A COMPARATIVE SURVEY ON DIFFERENT CACHING MECHANISMS IN NAMED DATA NETWORKING (NDN) ARCHITECTURE

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ABSTRACT

The Named Data Networking (NDN) is the forthcoming internet architecture which is developed and tested as an alternative to the standard IP architecture. It is acquired from Information Centric Networking (ICN). The data accessing depends on the name of the data content so that it is not depended on any particular server or location. Each router in the network stores particular data as cache based on different policies like Least Frequently Used (LFU), Universal Caching (UC), First in First out (FIFO), Least Recently Used (LRU), and etc., Caching process in NDN is the main function, where the availability of data to the user is based on getting and storing the appropriate required data in the storage area. So that it must be available whenever the user request for it. Due to this function, it is the major area to be concerned and researched in the NDN architecture. This survey is done on several caching strategies, their algorithm, caching types, their advantages and issues. Based on the survey work, various cache methods are compared depend on different criteria like. Different challenges in their works are analyzed, and a proposal based on these works is given at the end of this paper.

KEYWORDS: NDN, named data networking, caching, internet, cache, content store

I. INTRODUCTION

In current generation, data is the most essential and required part of the internet. Sharing, accessing, analyzing process of those data is important in most of the applications in Cyber world. Other than web-based distribution of information, there are various technologies like Peer-2-Peer (P2P), Inter planetary file system (IPFS) and Content delivery network (CDN) that assumes an essential job in named based communication, rather than server-based communication. To address the problem of network traffic caused by the video and cloud computing applications, some technologies has been implemented that is based on caching, replicating and distribution of data contents. Caching is the most productive methodology that can be utilized in all information oriented services and technologies to reduce the data traffic and storage overhead. Named data networking uses caching in different levels based on various strategies.

II. NAMED DATA NETWORKING (NDN)

NDN Internet architecture was introduced as a proposal by Van Jacobson that allows us to search the contents based on the name rather than identifying its owner like it's in IP networks. Named-data networking (NDN) is the advanced and enhanced level based on the CCN architecture [1]. Similar to CCN, NDN also uses the data request and data reply packet type of process to obtain the required data. Naming the data contents is a main process of the NDN solution. NDN uses the stratified structure of naming the contents. It organizes a content name with a prefix and suffix in the format of 'NDN:/ensi.org/audio/mp3/v2/'. The stratified structure shows the relationships and context of the data elements [7]. The process of communication involves data request and data reply packets. Requestor sends the data request packet with the name of the desired information to request a content and the producer responses with the content to the data requestor in the structure of a data packet. The router (node) saves the information of the route through which the request for data content came and sends the data reply message. When the data request message comes to a node which contains the required data, the router (node) will send the proper data packet which contains the content along with the verification sign of the content producer. The reverse process is done in case of the data reply packet.

III. NDN SERVICES

Named data networking (NDN) has various utilities based on which, the function of NDN works. It is shown in the figure 1.

NDN Utilities: It depends on the important characteristics of NDN, which are routing, storing and forwarding process, security, and portability. NDN is capable of in-network caching of the required contents and delivering them. Security is the special trait in this architecture that gives best secured transmission of data through named data contents.

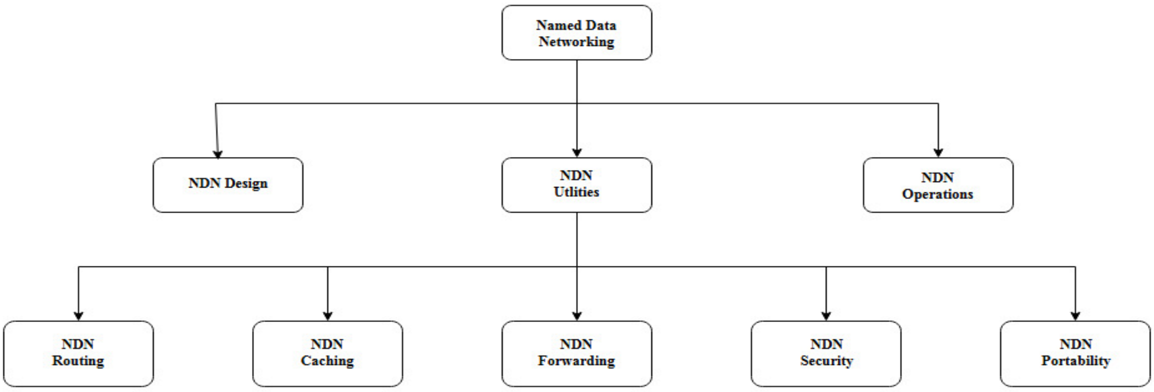

Fig 1. Classification of NDN Architecture

Portability is concerned with the treatment of the considerable number of issues with respect to the requestor and producer data exchanging process.

The principle segments in named data networking system are as follows:

- **Content Store (CS):** This is a storage unit that is established structure in all the nodes. At the point when a node gets a content, based on the standard cache strategies of the node, system will store a replica of this content in its content store (CS). So that it will respond to the following requests.
- **Pending Interest Table (PIT):** This is a table of contents that has two main process. Before transmitting them to the next node, it temporarily stores the received data packets which are requested by the nodes. Using this table, the content can pursue the invert ways to achieve the customers who have requested for the data.
- **First Information Base (FIB) table:** Similar table exists in the IP. This FIB is responsible for the transferring the information of data request messages to sources those have the requested contents. This table comprises of the data content distributions distributed by content suppliers.

IV. CACHING PROCESS IN NDN

Caching intends to spare information at some area and after that utilize it whenever if necessary. In Web based caching, the data substance replicates are stored closer to the clients or supporters, with the goal that they can get to them dependent on their prerequisites. The benefits of caching are, they improve the accessibility of data transmission by hindering the transmission of repetitive substance [2]. They diminish the information content recovery time and spare data transmission cost. At any rate, the primary issue is to realize what web substance can be reserved. To beat this issue, the standard web based standard protocol, hypertext exchange convention (HTTP) is constrained with some prerequisites to decide the estimation of information substance that should be cached. Caching might be intended to have the ability of distinguishing the disappointment of server and improving the assets of intermediary caching [5].

4.1. Network Caching

Network caching, it is the strategy of storing the generally used data in an area near the data endorser/user who demands them. A Web cache stores its web site's resource on a capacity unit which is reliably closer to the client [3]. So that it is nearer and quicker than a Web query. Contingent upon where a content piece is cached, its components can be arranged into on-path caching and off-path caching [6].

4.2. On-Path Caching

In on-path [4] caching, a content chunk is cached on the way to its requestor. Yet, as per the standard definition, on-path caching is characterized as: "A data packet is cached along the way in case of that the corresponding name resolution (e.g., a Data interest packet in NDN) ask for the data".

4.3. Off-Path Caching

In the off-path [4] caching, the content chunk could be or couldn't be cached at the nodes along the way it goes to the requestor. It is additionally conceivable only in the event that there exists a centralized topology administrator (ex: in the case of resolution handler RH). It, demonstrates that the central server is the one that does the off-path caching. The non-cached and supplanted data packets of the edge nodes are stored in the main core node [7]. Other than that, it doesn't straightforwardly gets some other data for caching. The focal router is constrained in cache estimate. Subsequently, the caching instrument to be utilized by the focal router (node) must be fit for choosing, which data contents it needs to cache when there are numerous contents touches base for caching from various edge routers.

V. CACHE DECISION POLICY

A decision policy must be there for caching the data packets, which decides which data to cache and which to not. In NDN, it has two main divisions.

a. Cache Archiving - *where to store the cache content?*
b. Cache Substitution - *which data content must be swapped for caching the different ones?*

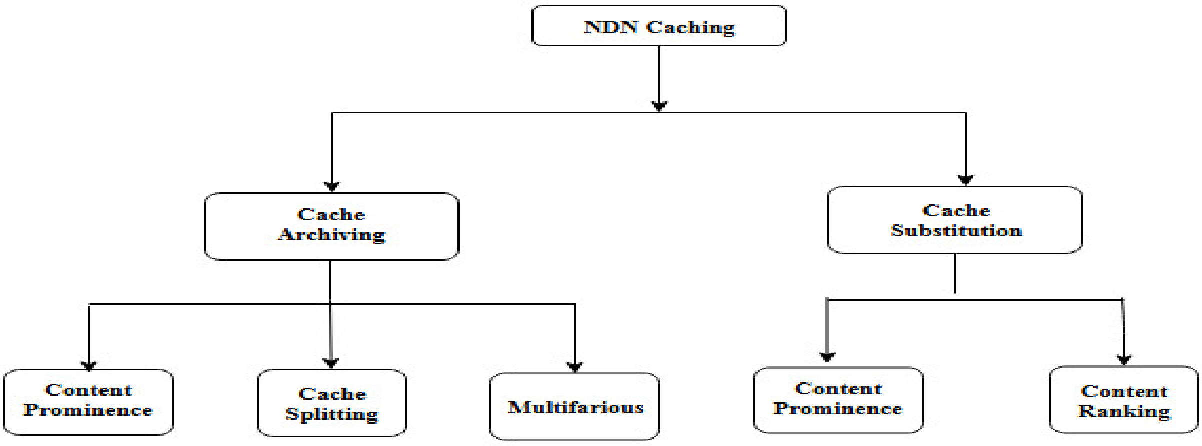

Fig 2. Classification of Different Caching Strategies

This caching divisions has been further divided into several categories, which is in the above figure. Various proposal journals has been published based on the above shown cache policies. Those journals have been surveyed and a brief summary is given below under each category.

5.1. Cache Archiving

This is a caching approach that store the data content in the cache. It chooses where to store it. Leave Duplicate All over the place (LDA) is the default cache situation approach utilized in the NDN engineering process. In LDA, a Data packet will be cached by every one of the routers which are in the middle of the maker, supplier and consumer. This prompts a similar content to be cached at numerous hubs in the framework. Then again, there are cache archiving algorithms for lessening the cache repetition which are as per the following:

(a) Leaving duplicates with Likelihood (LDL) – It caches the data at the router utilizing the likelihood of 1/(bounce tally)
(b) Leaving duplicates with Uniform Likelihood (LDUL) - It caches the data at the router utilizing a uniform likelihood.

For making the caching procedure viable, the mainstream contents in the network must be cached and stored at the corner nodes to decrease the data transfer idleness and to enhance the content variedness. This arrangement strategy is settled on 3 fundamental classifications. Content prominence, Cache splitting, and Multifarious.

5.1.1 Content Prominence

Content prominence is the procedure which is based on the prominence of the data contents in the network. Its calculation depends on the quantity of requests set for data contents amid a considerable period. Jun Li et. al [8] has proposed a caching plan to decrease the inter ISP (Internet Specialist co-op) traffic and the normal access dormancy. They have created composed caching plans to diminish the excess traffic experienced in the NDN networks and the quantity of access hops. The proposed caching calculation (AsympOpt) can settle on powerful caching decisions on the way with progress in the execution of access delay and intra-ISP connect consumption estimated by the quantity of bounces voyaged.

Wu et. al [9] have given fame based facilitated caching plan with the target of wiping out the whole in and out of the domain's excess data traffic of a core network. They have planned such that, the worldwide Content popularity is utilized for ascertaining the weight aggregation of nearby Content popularity at the routers, at that point the cache arrangement can be determined dependent on the usage cost guided by the worldwide content popularity.

Cho et. al [10] has planned the data substance caching strategy, "WAVE" in which the amount of information to be stored is balanced subject to the omnipresence of the substance. In this arrangement, an upstream hub proposes the quantity of pieces to be reserved at its downstream hub, which is epidemically expanded as the demand check increments. This plan accomplishes lower recurrence with higher cache hit proportion.

Banerjee et. al [11] has derived a ravenous methodology for cache position, where it chooses the arrangement of data contents to be cached at each network node. What's more, founded on that data contents, the network hit rate is augmented. In Greedy Caching process, the most well-known contents are cached at the network edge, at that point it recalculates the affiliated ubiquity of every datum content dependent on the demand miss stream which is acquired from the downstream caches and after that decides the content to be cached in the network center.

Li et. al [12] have strategized Content popularity ranking and node Importance Ranking Matched (PRIRM) caching procedure for ICN. This system goes for lessening the cache repetition and improving content assorted variety. The data in the travel way is scattered based on the prevalence of the data in the network. At that point the positioning of the data contents is done along with the dissemination of data in the network progressively.

Baugh et. al [13] has formulated a per face popularity (PFP) technique for decreasing the impacts of cache pollution assaults and furthermore to build the general cache vigor in NDN. They have standardized the contributions that touched base from every route. So that, the data requests that arrives from any node has no more impact on the popularity of content items than different routes. In this manner, the things that stay in the cache are those that have real popularity, spoke to overall routes. Most of the proposed frameworks are contrasted and the standard techniques like LCE, LRU, LFU, FIFO and furthermore their execution has outperformed them.

5.1.2 Cache Splitting

The capacity limit in each router is extremely constrained, so that to keep up the high functionality it is smarter to isolate the contents of certain applications like video, web, pictures and so forth., So that, they can be reused by different customers and can be stayed away from them from being supplanted by other non-cache able contents of applications like messages, telephony application and so forth.,

Cache Splitting has been considered utilizing network traffic examination, for improving the cache performance like, cache hit proportion. The reusable contents like, recordings and web, ought not to be supplanted by non-cacheable things similar to electronic mail, tele-phony applications, and so forth. For this purpose, the content store at the nodes can be split for various kinds of data traffic division, e.g., Constant Bit Rate (CBR) that is utilized for interactive media contents and non-Constant Bit Rate (non-CBR) [7].

Two sorts of partitioning has been proposed by Rezazad et. al [14] Static and Dynamic partitioning. In static partitioning, Content Store is split into rigid shares that can't be utilized by other data traffic divisions. In dynamic sort, each data traffic division can be utilized by different class-cache-space if that class doesn’t bother with cache space at that time. Utilizing the cache miss estimations of the partition sizes as test points in the cache miss equation, the partition sizes which return the base Content Store miss probability and decency is resolved.

Wang et. al [15] have proposed an aggregate in-network caching strategy with “Content-space Partitioning and Hash-Routing”, which is named as CPHR. In this plan, a smart partitioning process is completed to partition the data content space and dispense the allotments to caches, CPHR can constrain the path extend brought about by hash-routing. They have figured the partition task issue and proposed a heuristic calculation to settle it. So also, proportion partitioning issue is detailed into a min-max direct optimization issue to adjust cache workloads.

5.1.3 Multifarious

Wang et. al [16] in his paper have proposed an intra-autonomous framework (AS) cache cooperation plot, to control the excess dimension inside the AS and permits neighbor nodes in an AS to work together in serving each other's solicitations.

Li et al. [17] have built up an effective caching plans for Internet Service Provider (ISPs). That expands the intra ISP traffic investment funds. They have planned a caching framework dependent on the NDN network model and present composed caching algorithms. That progressively decides the cache archiving along the sending path.

Ming et al. [18] have proposed an age-put together helpful caching plan based with respect to the exceptional characteristics of information centric network. They utilized the coupling among directing and caching in information centric network to develop a feather weight joint effort framework that sends the data packets to the edge routers. Along these lines, it may be effectively gotten to by the data requestors.

Cai et al. [19] have proposed the multi-dimensional data learning based methodology (MDDL) to cache only the chose contents and store in couple of reasonable nodes. The mapping connection between the trait information and the planning relationship regard is taken out. A coordinating algorithm and semi-supervised support vector machine (S4VM) algorithm is proposed, to foresee the coordinating relationship and to improve the precision of the coordinating algorithm, separately.

Abani et al.[20] have proposed a proactive caching technique for caching in ICN. This technique impacts the ICN's adaptability of caching data anyplace in the network. The primary point of this paper is to utilize entropy to quantify the vulnerability in versatility prediction and find the best pre-fetching node, in this manner it decreases the excess.

Yao et al. [21] have proposed a caching plan dependent on mobility prediction for CCN. This paper is situated in the possibility of CCMP, which caches the mainstream contents at a lot of portable nodes that may visit a similar hot spot territories occasionally. PPM, Prediction based on Partial Matching is utilized to anticipate the mobility nodes likelihood of achieving diverse problem area regions dependent on their past directions. A cache substitution dependent on Content Prominence to ensure only prominent contents are cached is likewise proposed.

Ren et. al [22] have proposed a circulated caching technique for ICN. An appropriated caching system along the data conveyance path, called MAGIC (MAx-Gain In-network Caching) is proposed. It considers the Content Prominence and jump reduction, in this way lessening the bandwidth consumption. The cache substitution is likewise considered decreasing the quantity of caching operations, amid the cache position process.

Shi et al. [23] have cache mindful routing plan dependent on ICN for portable social organization. A plan called Interest Routing (IR) is concocted intrigue measurements among nodes. To trade contents with the content requester, Data Routing plan

(DR) is used. It is imagined subject to the recommended intimacy estimations among nodes. An In-network Caching plan (IC) is contrived to react to the approaching solicitations, and it can receive the less reaction inertness than the conventional portable mobile social network routing plans.

5.2 Cache Substitution

The cache substitution strategy as mentioned before, is the decision of evacuating the present cache contents for the fresher ones. Trade methodologies are critical for accomplishing powerful cache mechanism. This strategy evacuates the obsolete aged cache data and gives space to the approaching new cache data. The caching procedures depicted below are the ones, which are used as the most common substitution approaches [24]. Least recently Used (LRU) strategy in which the content that is least recently utilized is evacuated. This is a common cache substitution approach. It is mostly utilized because of its execution and cache hit proportion. Least frequently Used (LFU) is another most utilized cache substitution approach because of its arrangement of evacuating the less frequently utilized contents first. The decision taking time for these strategies depends on the content substitution and time the contents enter the node. The cache substitution is done based on either content prioritization (content with low need is supplanted first) or Content Prominence (content with ubiquity is supplanted first). But, both the LRU and LFU doesn't pursue this procedure that outcomes in incorrect deciding the level of the new approaching content [25], [26].

5.2.1 Content Prominence

The present arrangement of NDN is progressively forward towards the Content Prominence that is utilized for both cache archiving and substitutions. In a dynamic network, cache archiving and substitution both does an essential job for better network execution. Access-time-pattern based substitution strategies like, LRU and LFU, does not utilize the Content Prominence as trait in NDN. Different plans have been proposed as an option in contrast to traditional LFU and LRU.

Ran, et al. [27] has recommended a cache substitution plot dependent on the content prevalence. They have contrived a table called Content Prominence Table (CPT). It is a data frmwork which stores information on the content store. The required data like cache hit proportion, name of the content, and moment and previous prominence are also saved in the CS.

Kalghoum et al. [28] have proposed a cache substitution algorithm dependent on SDN (software defined networking) called NC-SDN. The proposition depends on the Content Prominence figuring done by the changes to clarify a cache substitution technique. The NDN-SDN integration builds the hit proportion and diminishes the bandwidth consumption, subsequently upgrading the NDN network execution.

5.2.2 Content Ranking

This arrangement relies upon the position given to the different data contents dependent on their significance in the network. Like the content prominence, this content ranking is additionally increasing more usage now in the NDN network.

Dron et al. [29] has formulated a cache substitution strategy dependent on the content need which is progressively centered on data naming that, brings about boosting the cached contents in ad-hoc networks. The categorization of data contents are named as hot for low ranked data and cold for high ranked data. Hot ones are supplanted first. The knapsack problem solving algorithm has been utilized for deciding the data as hot or cold.

VI. CACHE METRICS

The Cache performance estimation is the most required and critical one. It is the measurement which decides the execution of the nodes and effectiveness of the data access and transfer rate in the network. The most common measurements utilized for estimating the cache execution are:

(i) Hit proportion - The rate at which the required data contents by the consumers are in the cache.

(ii) Content retrieval delay - The complete period of time taken between the moments a data chunk is asked for by the consumer the moment it is obtained by the consumer

(iii) Avg. no. of bounces – The normal number of jumps taken to find and get the asked for content. It depends on the content distribution over the network.

(iv) Dissemination Speed – The time required to spread the data chunk to the edge routers in the network. Based on the survey work, the various works on caching with their algorithm, caching type, strategy, gains and issues are tabulated below.

Table 1: Comparison of Various Cache Strategies

AUTHORS	C – TYPE	ALGORITHM	GAINS	ISSUES	STRATEGY
Ming et. Al (2014)	On-path	Age calculating	Reduces the network delay and traffic	Only for read only objects	age-based cooperative
Wang et. Al (2012)	On-path	simple greedy heuristic	Cache hit proportion, Bandwidth optimization	Time factor is missing	intra-AS cache cooperation
Li et. Al (2012)	On-path	Collaborative , bridging	Solves the traffic explosion problem, efficient content retrieval	Hit ratio is low	ND
Cho et. Al (2012)	On-path	Chunk caching	Efficient content delivery and cache usage	LRU	WAVE
Li et. Al (2012)	On-path	Top – Down, AsymOpt	Minimizes both inter-ISP traffic and average number of access bounced during the process	Security vulnerabilities	Popularity based
Wu et. Al (2013)	On-path	Weighted popularity	Higher cache hit rate and more traffic reduction	overhead	popularity-based coordinated caching
Xuan Nam et. Al (2013)	On-path	NA	Efficient caching ,Lower overhead	Time	Open Flow strategy + Wrapper
Hoon-gyu Choi et. Al (2014)	On-Path	Prefix assignment algorithm	Mitigates directing adaptability and improves the productivity of the in-network storage	Naming	Coordinated Routing and Caching (CoRC)
Jing Ren et. Al (2014)	ND	NA	bandwidth consumption, server hit ratio	Time	MAx-Gain In-network Caching
Hani Salah et. Al (2014)	On-Path	NA	server hit ratio, expands the assorted variety of stored substance and decreases cache substitutions	Security issues	Caching Nodes with Monitoring and Re-routing capabilities (CNMRs)
Sabrina Muller Et. Al (2016)	ND	Oracle solution with Learning algorithm	Increased number of cache hits	Process Overhead	Context-Aware Proactive Caching
Kalghoum et. Al (2017)	Off-path	Data popularity Calculation (Zipf law)	Reduced bandwidth consumption, increased cache hits	Process overhead	Data popularity calculation
Noor Abani et. Al (2017)	ND	Markov model	Increase in latency	Hit ratio	Pro-active caching policy

Bitan Banerjee et. Al (2017)	On-Path	Greedy algorithm	Improvement of latency and improvement in hit rate over advanced cache policies	Time	Popularity based
Lin Yao et. Al (2017)	On-path	Prediction based on Partial Matching	High success ratio and Low content access delay	Data Loss	Cooperative Caching based on Mobility Prediction
Li Ding et. Al (2018)	On-path	Packets Processing Algorithm	Decrease of average hop count	Hit ratio	Popularity Ranking and node Importance Ranking Matched (PRIRM) caching strategy
John P. Baugh et. Al (2018)	ND	Popularity calculation, Dynamic Aging	Resistance to cache pollution attacks, increased hit ratio	Time factor not addressed	Per-Face Popularity
Junling Sh et. Al (2018)	Off-Path	Interest Routing (IR), Data Routing (DR)	Higher message delivery ratio, Lower network overhead	Popularity is not considered	Cache aware routing scheme

*C- Type – Caching Type which is used in the mechanism which is either on path or off path caching

*NA – Not Applicable

*ND – Not Defined

VII. OPEN RESEACH CHALLENGES FOR CACHING

Caching is the important process in NDN, which has various issues that should be addressed. It is considered to be the favorite research topic for several researchers in the field of NDN architecture. Various issues in caching starts from its divisions of placement and replacement. A proper and standard algorithm must be formulated which will be suitable for both placement and replacements. The resources consumed during the process of finding the content popularity must be reduced. Also the exception for not leaving out the privacy sensitive contents during the content popularity process must be followed. There must be a strong strategy to find the fake popularity contents. Edge routing must be encouraged and other various methods like grouping, clustering of nodes must also be considered. The caching decisions must be taken in such a way that, it does not affect the other process like routing, forwarding and mobility, etc. The presence of unused and unwanted data, straggles the overall performance of the network. The single solution algorithm must be formulated that addresses the other process like routing/caching /forwarding. Data compression in content store can be done in such a way, it does not add to process overhead. The unwanted/unused/low popularity contents must be removed effectively from the network. Privacy and security concerns must also include the caching process and the cached data contents.

VIII. CONCLUSION AND FUTUREWORK

In this survey work, we have depicted the Named data networking architecture, its process, and its components along with the comparison of various cache strategies. The caching process in NDN is mainly focused and its decision policies are explained in detail. The various works on caching process is also explained according to their type of strategies. Finally, the various research challenges existing in the caching are explained briefly.

Our future work will be based on the cache placement strategy which will give efficient hit ratio and high energy efficiency than the previous ones.

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