JATAED
Journal of Appropriate Technology for Agriculture, Environment, and Development
email: jataed@lkppl.org
E-ISSN 3031-0903
Volume1, Number 2, April 2024
https://doi.org/10.62671/jataed.v1i2.44

Optimizing Content Hit Rate On Named Data Network Using Multilevel Content Store

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Article History:
Submitted: 07-06-2024
Accepted: 26-06-2024
Published: 01-07-2024
Keywords:
Named Data Network; Multilevel Caching; Content store; hit rate; ndnSIM

ABSTRACT

The internet is a technology that allows users to exchange information more flexibly. As internet service users increase, communication not only between humans but also between machines (IoT), so does the need for internet access. With the architecture in use today, IP based network, Requires users to access the server / producer (of the content) to obtain the desired content. This architecture will meet with limitations where the density of network traffic will continue to increase. Named Data Network (NDN) is currently being developed as an internet supporting architecture which changes the interconnection paradigm that was previously address-based to the desired content/information. NDN which can support the needs of users to access content through the content caching feature. The content caching capability allows the router to store copies of content in memory for a specified period of time. So users who need content can simply access the closest source (content store). The scheme that is widely used in the content caching method is to place content in one large memory. This research develops a scheme where cache memory is divided into two levels (multilevel CS). The purpose of using multilevel CS is to improve the performance of the content store. Testing is done by comparing the single content store scheme and multilevel content store. The parameters tested are the hit rate, miss rate, and average content lifetime in the content store. As a test parameter is a large change in content store size, interest rate, topology grid size, and consumer deployment. From the simulation results, the 2-level content store scheme has better performance compared to conventional schemes.

INTRODUCTION

Interconnected computer networks or Interconnected Networks (Internet) were developed since 1966 due to the need to share resources effectively. One of the basic ideologies of the internet is sharing resources between distant devices over interconnected networks with many benefits such as reducing investment costs in devices, and increasing time efficiency. The initial stage of the internet was ARPANET. In communicating, devices connected to the network use the Network Control Protocol (NCP) protocol. Subsequently, NCP was replaced by Transmission Control Protocol (TCP), User Datagram Protocol (UDP), and Internet Protocol (IP) until now. These protocols work by addressing the devices connected to communicate. This architecture is used and used as the basis for the development of internet technology to date(Leiner et al., 1997).

As time goes by, the development of internet technology continues to increase and improve. Currently the internet is used in various aspects of human life such as social, economic, educational and health. The improvement in aspects supported by the internet cannot be separated from the increase in users all the time. In its survey in 2018, the Indonesian Internet Service Providers Association (APJII) recorded the growth of internet users in Indonesia in 2018 amounting to 171.17 million people, this is from a total population of Indonesia of 264.16 million people, an increase of 10% percent compared to 2017 namely 143.26 million people out of Indonesia's total population of 262 million people. And among internet users, 65.8% of them have a tendency to access multimedia content such as images, videos, music and live streams.(APJII, 2018).The same thing was conveyed by Cisco, Inc. In the 2017 Cisco Visual Network Index (Cisco VNI) it is predicted that global internet users in 2022 will reach 4.8 billion users, this is an increase from 2017 with internet users of 3.4 billion. With 82% of the service traffic used in 2022 being used to access multimedia service content, where in 2017 the same traffic was 72%(Thomas Barnet et al., 2018).

With this phenomenon, a new paradigm was developed to support future internet communications. Where the focus of the proposed architecture is focused on content circulating on the network, Content Centric Networking (CCN). CCN is a technology that is being developed by the Palo Alto Research Center (PARC). Subsequently, the CCN was developed into a Named Data Network (NDN) by the National Science Foundation (NSF). It is hoped that NDN technology will be

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able to improve performance in internet networks(Almeida & Lourenço, 2012; Yovita & Syambas, 2018).

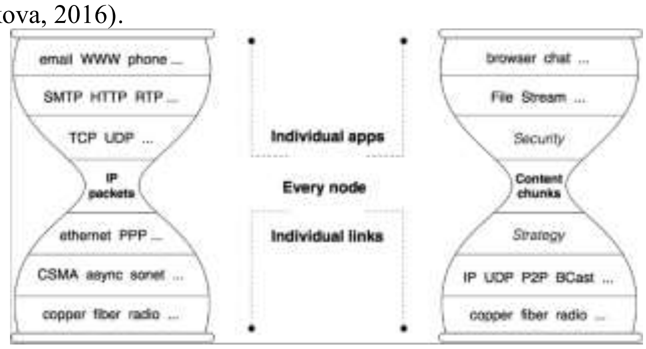
NDN is a network model where computing is carried out in a distributed manner. In NDN, the communication model between devices no longer uses the IP address as the destination, but rather identification is based on naming the expected content. That way the communication process will be more efficient(Almeida & Lourenço, 2012). By changing the system from where the content to what the content, NDN supporting devices, one of which is the NDN router, require the ability to store content, this method is also called content storing or content caching.(Yovita & Syambas, 2018).

Content caching is a method of storing data in memory for a certain period of time. Several aspects need to be considered in caching, including the cache allocation scheme and cache replacement policy. The cache scheme that is currently widely used is single cache. Meanwhile, cache replacement policies that are commonly implemented are Least Recently Used (LRU), Least Frequently Used (LFU), and First In First Out (FIFO)(Hull, 2002).

In this research, the contribution made is the simulation of a multilevel cache scheme on an NDN Router with an LRU cache replacement policy. By using a multilevel cache scheme, it is hoped that it can increase the hit rate and reduce the value of miss hit content in the cache. In addition, the proposed caching scheme is expected to be able to increase the duration of content in the cache, from cache entry to deletion, as a measurement parameter(Feldman & Chuang, 2002). Named Data Network Simulator (ndnSIM) version 2.6, and NDN Forwarding Daemon (NFD) devices(Putra, 2019). Next, testing scenarios designed to test the performance of the multilevel cache on the NDN router.

LITERATURE REVIEW

Named Data Network (NDN) is a new paradigm in internet architecture that was introduced in 2009. NDN itself is a continuation of the Content Centric NetworkI (CCN) concept developed by the Palo Alto Research Center (PARC). Meanwhile, NDN is then supervised by NSF. The initial implementation of NDN still uses the ccnx module as its codebase. In 2013, the NDN module was updated so that it was able to support the architecture used by NSF(Ahmed et al., 2016; Bartolomeo & Kovacikova, 2016).



Figures 1. NDN vs TCP Abstraction

The Hourglass architecture model shows the internet is centered on a universal network, namely IP, which implements the minimum functionality required for global interconnectivity. The thin waist concept is an important factor in the development of the internet but it also carries some limitations.

The NDN architecture still carries some of the existing technologies in TCP IP. Among them, routing which was initially only forwarding has become operational simultaneously (packets are still forwarded but also continue to make changes to the routing table) such as routing on IP-based networks. Apart from that, NDN brings several new features, which are implemented at the layers of the NDN architecture. At Layer Strategy, NDN has the advantage of several connection types (3G, Ethernet Plus, Bluetooth plus, 802.11) at once, designed to be able to dynamically select the optimal connection type in changing conditions. Layer 4 (chunks) combines several technologies such as self-regulation, namely automatic traffic management (not relying on load-balancing schemes), and the possibility of implementing NDN on top of existing architecture.(Bartolomeo & Kovacikova, 2016). This architecture also implements a security system by marking every content on the network.

The working principle of communication in the NDN architecture basically depends on the receiver. Receivers (consumers) who want content will send an interest packet, in the form of the name (identifier) of the desired content. Next, the router will store the interest packet data and forward it to the Forwarding Interest Base (FIB), which is in the form of a routing table from a name-based routing protocol. When the interest packet reaches the node (not necessarily the "server" node that generates the data) the requested data will be sent to the consumer. The requested content data packets carry the name of the content, and the content is marked with the key of its producer. So that in the Data or Interest packet there is no information related to the host being passed (especially the IP address)(Ahmed et al., 2016).

The NDN Router will store data and interest packets for a certain period of time. If there are several interest packets entering simultaneously, the first one will be sent first, and the others will go to Pending Interest Tables (PITs). Each router will be equipped with a Content Store (CS), which is a cache or buffer memory similar to current conventional

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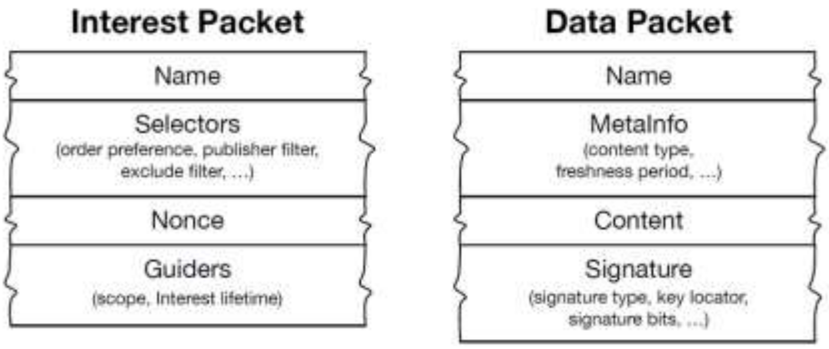
routers. What is different is that the NDN router will have the ability to forward data packets. A data packet can be said to be independent from both the producer and the consumer. So that each NDN Router can later store (caching) data packets and forward them to interest packets in the future.

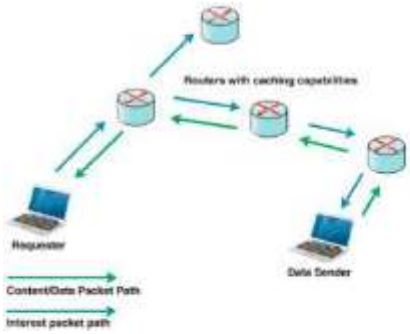
A. NDN architecture

The NDN architecture offered still has the same basis as the IP-based network architecture. The changes made are in the data access method. The NDN architecture no longer offers access based on the destination (IP address) where the content is located, but rather by using a name for the content. The name concept will be able to improve overall network performance(Zhang et al., 2014).



Figures 2. NDN Architecture

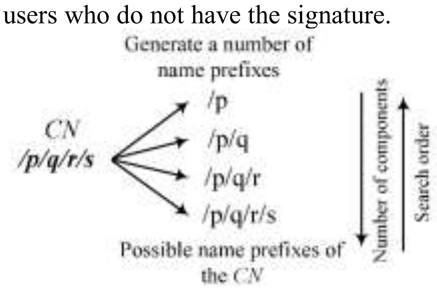
Interest Packet and Data Packet Components The image above shows the components used in the process of accessing content. Where the user will send an interest packet containing the content name, then sent to the network by the router and then forwarded to the nearest available source (either directly to producers or content stores). Then a data packet containing the same content name information will be sent to the user based on the path traversed by the interest packet. This method is also called reverse path.



Figures 3. NDN Interest Flow

B. Naming System

As a substitute for IP addresses, the NDN naming system has several rules. Choosing a name or prefix is important because it must be unique, can be read easily, is safe, and is based on location(Ahmed et al., 2016). What is commonly developed nowadays is naming with hierarchical prefixes, but there is a weakness in this method where the content will be exposed directly. To overcome this, signatures are used, where each package (interest and data) will have a unique signature. Thus closing the access gap for users who do not have the signature.



Figures 4. NDN Content Naming

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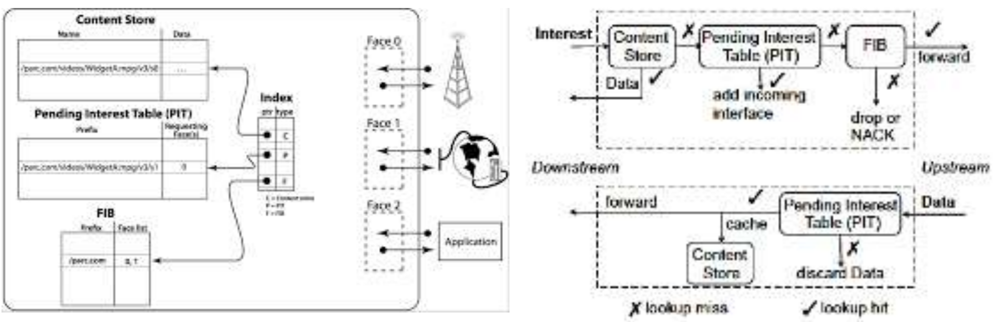
Figure 4 shows how the lookup process occurs using the hierarchical naming method. /p is the main address of the content, then followed by /q which is a sub part of /p, and also followed by /r and /s. In this research, the naming concept /prefix/name-content will be used.

C. NDN Routing

The NDN architecture routes and forwards packets based on their content name, so this covers several shortcomings that exist in IP-based networks, including(Bartolomeo & Kovacikova, 2016):

- *Address Exhaustion*or running out of IP addresses can be avoided on NDN. Basically the number of namespaces in NDN is unlimited. What limits the namespace is the size of the interest packet of 8 kb, where the content name can be an alphanumeric combination.
- *NAT Traversal*, by ignoring IP addressing, accessing content does not require translation,
- *In-network multicasting*, the data producer does not need to receive multiple interests for the same data because PIT entries downstream of the forwarder will aggregate the interests. The producer receives and responds to a single interest packet and the forwarding node that receives multiple incoming interest packets will be multicast to the interface where the interest packet was received,
- *High loss end-to-end reliability*, IP-based networks require several packets to be dropped during data packet transmission. But in the NDN network, when the interest packet expires before the data packet reaches the requester, the data packet will be stored in the content store along the path the interest packet travels. So it is possible that when the next interest packet is sent, it only needs to reach the last data packet stored in the content store.

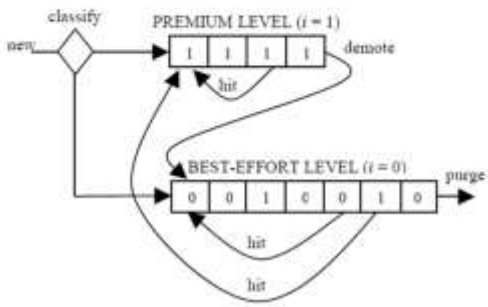


Figures 5. NDN Routing

D. Store Content

*Cache Replacement Policy*LRU is an algorithm for managing cache usage. The LRU mechanism is by shifting the most recent (latest) referenced content to the front cache block. Next, other content will follow shifting to the empty cache block. When the cache block is full while new content is coming in, the content in the last block will be deleted, so that all content is shifted and new content fills the front block(Putra, 2019).

*Multilevel Content Store*uses the concept of multilevel cache as its basis. Multilevel cache itself is a mechanism to improve the performance of a cache by increasing access time and reducing miss hits []. Multilevel Content Store will divide the content store into several levels, then apply a replacement policy in managing the stored content(Feldman & Chuang, 2002).



Figures 6. Multilevel Content Store Algorithm.

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METHOD

This research will be carried out entirely using the modules provided in ndnSIM as a basis. The coding process for implementing the multilevel content store will modify the LRU content policy as a module included in ndnSIM. Other parameters used in the simulation include:

1. Topology: this research will use a grid topology with variations in size and distribution of consumers as the basis for testing,
2. CS size: the size of the Content Store will be varied so as to obtain more varied results,
3. Interest Rate: to monitor CS performance the interest rate from consumers will be tested with different values for each scenario,
4. Simulation time: each scenario will be run within the same time period, 300 seconds.

This research will test the performance of a multilevel content store with two main topologies, namely grid topology and palapa ring topology. Next, the multilevel content store scheme that has been implemented in csPolicy.cpp will be implemented using the LCE model as explained in Chapter II. This section will explain the topology generation process on ndnSIM. Grid topology is basically a ring topology formed with core nodes of size (n × n). The grid topology generation in ndnSIM most commonly uses a point-to-point module. So that configuration of variations in topology size can be done easily. This research will use several variations of size.

As explained above, this research focuses on testing the performance of two content store schemes. The schemes tested are single level content store and 2-level content store. One of the references for this research is research [7], where in this research the implementation of multilevel cache in web services, and the addition of priority based and best effort in content selection. And updates are also carried out at each cache level. The working principle of a multilevel content store is to divide the content store into several sections and fill each level based on certain parameters. In this research, the content store is divided into 2 levels, and content is placed into the content store based on its prefix.

Table1. Simulation Parameters

Parameter	Mark	Information
Data rate	1 Mbps	Consumer and router link throughput values
Link delay	10 ms	Delay value for each link
Producer	2 producers	Number of content producers (servers) in the network
Forwarding strategy	Best-route	Forwarding strategy for interest packets
Routing strategies	ndnGlobalRouting	To map the prefix address to the producer position
Consumer helper	ZipfMandelbrot s = 2.5 ; q = 2.5	Interest Generator for each consumer
Prefix name	“/prefix” “/prefix2”	Producer prefix address 1 Address prefix producer 2
Payload size	1024 bytes	The size of the data packet for each content
Simulation time	300 seconds	Simulation time
Content Store Allocation	Single Level Multilevel (L1 = 30%, L2=70%)	Content store configuration between single level and multi level

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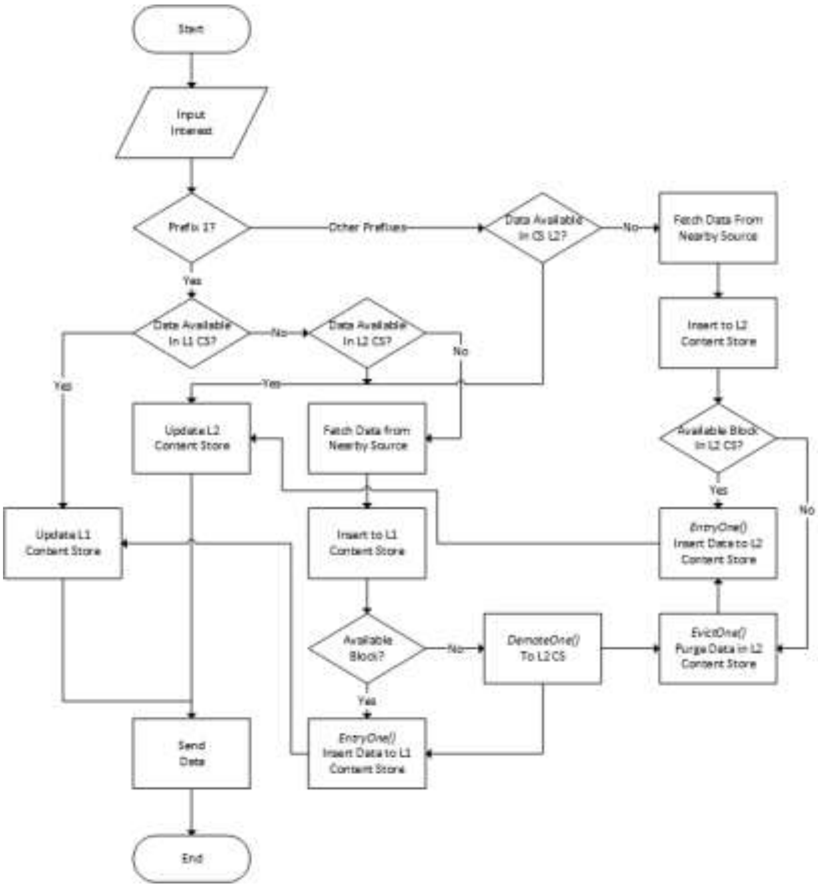
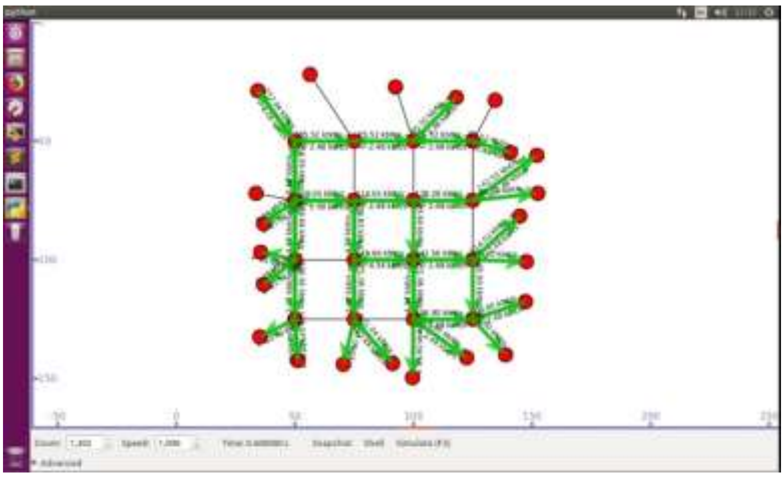


Figures 7. Simulation Flowchart

RESULTS & DISCUSSION

The first test was carried out using a 4x4 grid topology. It uses two producers and 20 consumers. Consumer deployment is done by placing two consumers on the outermost router. The following is a visualization of the form of the network being tested:



Figures 8. Network Topology used in Simulation

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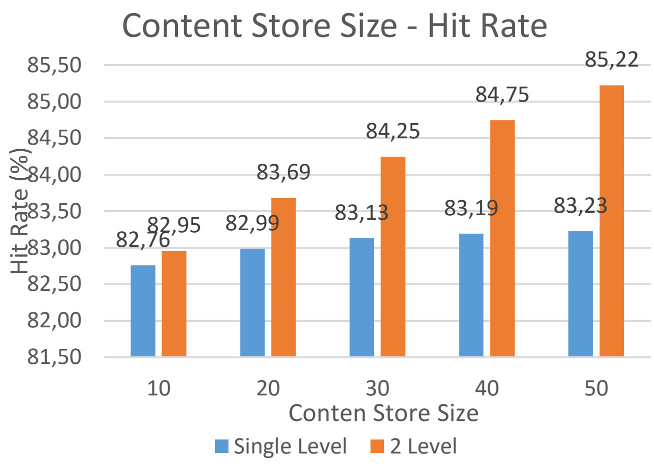
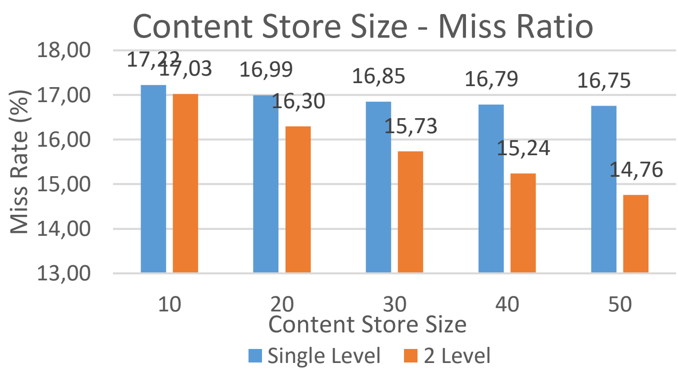


Figures 9. Probability of Content Hit Rate of Single Level and 2-levels Content Store

The first content store performance testing parameter is the large influence of content store size on the hit rate value. One of the parameters that shows the performance of a cache replacement is good is having a high hit rate value. The picture above shows that when the content store size is 10, the single level CS scheme has a hit rate value of 82.76%, whereas using a 2-level CS scheme with a size of Level 1 = 3, and Level 2 = 7 has a hit rate value 82.95%. When the CS size is 10, there is an increase in the hit rate value in the 2-level CS scheme compared to the single level CS scheme of 0.19%. This shows that the multilevel CS scheme is able to increase the hit rate parameter.

When the CS size is changed to the range 20 < CS size < 50 there is an increase in the hit rate value in each range. When the CS size is 20, 30, 40, and 50, the difference in hit rate is 1.3%; 1.12%; 1.56%; and 1.99% respectively. This shows that the use of a 2-level CS scheme has an increase in hit rate performance at a larger size compared to the conventional single-level CS scheme.



Figures 10. Probability of Content Miss Hit Rate of Single Level and 2-levels Content Store

The next test parameter is the effect of CS size on the miss rate value. A lower miss rate value indicates that the cache replacement performance is getting better. When the CS size is 10, the single-level CS scheme has a miss rate of 17.22%, while the 2-level CS scheme has a miss rate of 17.03%. Shows that the 2-level CS scheme is able to reduce the miss rate value by 0.19% when the CS size is 10. A decrease in the miss rate value is also experienced in each CS size parameter tested. When the CS measures 20, 30, 40, and 50, the decrease in miss rate values respectively is 0.69%, 1.12%, 1.55%, and 1.99%. This is in line with the increase in the hit rate value for each different CS size. By decreasing the miss rate value in the 2-level CS scheme, it reduces the probability that an interest packet will not find the expected content.

CONCLUSION

Based on the literature review and simulation analysis carried out on the performance of 2-level CS and single level CS schemes, it can be concluded that:

1. Overall, the 2-level CS LRU scheme test has better performance values than the conventional single level CS scheme
2. Changing the size of the Content Store will affect the performance of the content store quite significantly. The larger the content store will produce better performance. The average increase in the hit rate value provided by the 2-level

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content store scheme with the effect of changing the content store size of 10, 20, 30, 40, and 50 on the three test topologies is 0.24%; 0.77%; 1.32%; 1.91%; and 2.53%.

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