A Review on Cache Replacement Strategies in Named Data Network

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***Abstract*—Named Data Network (NDN) architecture is one of the newest and future-aspired Internet communication systems. Video-on-Demand (VoD) has rapidly emerged as a popular online service. However, it is costly, considering its high bandwidth and popularity. Internet on-demand video traffic has been growing quite fast, and on-demand video streaming has gained much attention. The problem of this study is that the NDN architecture is processing several forms of online video requests simultaneously. However, limited cache and multiple buffering of requested videos result in loss of data packet as a consequence of the congestion in the cache storage network. Addressing this problem is essential as congestion cause network instability. This work emphasizes on the review of cache replacement strategies to deal with the congestion issue in Named Data Networks (NDN) during the VoD delivery in order to determine the performance (strengths and weaknesses) of the cache replacement strategies. Finally, this study proposes the replacement strategies must be enhanced with a new strategy that depends on popularity and priority regarding the congestion. This study would positively benefits both suppliers and users of Internet videos.**

***Index Terms*—Cache Replacement Strategies; Name Data Network; Video on Demand, Congestion.**

I. Introduction

The rapid growth of Internet use these days is mainly because it is often used for content distribution. This is originally attributed to the Information-Centric Networking (ICN) development within the industry's wider and academic domains. Its utilisation goes back to the 1960s and 1970s when there was the wide utilisation of the Internet's point-to-point paradigm at the start of computer networks. However, in today's context, rich multimedia content mainly dominates the Internet. The ICN, being the future Internet's forerunner, suggests an infrastructure of network redesign built around the content. This represented an important moving from the current sender-driven point-to-point communication to receiver-driven communication that is content distribution. This new architecture for the network aims to address the current Internet's many issues (content distribution efficiency, security, congestion, etc.) and thus provide users with better communication network [1-5]. However, when a network is loading more data than it is able to handle, the congestion of the network decreases the quality of service [6-8].

The major platforms utilised in online video streaming or the Internet are game consoles, TVs, and web browser plug-in. These are supported by the techniques of video streaming between clients and suppliers. The researchers have established that the sources of the videos are either the traditional way or the Internet. The video starts the playback after the download is completed; therefore characterising both ways with the issue of traffic. Earlier the researchers have emphasised that many Internet videos are encoded at varying rates ranging from a standard definition of 235Kb/Sec to 5Mb/Sec high definition [9], [10]. Thus, the videos on the Internet need to be stored on the server as many small files that representing video chunks and this causes the storage cache to work more.

At times, the large storage of Internet video streaming fails while users access it. This is due to the Video on Demand's (VoD) workload where the number of different entities is relevant. The VoD system makes it possible for the consumers to choose and watch the content of the video whenever they want to instead of them having to watch a video within a particular time of broadcast. Often, the technology of IPTV is utilised to provide VoD to personal computers and televisions [11]. One of the newest and future-aspired Internet communication systems are called the Named Data Networking (NDN) architecture. This architecture has produced new opportunities in Internet applications. NDN architecture has made sure of smooth communication between the request and the online video's receiver [12]. Therefore, it allows the cache storage to process several forms of online video requests simultaneously [11], [12].

Furthermore, researchers have emphasised the flexibility of NDN and its capacity to support many of the encoding formats that the streamer allows. Whereas, the streamer is a pipeline-based framework of multimedia [13]–[15]. Thus, publishers are able to sign content object from the input video stream. This video stream could either be pre-recorded or live and then stored in local repositories. Whereas, VoD has congestion as a result of the persistent workload such as when the signed content object into the local repository is stored quickly and frequently [7], [16], [17]. Moreover, frequent VoD workload congestion results in a buffer in request content, especially for request of Internet videos [17]. Ideally, the inner layer controls the handling of large video data. This prompts the information that is required to allow the NDN-video compatibility with frame rate codes and guarantees buffer playback. However, various videos request buffering is resulting in loss of data packet as a consequence of the congestion in the cache storage network [7], [10], [12], [16], [17]. Thus, improving the architecture that is utilised in Internet video streaming is vital.

This work reviews and evaluates previous works on NDN architecture during the operation of cache replacement strategies and VoD workload. This was done in order to address congestion issues. The rest of the paper is then divided in the following manner: Section II provides a description of the Named Data Networking, Section III presents the characteristics of the NDN Operational Architecture, Section

IV discusses the In-network Storage, Section V describes NDN Congestion, Section VI presents a characterisation of the cache replacement policies, and Section VII is the conclusion.

II. NAMED DATA NETWORKING (NDN)

NDN is the communication architecture that is most often utilised in Internet video storage. It prioritises the data, including videos. As shown in Figure 1, the NDN architecture is essentially made up of communication units, such as interest and data packets [7]. The interest packet is considered one of NDN's communication units that are sent once there are requests from consumers of video streaming or data. On the other hand, a cryptographic signature protects the data packet and provides the data of video source with more integrity from the cache. Thus, the interest packet brings with it a selector field that signifies instances where there are multiple data so that they can satisfy the interest packet [7], [13]. Consequently, the data packet satisfies essentially the interest packet since this packet carries the data's prefix name [13]. Additionally, notable Internet architecture like TCP/IP provides the host with IP addresses and therefore allows the Internet to be seen as a point-to-point communication system [7]. It has been considered that NDN is the Internet architecture that has more advantage over TCP/IP since it is able to provide a venue for content distribution (such as video streaming) and help the content arrive in its designated destination successfully [7], [14].

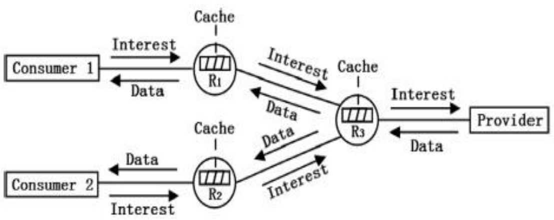

Figure 1: Data flow in NDN architecture [7]

III. THE NDN OPERATIONAL ARCHITECTURE

This section is linked to the diagram shown in Figure 2. This diagram demonstrates how each NDN router maintains three data structure forms. Here, the interest and data packets can be forwarded using Forwarding Information Base (FIB), Pending Interest Table (PIT), and Content Store (CS). Given these three processes, one can observe that the re-routing strategy guides the operation. Then, this re-routing strategy determines where and when to divert each of the NDN architecture's trays. For this type of situation, all the PIT Interests' stores are considered as routers. However, they were not able to fulfil the stage [7], [18], [17] [19]. For the majority of cases, the interest package prompts the substance's preparatory examination through an NDN router, which in turn results into a preliminary content store examination in order to match the data. This is performed to restore the interest packets on their sources and the data packets on the router interface.

However, if this process is not done, the router is utilised to look for the PIT's name. As such, if there are matching entries, the interest's incoming interface with the introduction of PIT is simply recorded by the router [19], [20]. Nevertheless, if there is no input matching PIT, the router will readdress attention to the data product, which in turn is based on the FIB information, along with the strategy of adaptive forwarding router [21], [22]. This makes sure that the re-routing strategy can recover the package's longest prefix of interests. As a matter of fact, these procedures guide the NDN's Content Store and justifies it as a temporary cache for the data packets that will have to be received by the router. As such, the packaged NDN data's autonomous component becomes more meaningful. It is important at any point where it has been put away incidentally in order to meet future interests [7], [21], [22].

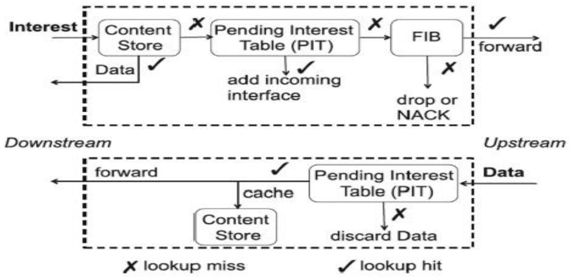

Figure 2: Interest and data processing in NDN node [7]

IV. IN-NETWORK STORAGE

For some reasons, the requester or the organizer asked for recovering autonomous tasks of the independent projects, alongside the NDN package that bears the name and the signature of the data. Along these lines, the router reserves the rights of receiving data parcels within the content store and utilizes it to meet future requests. Furthermore, the content store shares similarity with the buffer memory in IP routers, yet, in most cases of the IP router cannot be reused after the packet is sent to the consumer. However, the NDN directing gadgets can. Now and again, it can be acknowledged that the NDN treats stockpiling channels and as well, a comparable system that stands to be vital for the information recovery. In measurable setting and substance conveyance, NDN accomplishes almost ideal information conveyance and exploits reserving on catching multicast or retransmission after packet loss [11], [23].

Therefore, in this study, it can be accounted that the caching data reserves information, in order to uniquely raise the customer's name in relation to the IP, which permits examination of security concerns and load packet index of the consumer information [24], [25]. In this reality, naming and caching of data within the NDN systems do not encourage control what information is asked for, but rather without the goal addresses it is hard to figure out who demands it. Along these lines, the NDN offers a drastically extraordinary sort of privacy protection; or rather it provides security insurance of the existing IP networks. This goes by the number of researchers that have affirmed the importance of the caching system, for example, the essential additions to structures ICN in setting [26]. Regardless of the way that the NDN can bolster all the more intense CDN models of TCP/IP, the systems of the NDN gives numerous different capacities, for example, information prompting to various protection picks up in order to demonstrate huge and imperative favourable circumstances [11], [26].

V. Congestion in Named Data Network

Extensive research has been conducted on congestion handler in NDN. Most of the previous follow the actual end-to-end technique of TCP by adjusting one Interest to suitable characteristics of a certain network and usage settings [27]. However, the heterogeneous Round Trip Time (RTT) due to caching, multiple suppliers and multipath forwarding makes it hard to line retransmission timeout as in TCP is designed to provide further support to detect blockage [28]. Consequently, some solutions seek to help predict RTT a lot more accurately through certain areas based on the association of stored data with future content relevant to the data packets. In this case, congestion control in NDN is always recognized to be a smart and adaptive way in which the information is processed similarly to the IP manner [11].

In addition, the congestion control comprises procedures which are same as the IP network in regards to registering computable behaviour, in order to process tables of information. Therefore, the procedure for sending data in the NDN system is part of two-stage technique: (a) client-first sends interest packets, (b) information applies to interest packet stream back in a similar way inside the turn-around heading [26]. On the other hand, a number of perspectives can be attained when dealing with congestion enhancement in NDN based routers. This includes balancing the pending requests associated with clients' interest to steer Data packets time for requesting packets. The impending Interest condition together with all the two-way info makes it possible for NDN routers' forwarding procedure to measure the performance associated with different trails.

Furthermore, the NDN includes determining any potential failures as well as retry alternative paths. Such features associated with NDN is referred to as adaptive forwarding that provides the possibility for routers to detect network issues quickly without anticipating global direction-finding convergence. However, if data is not received before the timer expires, there might be potential forwarding issues where NDN routers can begin exploring alternative paths instantly using regional state info [11].

The moment congestion arises; data retransmission is aided by simply caching the attached information within the same path. For instance, if more than one congested inbound link is found on the path between the client and server in which the data supply gets through the first infected link may not make it in the second link [7], [22]. After this caching, the result will permit the information dedicated to the certain packet to be retransmitted more than only the other congested link. Meanwhile, the current characteristics of the Internet make it difficult to control the congestion in NDN where the retransmission connected with data could happen all the way backs to the server. This can lead to increase the number of trails packets need to pass a certain link [23].

VI. Congestion in Video on Demand Requests

Congestion has a vital role in determining any network's performance. Network performance deteriorates with more congestion. Congestion issues are mainly caused by frequent video storage requests in the local repositories. For a multimedia framework that is pipeline-based, publishers can use the input video stream to obtain a signed content object. Moreover, this input video stream can either be live or pre-recorded and it can even be stored in the local repository [14], [29]. Since there are frequent requests for online videos, the signed content objects have to be stored in the local repositories quite frequently. This continuous workload results in further congestion of videos on demand [7], [16], [17]. Moreover, workload congestion results into a buffer of the requested videos. Consequently, multiple buffering of these video requests can lead to data packet loss as a result of congestion in the storage network.

VII. Cache Replacement Policies

The cache replacement policy has an important role in web caching. Replacement strategies are an important part of achieving the highly sophisticated mechanism of cache. This replacement policy helps evict the object from the cache and create a new space for the incoming object. However, a cache is not able to store the entire requested object because of its limited size. Therefore, room for new documents is provided by the cache replacement policy [30], [31]. This applies to a cache full of objects. Hence, the new object will then be inserted into the cache. In the caching strategies described below, cache replacement strategies are utilised as the most common replacement policies.

Least Recently Used (LRU) (the content that is least recently accessed is discarded) is a common cache replacement policy. It is popular because it has been known to perform well. Furthermore, it is even known that it increases the likelihood of a cache hit since it is capable of storing the most recent data for a longer period of time. Least Frequently Used (LFU) is also an important cache replacement policy because it gets rid of the contents that are less frequently used first. The cache decision's timing can be based on the content replacement and the arrival of the content at the router. To improve the performance of the network, any content should not be deleted from the cache. For caching, however, one can make it move one-level upstream within the hierarchy of the cache. Further classification of cache replacement was done based on either content prioritization or content popularity. This means that content with low priority or popularity is replaced first. However, LRU also uses the timestamp of the content and does not consider content popularity. Meanwhile, the LFU's content calculates distribution frequency. This results in inaccuracy in determining the degree of the new incoming content [32], [33]. Therefore, the classification of cache replacement is based on:

A. Content Popularity

In recent times, the issues related to content popularity in cache replacement schemes have been dealt with by maintaining a data structure that displays content names and that have their popularities available at the router's cache [32], [34]. Cache replacement for a dynamic network also has an important role in making sure that the network performance is improved. Policies like LRU and LFU are based on access-time-patterns and as such, do not have the capacity to fully make utilize the popularity of the NDN network's contents. The network of NDN needs a content popularity-based cache replacement scheme in order to develop a caching strategy that is efficient. To improve the cache performance, Ran, et al. [32] came up with a scheme of cache replacement that depends on the popularity of content which it is Cache Content Popularity (CCP).

In terms of the data structure, the addition of a Content Popularity Table (CPT) that stores information was done on the CS. Along with this, other information like cache hit, content's name, and instant and past popularity are also stored. Based on the cache hit, and content access frequency and. Thus, the CCP will calculate the present popularity of the periodically content then replace the least popular content with the other existing contents. This new proposed scheme performs better compared to LFU and LRU. Additionally, the suggested manner consumes most of the CPU time for updating the table of CCP. This characteristic is not ideal for the networks of large-scale. Thus, in order to reduce resource consumption at the resource-constrained routers, Dai et al. [34] suggested a method that is space-efficient and online Bloom-filter based. This method is capable of determining the popularity of content at the speed of the line.

B. Content Prioritization

Lately, the content priority adoption was done to access the content of cached by utilizing the problem of knapsack [35]. A priority is assigned to the content. Then, this priority determines which content is first exchanged. When two mobile nodes quickly meet up, their encounter time is used to interchange their high priority of contents. Content prioritization in extremely effective networks plays a significant role in application performance. The content of high priority has a lot of availability in the network by comparing it to the contents of low priority. It is also known that low priority contents have high access latency. The main consideration is determining each content priority. The two major priorities are setting the factors which are the content demand and the general information that is swapped/generated amongst the nodes.

Moreover, Dron et al. [35] suggested policy for in-network content prioritization that can be utilised for cache replacement. They also emphasised the benefits of data naming for information delivery, thus maximising the cached content within ad-hoc networks. However, each item saved in the cache is then categorised to be either cold or hot. Therefore, when an encounter happens, the contents categorised as "hot" are exchanged first. The authors formulated the knapsack problem to determine what the contents are hot among the cached data. For this problem, the items within the knapsack must be capable of maximising their utility via all the replies to the user query. The items are labelled hot if they are utilized-maximising. To analyse the information-maximising policy, three performance metrics are used - coverage per query (amount of space a query response occupies in the case of a sensor), responses per query (throughput), and average delays (latency).

C. Least Recently Used (LRU)

The LRU replacement policy is easy to use and simple. This strategy is based on the timestamp. When the cache goes over its maximum size, it gets rid of the last recently used object that has not been used for a long time and replaces the evicted object with a new one [30], [36]. If the cache size is not full yet, the object will be inserted in the cache memory. For example, if we have "10 requests as video pages", Table 1 will show an example of how an LRU caching replacement strategy operates.

Table 1
Example of LRU Replacement Policy

Requests	V7	V0	V1	V2	V0	V3	V0	V4	V2	V3
Part3			V1	V1	V1	V3	V3	V3	V2	V2
Part2		V0	V0	V0	V0	V0	V0	V0	V0	V3
Part1	V7	V7	V7	V2	V2	V2	V2	V4	V4	V4

Using the LRU video replacement method is easy. This strategy also works with a timestamp. It evacuates the least as of late utilised question that has not been used for quite a while. This process takes place when the reserve exceeds its most extreme size. Another protest of the removed question is then set up [30], [36], [37]. If the reserve size is not full, the question will be embedded in the storage memory.

D. Least Frequently Used (LFU)

Every now and again, the LFU video replacement method expels the minimum recordings and puts another requested video within some free portion of the cache memory [36], [38]. It is exceptionally simple and straightforward. As such, a counter that tallies video recurrence is maintained. Often, the less persistently continuous videos are displaced by the newly approaching video. For example, if we have "10 requests as video pages", Table 2 will show an example of how an LFU caching replacement strategy operates.

Table 2
Example of LFU Replacement Policy

Requests	V7	V0	V1	V2	V0	V3	V0	V4	V2	V3
Part3			V1,1	V1,1	V1,1	V3,1	V3,1	V3,1	V2,1	V2,1
Part2		V0,1	V0,1	V0,1	V0,2	V0,2	V0,3	V0,3	V0,3	V0,3
Part1	V7,1	V7,1	V7,1	V2,1	V2,1	V2,1	V2,1	V4,1	V4,1	V3,1

Considering this, and since the network proxy system is situational and required to serve a vast amount of solicitations per second, the overhead system is logically expected to be maintained at the minimum base. To address this situation, the least utilised videos have to be ousted and evicted. In situations like this, the videos that are frequently used are upheld instead of the less utilised videos [30], [38]. Thus, as demonstrated, many contentions were in order to counter the affirmation that the majority of the frequently utilised recordings may not be needed later on, or in any case, this is not a standard rule.

VIII. CONCLUSION

This work presented and discussed the NDN architecture, cache replacement strategies, and attributes. It also discussed the content popularity or content prioritization based cache replacement methods, i.e. LFU, LRU, and CCP. This review can help researchers who work on current issues of NDN architecture. It will also help them to address congestion problems during VoD workload.

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