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NDNS performance with variation of topology and prefix on named data networking

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ABSTRACT

NDNS is DNS embedded in Named Data Network (NDN) architecture, support NDN caching and know the content's location. In this research, simulation performed using Abilene & Pan-Europe with prefix changes to see performance of NDNS with pure name/data resolver without cache capability and know the importance of cache from a brief comparison scenario at the end. There is no differences of prefix variation at Second or Top Level Domain from both topologies, increase 1% average delay and Cache Hit Ratio decrease by 0.16% (Abilene), 0.18% (Pan-Europe) as increases in prefix variation. Variation of prefix cause queue delay to server and probability to hit the cache are very small, more transmission delay towards server instead cache. In change of interest rate, average delay increases, and Cache Hit Ratio decreases slightly as the increases of interest rate because more data are forward to server and smaller probability to hit cache. NDNS with cache shared cache get average delay 43% (Abilene), 44% (Pan-Europe) lower than NDN with cache and 57% (Abilene), 60% (Pan-Europe) lower than NDNS with Caching Resolver only. It proves that name resolver still needs a cache to help resolve interests for data, NDNS are better to support NDN, but still need a cache capability to resolve interests for data.

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1. INTRODUCTION

Named Data Networking (NDN) is one of the evolutions of a new network architecture for communication on the internet, which is a derivative of the concept of Information-Centric Networking (ICN) network architecture [1][2]. NDN is beneficial in more content retrieval, namely with the content caching system on the NDN router to provide faster content retrieval without asking the service provider's central server. NDN uses identity as the address of the requested data content, in contrast to the TCP/IP protocol, which uses an identity with an IP address. In NDN, the desired content will be cached on the content store (CS) router, where this router is close to the user, reducing content retrieval time [3]–[5].

However, the weakness of NDN is that when many interest packets are sent to various available networks, there is no cache of the desired content, so mapping the location of the desired content is needed[5][6]. A distributed database and lookup-service system is needed to help find the desired data content to improve NDN performance. NDNS is a solution for the shortcomings that exist in the NDN network. NDNS is a DNS-like system embedded in NDN architecture to provide strict namespaces management, routing scalability, and security support with cryptography in NDN [7], [8]. NDNS use a query as a name resolver in Named Data Network architecture. Query performed in NDNS same as an interest send to find desired data packet, but there is some adjustment because the query is DNS system in IP embedded in NDN. The query performed in NDN is the same as DNS in IP[9]. There are two types of queries, that is recursive and iterative queries. Recursive query performed to find data packet between Routers or Caching Resolvers, and iterative query performed to find the location of the data packet through the producer.

Previous study by Melati et al. [10] performed simulation with just one prefix and was just intended for the Root Server. There is no actual data packet because the answer from the root server is just a hint of the Authoritative Name Server location. The simulation used topologies with non-looping links so a node can only pass a single link to reach the authoritative name server/producer. While the NDNS itself provides a mapping capability of the presence of the desired content so that if a node is connected through a link and also connected through another link, it will provide a more realistic network.

In this paper, we completed it using two real topologies, Abilene and PAN-Europe, with the interconnected nodes mostly being point-to-multipoint links. The prefixes are variated for both topologies to see the effect of prefix variation on NDNS performance. This research also focuses more on performance directly from consumer to producer data so that the effect of name resolver from NDNS can be seen more clearly. At the end of the scenario, we will discuss a little about the performance of NDNS compared to NDN when the cache is used to compare capabilities with and without cache. It is hoped that the results obtained will be more realistic simulation results with the two real topologies and prefix variation used with the effect of the NDNS resolver without or using cache capabilities in the NDN network.

2. METHOD

What is observed in this paper is the performance in the form of a cache hit ratio, packet drop, and average delay. In this paper, actual topological variations and variations in the prefix or content in the form of the main page of websites that already exist in the world were carried out. Topology variations using actual topology variations follow the connected nodes according to the authentic topology d used. There are four types of nodes in all topologies that will play a role in the NDNS system on this NDN architecture, the first is the Consumer node as the sender of the request, the second is the Router node as the gateway, the third is the Caching Resolver node as the request resolver sent by the consumer to the Root Server, the fourth is Root Server as the guider to authoritative name server, and fifth is the Authoritative Name Server node as the content provider [7], [8].

This paper will use four scenarios, as shown below in Tables 1 and 2. The first scenario is a prefix change at the Second Level Domain level and the second is a prefix change at the Top-Level Domain level. These two scenarios are used to see the effect of changing the prefix on the Second Level Domain and Top-Level Domain on the performance of NDNS and NDN. The third scenario is to see the effect of changes in interest frequency on NDNS performance. The interest rate per second will be changed during this scenario. The fourth scenario is divided into two parts, the first is a change in the active cache node, and the second is a change in the content store. The first part is carried out to look at the importance of cache both on the NDN side and the responsibility of shared cache on NDNS. The second part is to see the effect of changes in the content store on the performance of both NDN and NDNS with full cache capabilities.

Table 1. Simulation Parameters Scenario 1-2

Parameter	**Value**
Producer (*Server*)	4; 6; 9; 16; (1 *root server*)
Consumer	30 (Abilene), 16 (PAN-Europe)
Interest Rate	1 interest / seconds
Content Store Size	1 packet
Time To Live Cache (Second)	1 seconds
Prefix Variation	3,5,8,15 packets

Table 2. Simulation Parameters Scenario 3

Parameter	**Value**
Produsen (*Server*)	16 (1 *root server*)
Consumer	30 (Abilene), 16 (PAN-Europe)
Interest Rate	5, 10, 15, 20 interest / seconds
Content Store Size	1 packet
Time To Live Cache (Second)	1 seconds
Prefix Variation	15 packets

Table 3. Simulation Parameters Scenario 4 (Active Cache Node)

Parameter	NDNS + Caching Resolver	NDN + Router Cache	NDNS + Router Cache + Caching Resolver
Interest Rate	1 Interest / seconds	1 Interest / seconds	1 Interest / seconds
Content Store Size	1 packet	10 packets	10 packets
Time To Live Cache	20 second	-	20 seconds
Prefix Variation	15 packets	15 packets	15 packets

Table 4. Simulation Parameters Scenario 5 (Content Store Size)

Parameter	NDN	NDNS
Interest Rate	1 Interest / seconds	1 Interest / seconds
Content Store Size	5, 10 packets	5, 10 packets
Time To Live Cache	-	20 seconds
Prefix Variation	15 packets	15 packets

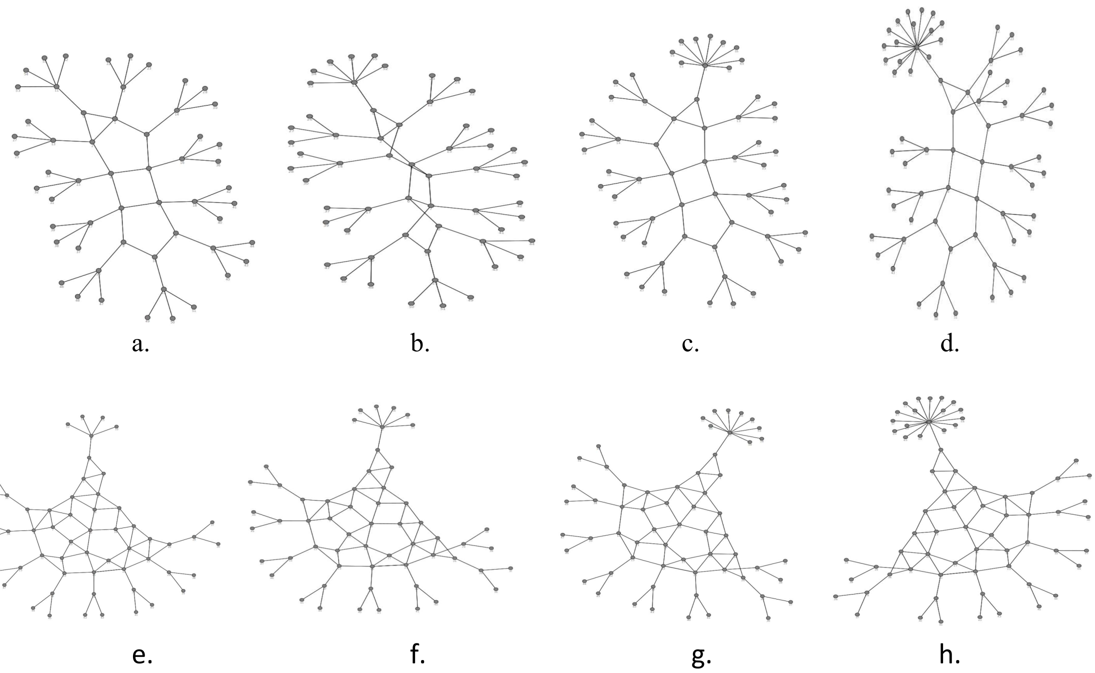

Figure 1. Abilene (a-d) and Pan-Europe (e-h) Topology

In this simulation, there are 3 test parameters that will be used, Average Delay, Cache Hit Ratio, and Packet Drop. Average Delay is the average length of time for data in the network to reach its destination. Average delay indicates the value of the data travel time to its destination from the total requested data. The formula for the average delay is as follows [6].

$$\frac{\sum(Delay\ Value\ of\ All\ Data)}{Amount\ of\ data\ received}$$

Cache Hit Ratio is the probability that data can be found in the cache. The hit ratio is between the number of requested data in the cache and the number of requests made. The cache hit ratio is formulated [4][6].

$$h = \frac{Cache\ Hit}{Amount\ of\ data\ requested}\ x\ 100\%$$

Packet Drop is one or more data packets that fail to reach their destination through the network. Packet Drop can be caused by data transmission errors or network congestion. A small packet drop indicates that the performance of a network is good, which means that much data has succeeded in reaching its destination [4][6].

$$\sum(Total\ of\ all\ packet\ drops)$$

3. RESULTS AND DISCUSSION

The result of all scenarios simulations will be discussed here. In the final part, after simulation results, graphs from each scenario. will discuss the result obtained.

3.1. Scenario 1

In this scenario, we want to see the effect of prefix variation in Second Level Domain. We know that in an NDN name, a prefix is one NDN name. But, in NDNS, there are top-down search from top to lower-level domain performed by queries. This scenario is performed pure name resolver that cache are set minimum.

3.1.1. Scenario 1 Average Delay

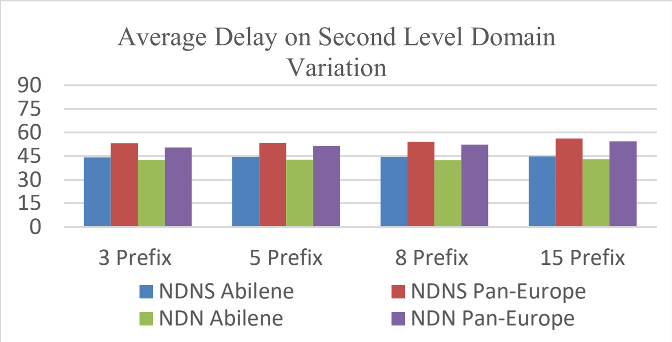

Figure 2. Average Delay on Second Level Domain Variation

From Figure 2, NDNS and NDN in both topologies, the higher variation of the prefix/content searched for, the higher the Average Delay occurs. There is 1% increases of average delay as increases of prefix variation. A higher average delay happens because the variation of prefix effect the search for diverse content. More content will not be stored in the Content Store, so the demand to servers will increase. The delay comes most from propagation delay towards producer higher than towards Router or Caching Resolver cache. The graph above compares NDN and NDNS average delay and shows that NDN average delay is smaller than NDNS. This occurs because there is more query (interest) in NDNS towards Root and Authoritative Name Server asking for Name Server hint and data packet compared with NDN interest.

3.1.2. Scenario 1 Cache Hit Ratio

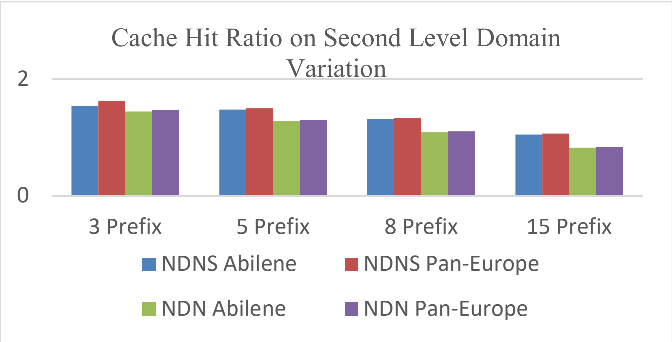

Figure 3. Cache Hit Ratio on Second Level Domain Variation

From Figure 3, on both NDNS and NDN in both topologies are same that the higher variation of the prefix/content searched for, the smaller the Cache Hit Ratio occurs. There is a 0,16% (Abilene) and 0,18% (Pan-Europe) decreases of Cache Hit Ratio as increases of prefix variation. A smaller Cache Hit Ratio happens because the probability of caching the content in the Content Store or Caching Resolver will be more negligible. More content will not be stored in the Content Store, so there will be more Cache Hit

Misses. NDN and NDNS both have the same cache hit ratio because Content Store and Caching Resolver are set very minimum to cache the content.

3.1.3. Scenario 1 Packet Drop

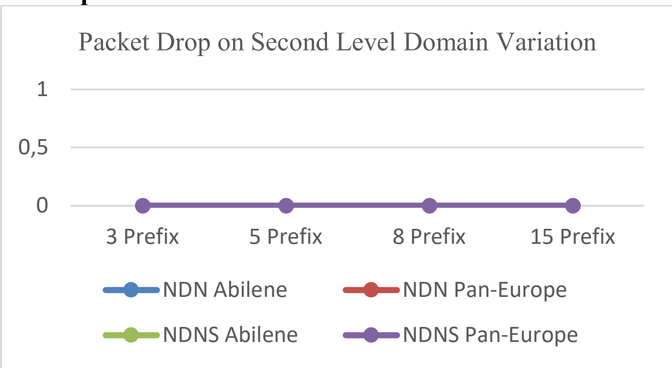

Figure 4. Packet Drop on Second Level DomainVariation

From Figure 4, prefix changes at the Second Level Domain level, there are no Packet Drop changes in both topologies in every prefix change. This indicates that all data packets have been successfully returned to the consumer.

3.2. Scenario 2

In this scenario, we want to see the effect of prefix variation in Top Level Domain. We know that in an NDN name, a prefix is one NDN name. But, in NDNS, there are top-down search from top to lower-level domain performed by queries. This scenario is performed as comparison to scenario one to see the effect of prefix variation in difference level domain changes.

3.2.1. Scenario 2 Average Delay

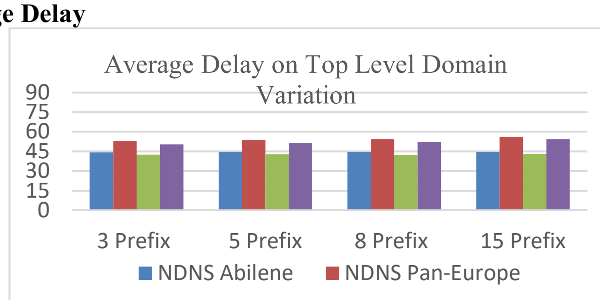

Figure 5. Average Delay on Top Level Domain Variation

From Figure 5, same as the Average Delay on Second Level Domain variation with 1% increases of average delay. It occurs because the number of queries or interests toward the producer is the same. In NDN name, they all still as one NDN name. Queries towards Root Server for Authoritative Name Server hint between Top or Second Level Domain variation and the question towards Authoritative Name Server for Data Packet are still the same number of queries. There is no difference between Average Delay in Top or Second Level Domain.

3.2.2. Scenario 2 Cache Hit Ratio

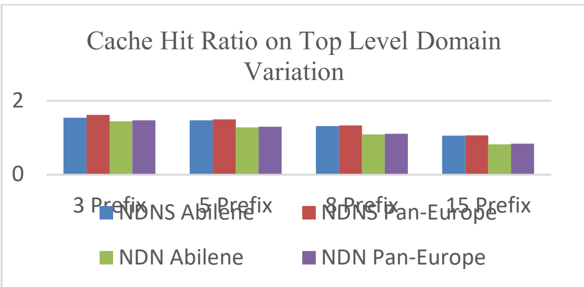

Figure 6. Cache Hit Ratio on Top Level Domain Variation

From Figure 6, same as Cache Hit Ratio on Second Level Domain variation with 0,16% (Abilene) and 0,18% (Pan-Europe) decreases of Cache Hit Ratio. It occurs because the number of queries or interests that hit the cache on Routers or Caching Resolvers is the same. They all still as one NDN name. There is no difference between both scenarios for Cache Hit Ratio results.

3.2.3. Scenario 2 Packet Drop

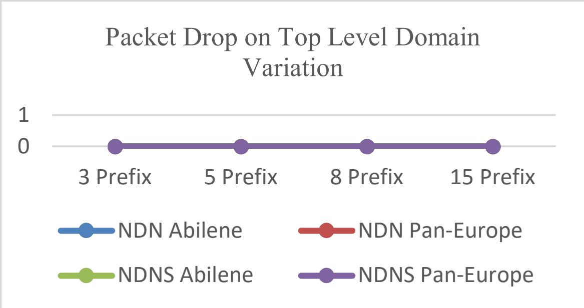

Figure 7. Packet Drop on Top Level DomainVariation

From Figure 7, prefix changes at the Top-Level Domain level, there are no Packet Drop changes in both topologies in every prefix change. This indicates that all data packets have been successfully returned to the consumer.

3.3. Scenario 3

Sub-section scenario three will discuss the result obtained from the simulation of Interest Rate to see the effect of interest rate change to name resolver performance. This scenario is just a brief comparison for scenario 1 and 2 to see how big the impact of interest rate change to name resolver performance.

3.3.1. Scenario 3 Average Delay

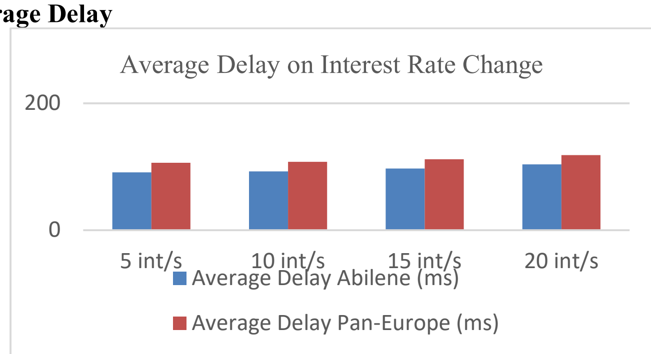

Figure 8. Average Delay on Interest Rate Change

From Figure 8, changes in the Interest Rate, there is a change in Average Delay in both topologies. There is 4% increases of average delay as increases of interest rate for both topologies. The higher the Interest Rate, the higher the Average Delay. This happens because the iterative query only has 1 query against a desired zone on the root server, but more than one query per second causes the query to accumulate on the root server, and references go to the destination name server, causing delays in data packets' arrival to consumers. The cache in this scenario is set to minimum capability to see the name resolver performance. The results are worst for both topologies. As shown in the graph above, the Average Delay obtained is more than 90 ms.

3.3.2. Scenario 3 Cache Hit Ratio

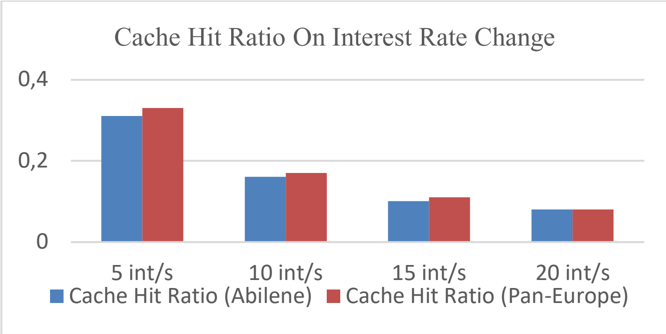

Figure 9. Cache Hit Ratio on Interest Rate Change

From Figure 9, changes in the Interest Rate, there is a change in Cache Hit Ratio in both topologies. There is a 0,08% decreases of cache hit ratio as increases of interest rate. The higher Interest Rate, the smaller Cache Hit Ratio. This happens because the frequency of interest per second is random for a searched content. This random interest causes content to be increasingly unsuccessful in obtaining from the cache, especially when the frequency of interest per second is getting bigger. This is also due to the possibility of getting the desired content in the cache which is very small because the content store is set to only store 1 content and Caching Resolver set to 1 s cache time. Thus, the content store will continue to change its cache as content changes occur.

3.3.3. Scenario 3 Packet Drop

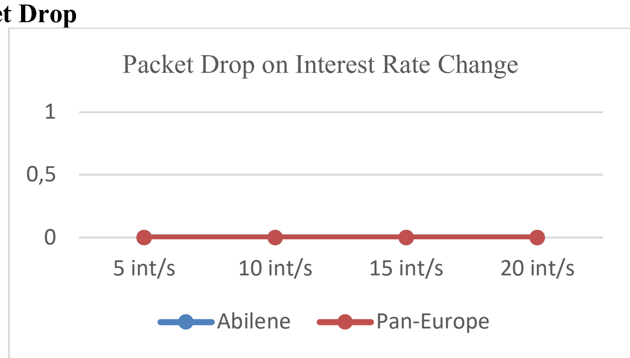

Figure 10. Packet Drop on Interest Rate Change

From Figure 10, there are no Packet Drop changes in both topologies in every interest rate change. This indicates that all data packets have been successfully returned to the consumer.

3.4. Scenario 4

Scenario 4 will discuss some cache node activated in NDN and NDNS with NDNS full cache capability between Router and Caching Resolver. as the comparison without cache. This scenario is comparison from previous scenario without cache / just name resolver to find out how vital cache capability is in NDNS.

3.4.1. Scenario 4 Average Delay (Active Node Change)

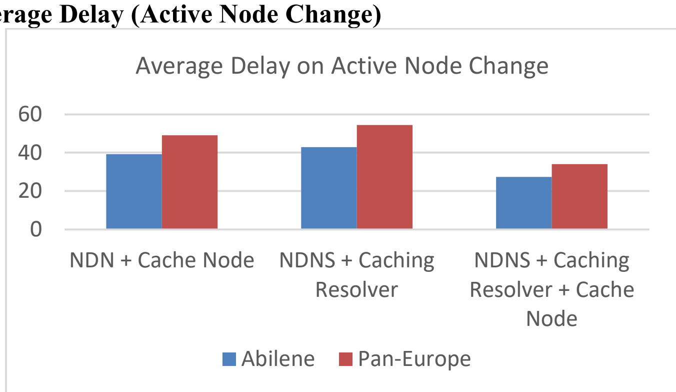

Figure 11. Average Delay on Active Node Change

From Figure 11, it was found that NDNS with Caching Resolver and active NDN Router cache nodes got better results than NDNS with Caching Resolver only and NDN with Cache in Router. NDNS with cache shared responsibility have 43% (Abilene), 44% (Pan-Europe) better than NDN with cache and 57% (Abilene), 60% (Pan-Europe) better than NDNS with just Caching Resolver. This happens because NDNS, at its total capacity, shares responsibility for the cache between the Caching Resolver and the cache on the NDN. In the case of NDNS, which only uses the Caching Resolver capability, the delay results are greater than NDN with a cache on the Router because NDNS, in this case, still prioritizes the cache on the side of the NDN Router. NDNS runs on top of the NDN architecture, relying on caches on the NDN router to quickly get data from repeated queries. The cache on the resolver can cache, but the higher delay is due to queries, mainly iterative queries against the Root Server and Authoritative Name Servers, to get data that is not cached—average Delays caused by propagation between nodes as well as queue delays from the queries itself.

3.4.2. Scenario 4 Cache Hit Ratio (Active Node Change)

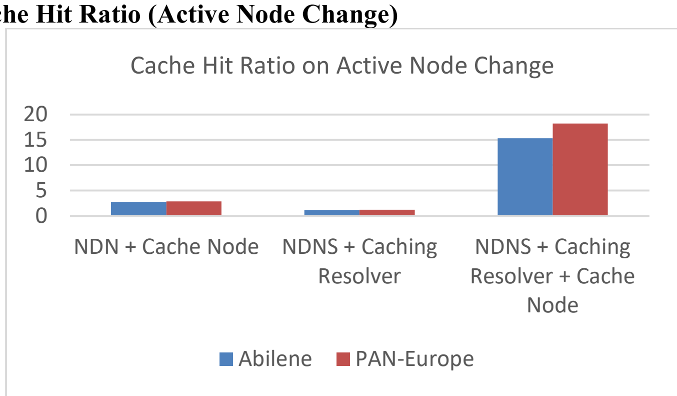

Figure 12. Cache Hit Ratio on Active Node Change

From Figure 12, in the case of NDN with its cache capabilities, it is still smaller than NDNS with cache capabilities on the side of the caching resolver and its NDN cache. NDNS with cache shared responsibility have 12,58% (Abilene), 15,27% (Pan-Europe) better than NDN with cache and 14,11% (Abilene), 16,96% (Pan-Europe) better than NDNS with just Caching Resolver. It happens because there is a guarantee of larger cache space on NDNS. However, for the case of NDNS with only the caching resolver active, the cache hit ratio is smaller than NDN with the cache. It happens because the primary cache relies on the NDN router, which is then shared with the caching resolver to shorten the query process later. Although the cache space is larger than that of an NDN router, there will be more interests that do not get data on the resolver and the NDN router because of the large number of repeated queries that cannot be filled with data requests, so there will be more cache misses from unsatisfied queries towards the Router Content Store.

3.4.3. Scenario 4 Packet Drop (Active Node Change)

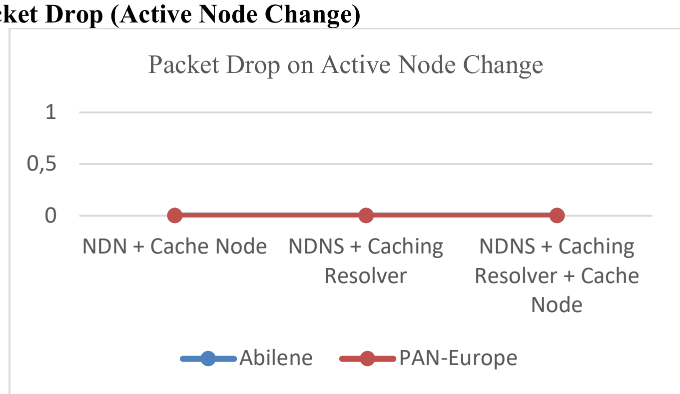

Figure 13. Packet Drop on Active Node Change

From Figure 13, there are no Packet Drop changes in both topologies in every Active Node change. This indicates that all data packets have been successfully sent back to the consumer.

3.5. Scenario 5

Sub-section scenario five will discuss the result obtained from the simulation of active node as shown in the subsection below. Scenario 5 will discuss cache activated both NDN and NDNS with change in content store to see a brief comparison between full cache capability between NDN and NDNS and to find out how vital cache capability is in NDNS.

3.4.1. Scenario 5 Average Delay (Content Store Change)

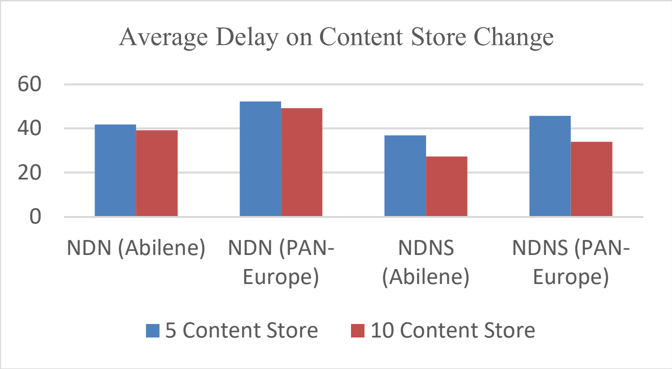

Figure 14. Average Delay on Content Store Change

From Figure 14, changes in the Content Store to the average delay of NDN and NDNS, the larger the Content Store, the smaller the Average Delay. It happens because more data is obtained from the Content Store. For the case of NDNS, the average delay is smaller than NDN. It occurs because NDNS shares cache responsibility between the Caching Resolver and the NDN Router. However, it is preferable to cache on the edge of the NDN on an NDN architecture or use NDNS.

3.4.2. Scenario 4 Cache Hit Ratio (Content Store Change)

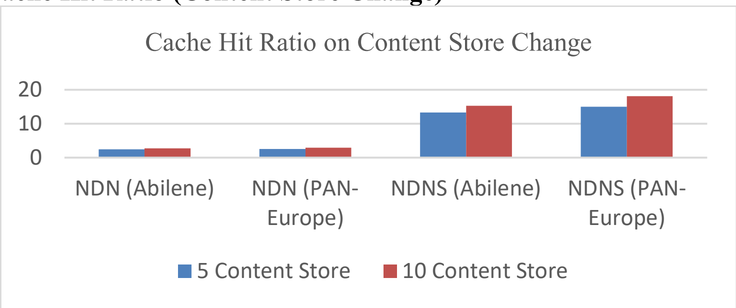

Figure 15. Cache Hit Ratio on Content Store Change

From Figure 15, changes in the Content Store to the NDN and NDNS Cache Hit Ratio, the larger the Content Store, the greater the Cache Hit Ratio. NDNS with cache shared responsibility have 26% (Abilene & Pan-Europe) decreases of Cache Hit Ratio and NDN with cache have 6% (Abilene & Pan-Europe) decreases of Cache Hit Ratio that NDNS have better Cache Hit Ratio than NDN. It happens because more data is obtained from the content store for NDN. For the case of NDNS, the results obtained are a greater Cache Hit Ratio than NDN. It occurs because NDNS shares cache responsibility between the Caching Resolver and the NDN router so that NDNS will get more data from the cache in Router and Caching Resolver.

3.4.3. Scenario 4 Packet Drop (Content Store Change)

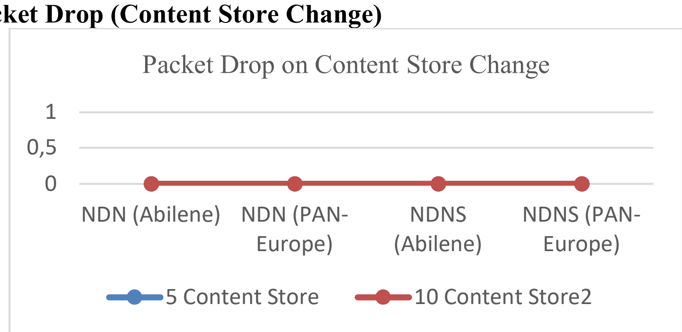

Figure 16. Packet Drop on Content Store Change

From Figure 16, there are no Packet Drop changes in both topologies in every Content Store change. It indicates that all data packets have been successfully sent back to the consumer.

4. CONCLUSION

From the research that has been done, average delay can be affected by variations in prefix/content aimed at the server, both the root server and the authoritative name server. It happens because the Delay that is obtained is influenced by the queue delay on the server and the propagation delay, which is dominated by direct requests from the consumer to the server which is caused by the number of interests that are not obtained from the cache, both caching resolvers and on the side of the NDN router. This situation causes more repeated queries directed to the root server and authoritative name server when the Prefix variations are more diverse. In the delay results obtained, the Delay for each variation of the Prefix changes in the Second Level Domain and Top-Level Domain levels, there is no difference in Delay. The number of queries directed to both root and authoritative name servers remains the same.

The frequency of interest per second can also cause an average Delay, where the greater the frequency per second, the greater the Delay. It is caused by the influence of random interest per second, where the more there are, the less possibility to get Data Packets from the cache due to changes in the content store that are getting faster in changing cached packets and the cache on the side of the caching resolver which can only store one package and time to live for cache which is set for only 1 second.

The difference in average delay is not too big between the two topologies due to the connectivity between the nodes, where PAN-Europe has more connectivity between nodes than Abilene, so the distance to reach the server is getting longer. It causes a larger propagation delay, so the average PAN-Europe delay is higher than Abilene.

The cache Hit Ratio is influenced by the number of intended prefixes. The more prefixes, the smaller the Cache Hit Ratio. Then, the Cache hit Ratio can also be influenced by the frequency of interest, where the more the frequency of interest, the smaller the Cache hit Ratio. It happens because the Cache on both the NDN router side and the resolver caching is minimal. However, in this study, it can be concluded that a small Cache Hit Ratio proves that consumers request content directly from producers.

In this paper, it can be concluded that the role of the caching resolver and the NDN router in joint responsibility to cache the intended content is very important to distribute traffic loads on the network, especially requests to the root server and authoritative name servers directly that from the simulation results, the performance of NDNS with shared responsibility for the cache in the NDN router and the caching resolver has a much better performance than NDN with cache on the router and NDNS with cache in the caching resolver only. Name resolver is a protocol that must be on NDNS, that is, DNS-like services embedded in Named Data Network. Name Resolver can be profitable if the cache in-network NDN is shared cache responsibility with Caching Resolver to fasten queries that are not satisfied by Caching Resolver. NDNS needs NDN in-network caching as the best-effort cache, but NDN still needs scalability support that is distributed database from NDNS to guarantee cache space in the application layer.

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