1Mbps
Number of nodes	120
Node link	148
Node distance	150 meters
Cache strategy	FIFO, LFU, LRU,

Our CDF chart presents the delay that was recorded in simulation time of 10 s, 20s, 30, 40 and 50s with the aid of cumulative distribution function. In every iteration, simulation result produce varies differently in term of depending delay. In figure 3, best route simulation for 10s on the CDF delay chart carries an absolute delay of 3.23s and 0.43s average delay while CDF cost for 0.77. For broadcast simulation of 10sec, absolute delay was recorded as 3.92s and average delay of 0.55s while CDF cost for 0.79. The two simulation outcomes were presented for first iteration of 10 seconds. It implied that best route strategy shows absolute delay lesser compared to broadcast strategy in this case.

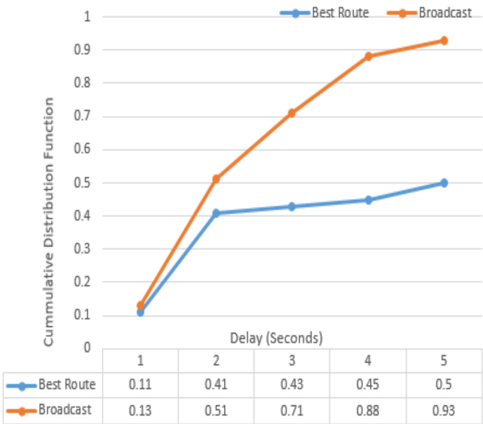

Fig. 3 CDF for 10s Delay

In second simulation, the CDF delay chart present outcomes for 20seconds. The best route strategy carries absolute delay of 6.22sec, and average delay of 0.50s, while CDF cost of 0.89. Broadcast strategy carries absolute delay of 8.41s and average delay of 0.69s while CDF cost of 0.85. The two simulation outcomes were presented for second iteration of 20 seconds. It also implied that best route strategy shows absolute delay lesser compared to broadcast strategy as shown in figure 4 below.

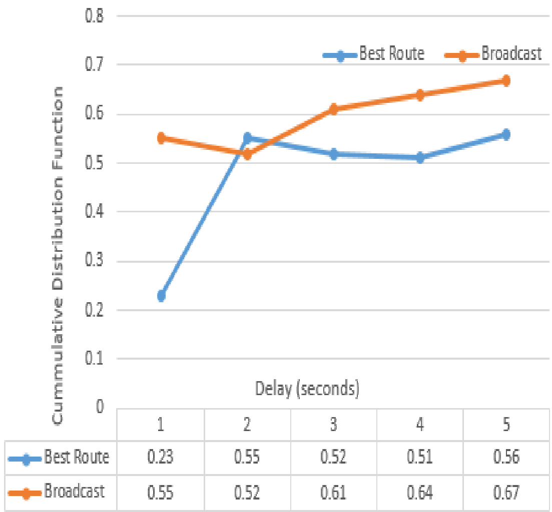

Fig. 4 CDF for 20s Delay

In third simulation, the CDF delay chart present outcomes for 30seconds. The best route strategy carries absolute delay of 40.12sec, and average delay of 1.52s, while CDF cost of 0.75. Broadcast strategy carries absolute delay of 29.10s and average delay of 1.15s while CDF cost of 0.71. The two simulation outcomes were presented for third iteration of 30 seconds. It also implied that broadcast strategy shows absolute delay lesser compared to best route strategy in this case.

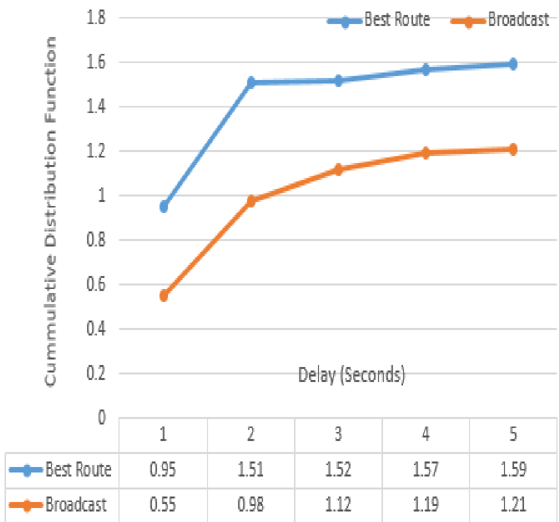

Fig. 5 CDF for 30s Delay

In fourth simulation, the CDF delay chart present outcomes for 40seconds. The best route strategy carries average delay of 2.52s, while CDF cost of 0.69. Broadcast strategy carries average delay of 1.91s while CDF cost of 0.75. The two simulation outcomes were presented for fourth iteration of 40 seconds. It also implied that broadcast strategy shows absolute delay lesser compared to best route strategy in this case.

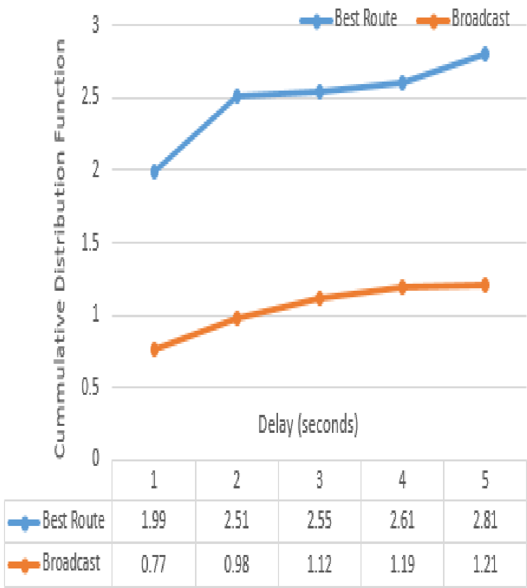

Fig. 6 CDF for 40s Delay

B. Delay Metrics on the NDN Producer

The chart for the NDN Producer node presents delay parameters of several simulation for 10s, 20s, 30, 40s and 50s vales. The producer node also present delay metrics at each node for both the two forwarding strategy technique. These are, the best route and broadcast.

By assessing the maximum delays in simulation on producer's best route strategy; we obtain 0.65s delay in 10sec simulation on node 4, 0.81s delay in 20s simulation on node 8, 1.51s delay in 30s simulation on node 12, and 3.2s delay in 40s simulation on node 16. Also by assessing the maximum delays in simulation on producer's broadcast; we obtain 0.71s delay in 10sec simulation on node 4, 1.011s delay in 20s simulation on node 8, 2.31s delay in 30s simulation on node 12, and 4.42s delay in 40s simulation on node 16.

Table 5. NDN Producer Node Delay

S/No	Producer Node ID	Best route strategy				Broadcast strategy			
		10sec	20sec	30sec	40sec	10sec	20sec	30sec	40sec
1	0	0.27	0.31	0.32	0.31	0.33	0.48	0.45	0.58
2	4	0.39	0.43	0.68	1.30	0.18	0.46	1.53	1.54
3	8	0.41	0.58	0.91	1.01	0.47	0.49	1.65	4.66
4	12	0.44	0.63	1.12	1.24	0.28	0.53	1.35	1.87
5	16	0.51	0.84	0.89	1.29	0.6	0.60	1.44	4.43
6	20	0.63	0.91	0.10	1.50	0.73	0.63	1.51	5.01

V. CONCLUSION

This research paper was carried out using analytical and simulation for NDN applications. Results presents strategy used and traffic for content interest that is produced positively affect NDN network performance. And choice of strategy also. In analytical, an assessment was made for probability distribution function for forwarding strategy using PDF & CDF- Probability Distribution Function and Cumulative Distribution Function. In simulation, we assess the mobile producer's forwarding strategy for best route and broadcast to enhance voice content delivery in NDN application. Simulation was carried out in five intervals of 10 seconds difference to a greater distance of 50 seconds. In best route strategy, absolute delay was recorded at 30.22 seconds far higher than in broadcast strategy of 14.89 seconds absolute delay. This implies that best route has higher delay compared with broadcast strategy. This then makes transmission of NDN application such as voice to be easier and faster than data applications because of minimal delay obvious in broadcast strategy. An observation is made on the cache hit ratios such as the first in first out, least frequently used and least recently used. They increase immediately the amount of interest packet send increases. Using best route strategy, when the number of content interest per second is 100, the fraction of cache hits is equal to 19.60%. Similarly when the number of content interest per second is 1000 using similar strategy, the fraction of hits must increases to 42.47%. It is also observed that subsequent simulations require longer intervals for better and minimum delay records.

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