International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

A Novel Weight Based Interest Forwarding Protocol for Information Centric Networking

Krishna Delvadia*[1]

Submitted: 04/02/2024 **Revised**: 12/03/2024 **Accepted**: 18/03/2024

Abstract: Information centric network (ICN) is a new communication paradigm that is introduced to satisfy the needs of internet users in context of throughput and delay. Content request routing is an important research domain of content centric network. If request is routed efficiently within network, then retrieval of desired content is possible in least duration with less overhead. This paper introduces a weight-based interest forwarding strategy that aims to route interest message towards content router (CR) having maximum likelihood of having desired data. This can significantly contribute in reduction of latency and overhead. The protocol exploits three different parameters namely interest packet forwarding ratio, size of node's pending interest table (PIT) and count of data messages produced by router to take decision for interest packet forwarding. The experimental analysis of proposed strategy is done inside ndnSIM 2.0. The performance testing of state-of-the-art caching mechanisms with and without inclusion of proposed protocol in context of data discovery delay, overhead and content store (CS) hit ratio. We have also compared the integrated variants of protocols against recent existing forwarding protocols. The extensive simulation study proves that the coupling of proposed mechanism to existing mechanisms remarkably enhances the performance by 10-42%.

Keywords: *ICN, ICN Routing, Weight based, Request forwarding, Named data networking*

1. Introduction

The internet service requestors are interested in fetching needed content with least delay regardless of its source. Hence, the future networking functions need to be optimized for data discovery delay. The applications running on the internet deals with huge volume of data and also need faster data discovery. To satisfy the needs of internet users, desired content must be accessible from any source rather relying only on data server. This can be achieved if the fetched data adhere the integrity and authenticity properties [1]. The notion of content centric infrastructure named information centric network is designed to enable access of any data from any location. The successful ICN implementation can surely meet the requirements of future network users [2]. In ICN, the desired content is accessible from any intermediate node, the dependency on origin server can be minimized which can help to reduce network traffic and latency. The conception of ICN redefine the traditional IP driven network. It searches the desired data through its location independent name instead of location dependent IP address. Data is considered as first class citizen in network and not the host identifiers. The content routers (CRs) must be able to save data to access it in future. ICN needs unique naming scheme to every content piece available inside ICN. Also, it requires a name based routing protocols instead of traditional IP driven routing protocols [3]. Therefore, this new paradigm has introduced various issues to be addressed in front of research community.

Information centric networks in itself has different research fields like data naming, data caching, data driven routing and data security [4]. The functions of ICN forwarding and caching mechanisms are driven by content names unlike id addresses in case of traditional network. Any network node having desired data can respond to requestor with relevant data message.

To develop an efficient request forwarding protocol is a key research area in ICN. If interests are forwarded efficiently, it can noticeably enhance network performance by decreasing data discovery latency and increasing throughput. This paper introduces a weight based forwarding mechanism for ICN that takes interest forwarding decision using following parameters with different weightage: interest packet forwarding ratio, size of node's pending interest table (PIT) and count of data messages produced by node. The first parameter helps to identify the node with greater probability of containing desired data. The second one reflects the number of queries yet need to be answered by node. The last one shows the past successful cache hit records of node. These parameters combinedly can assist the forwarding plane to select node with highest likelihood of cache hit for interest forwarding. The proposed strategy can co-operatively work with any existing caching strategy and improves the data discovery delay, overhead as well as cache hit ratio parameters.

[1] *Department of Computer Engineering, Shree Swami Atmanand Saraswati Institute of Technology, Surat, Gujarat 395006*
** Corresponding Author Email: krishna.delvadia@ssasit.ac.in*

The remaining research paper is structured as follows: The literature review for ICN forwarding mechanisms is presented in Section 2. The working of proposed protocol along with algorithm is discussed in Section 3. The simulation study of protocol along with extensive outcome analysis is presented in Section 4. The conclusion and future research scope is discussed in Section 5.

2. The state-of-the-art research studies

The forwarding plane of ICN is responsible to forward request towards appropriate content router to fetch needed content. In this section we have reviewed state-of-the-art forwarding mechanisms in ICN. The investigation for efficient forwarding in ICN yet requires further research efforts to satisfy needs of network users.

The first key investigation for ICN driven routing approach is carried out in [5]. OSPFN is an incremental version of existing link state algorithm to compute paths and to disseminate names. It does not offer dynamic multipath routing support instead it provides name driven content routing mechanism. The NDN driven link state routing mechanism named NLSR is proposed in [6]. It follows hierarchical convention for naming and trust model. It also uses chronosync mechanism for routing update distribution and multipath forwarding. The performance of NLSR required to be tested for inter-domain forwarding and on real time network scenarios. These both protocols are currently deployed on NDN testbed. The authors in [7] have designed a controller driven forwarding approach that addresses the problem of forwarding information base explosion through minimization in control message overhead. The researchers in [8] have developed a strategy named MUCA that is capable enough to minimize latency and overhead so that network resilience can be increased. It uses a dedicated mechanism for link state repository synchronization and this makes the performance of this protocol superior than NLSR. The authors in [9] have developed a FIB construction strategy coupled with interest forwarding method. For advertisement of data, the notion of bloom's filter is utilized in the research work. The research work presented in [10] introduces distance driven content forwarding which permits content routers to store different loop free paths within closest data holders in network. It supports scalability in terms of time required to fetch correct routing details to named data as well as signalling overhead. The above mentioned protocols are focused towards enhancing performance of existing routing approaches with no utilization of advantages of named data networking characteristics. It leads to significant rise in data discovery delay and overhead.

The researchers in [11] have designed an interest routing method driven by content chunk's probabilistic duration and centrality value of node. It operates on dijkastra's routing strategy and works with any underlying caching protocol. The researchers in [12] have designed a request forwarding mechanism which uses monte carlo tree search algorithm to send interest to appropriate data source. The researchers have also started utilizing strengths of artificial intelligence in ICN forwarding. The authors in [13] have used the deep learning based models to take forwarding decisions in data centric networks. The researchers in [14] have designed a Q-learning driven strategy to store data chunks in content store of ICN router for software defined networking based internet of things scenarios. The authors in [15] have used the concept of support vector machines while taking routing decisions for request packets. It predicts the probability for locating content from data store and forward request based on prediction. Though the forwarding approaches based on machine learning concepts are efficient, it incurs noticeable quantity of computational and message overhead.

The efficiency of routing mechanism can be enhanced when the forwarding plane is aware about data locations inside network [16]. The researchers have also introduced co-operative mechanisms for caching joint routing approaches. The research work presented in [17] proposes a caching and forwarding mechanism driven by rendezvous points. In this protocol, requests asking for similar data chunks are forwarded to same router, to avoid the explosion problem linked to different repositories preserved at the content routers. Despite this, the authors have not worked on optimization of data structures of router for proposed method to achieve performance enhancement. The research work in [18] investigates theoretical and practical functioning of latency awareness for network performance in context of multipath delivery. It also examines a mechanism that couples caching and routing protocols for content discovery latency reduction with no need of signalling in network and collaboration between routers. These approaches can reduce the latency with the cost of excessive communication overhead which is not desirable to support network scalability.

2.1 The review summary

Almost all existing ICN routing protocols focus on developing forwarding strategy from base with distribution of routing update and FIB population. While proposed forwarding protocol can run on top of any available routing mechanism and can operate with any caching protocol with no efforts for redeveloping routing protocol from base and FIB build. The in-detail simulation runs justify that the ICN routing mechanisms can use the benefits of NDN's forwarding plane due to relaxed requirement on timely recognition of convergence latency and related failures. Also, the smart and adaptive forwarding plane of NDN allows new routing protocols that were not adjustable with

IP network to be exploited for NDN. Because of this, we have directed research focus in proposing an efficient ICN forwarding protocol. The research objective is to design an efficient request forwarding protocol for ICN that can improve user as well as network level performance parameters.

2.2 Research contributions

The objective of the carried research work is to design an interest forwarding strategy for ICN. The research contributions related to proposed work can be articulated as follows:

- A weight based interest forwarding technique that can retrieve desired content with minimal latency and overhead.
- A request forwarding protocol that forwards interest to node having greater likelihood of cache hit. It utilizes three different parameters while taking request forwarding decision namely: interest packet forwarding ratio, size of node's pending interest table (PIT) and count of data messages produced by node.
- The protocol performance analysis using extensive set of simulation study along with comparative performance analysis is carried out inside ndnSim simulator.
- If interest packet is routed to the node with greater probability of cache hit then the ICN forwarding plane can retrieve desired data in least time with lesser overhead. The proposed protocol can help forwarding plane to identify such node in network for request forwarding. Majority of state-of-the-art approaches [5, 6, 7, 9, 12, 14, 15] uses existing name driven Dijkstra's shortest path mechanism for request forwarding and adopts different caching techniques to reduce latency. Here, the in-network storage capability of ICN cannot be fully utilized and this results in higher content retrieval delay. On the other hand, proposed protocol aims to utilize the ICN strengths and identify the potential caches in network to forward interest so that content can be retrieved in least time and least overhead. Our protocol can work and also comparable with any existing routing and caching variants for ICN. The novel contribution of proposed mechanism is that the concepts like interest packet forwarding ratio, size of node's pending interest table (PIT) and count of data messages produced by router haven't been utilized combinedly till date for request forwarding in ICN as far as we are aware.

3. Proposed work

3.1 Research problem statement

The key purpose of proposed mechanism is to retrieve asked data piece via fastest route so that data retrieval latency can be reduced. Proposed work considers a scenario having N different content routers having enough cache size to store D data pieces from S data sources in which data is believed to be available anytime. The size of content piece is assumed as B bytes. The consumers produce request packets with rate R per second. The request messages adhere a model called independent reference model. Proposed protocol exploits Dijkstra's shortest path mechanism as a foundation and execute on top of it. Every content router adheres to fixed caching protocol and exploits LFU (Least frequently used) as replacement mechanism for cached data chunks. The data packet adheres the identical but reverse path of interest transmission. Our protocol uses three different parameters related to node N, namely request message forwarding ratio ($RMFR_N$), size of node's pending interest table (PIT_{sizeN}) and count of data messages produced by router (DM_N) to take request forwarding decision. The Calculation of weighted forwarding factor for node will be done as per equation (1). Each content router is responsible to compute its own forwarding weight factor and share it with its 1-hop neighbour nodes using special query packet. On reception of this query packet by neighbours, each content router will build its weight factor table. This table stores the weight values of each of the 1-hop nodes connected to given content router. This repository plays an important role for proposed protocol while taking request forwarding decision. The structure of this table and its significance is already presented in Fig. 1 along with its explanation. The discussion on the weighting factors used for weight calculation is given followed by below equation.

$$FR_{wf}=w_1 \times DM_N + w_2 \times PIT_{sizeN} + w_3 \times RMFR_N \quad (1)$$

Here, the weighting co-efficients are w_1, $w_{2,}$ and w_3 (where $w_1 + w_2 + w_3 = 1$ and w_1, $w_{2,}$ $w_{3,} \geq 0$) for above mentioned three parameters DM_N, PIT_{sizeN} and $RMFR_N$ respectively.

Rational 1. Request message forwarding ratio (RMFR):

It represents the ratio of count of interests that results in cache hits at given router ($R_{CSH}(t)$) over total count of requests a router receives ($R_{All}(t)$). It can be expressed using equation (2). This is a key indicator to identify the potential content router in network to forward given request. The higher value of this ratio is desirable for our protocol and forwarding engine select such node to forward request further. The higher value of this ratio represents that the node has good past record to respond requests successfully. The lower ratio value suggests the forwarding engine to not select such node to forward request further. Each content router is responsible to compute the count of the cache hits occurred at itself. We have used counter variables at each router to maintain record for the cache hits and to count the requests it receives respectively. This ratio value is used to compute the total forwarding weight parameter of content router.

$$RPFR = \frac{R_{CSH}(t)}{R_{All}(t)} \quad (2)$$

Rationale 2. PIT (Pending interest table) size of router:

The pending request repository of any router contains data regarding unsatisfied requests transmitted through that router. The weighting co-efficient related to this factor is minimal in comparison with remaining two factors. The rationale behind this is the fact that when a router already has a huge pending queue for unresponded requests, then it is less likely that a router contains the requested content or it will become an intermediate router to send required data back to consumer. Hence, from the context of request forwarding decision, a router having least repository size is more reliable compare to ones with higher PIT size to retrieve desired data. To compute this factor, each router will increase the counter variable related to PIT size with 1 as soon as the new record is inserted in PIT. For simplicity, we will express PIT size in terms of number of records in PIT table (unanswered interests).

Rationale 3. Number of data messages generated by router:

This is an important factor to be considered while taking request forwarding decision. It keeps the record about the successful contribution of any router in network. Here, the contribution signifies the generation of desired data packets by router to satisfy request. For any given router, the higher value of this factor is desirable as it makes it more trustworthy to fulfil future incoming requests at that router. The routers having higher value for this factor are more likely to be selected to forward incoming interests. The router with lesser value for this factor will have less likelihood to be selected as next node to forward incoming request. Due to this reason, this factor has assigned the highest weighting co-efficient compared to others to calculate the total forwarding weight factor of router. This factor also significantly influences the process of reducing data discovery delay. For calculating this factor, we have introduced an extra field in every data message transmitting back to consumer. This field holds the details about the data source of asked content. Every intermediate node on data transmission path will refer this field that has data source name, from where data packet is generated. We will increase the counter variable associated with this factor for router when the particular router becomes the source/originator or generator for the data packet corresponding to given content request.

3.2 Integrating weighted forwarding factor to request forwarding strategy of ICN

In this section, we have explained the functioning of proposed protocol that uses weighted forwarding factor to take request forwarding decision in network. It forwards request to node having maximum likelihood of containing desired data. We have represented the weight factor calculation method in Algorithm 1. The proposed weight based request forwarding mechanism is presented in Algorithm 2 followed by related functional description.

Algorithm 1: Forwarding weight parameter calculation for each node N

Computation of weight factors after initial t_n quantity of time interval

1: Calculate_WF(Content router CR)

2: $DM_{\mathrm{N}}(t)$ =count_DataMessages();

3: $PIT_{sizeN}(\mathrm{t})$ = search_PITLengthResponse();

4: $RMFR_N(t)$ = compute_RMFR();

5: $FR_{wf}(t) = w_1 \times DM_N(t) + w_2 \times PIT_{sizeN}(t) + w_3 \times RMFR_N(t)$

6: return $FR_{wf}(t)$

The initial phase (t_n quantity of time period) of proposed algorithm is all about calculating three weighting parameters for forwarding decision process followed by construction of weight factor table at content router. We will understand the request forwarding strategy using an illustrative scenario as represented in Fig. 1 (Refer

Algorithm 2: Proposed request forwarding strategy for ICN

N= Content routers of network= $\{N_1, N_2, N_3, \ldots.. N_n\}$

$Cache_N$=Content store for any router N

WFT_{N}= Weight factor table for every router N

1 For every $N_i \in N$

2 Calculate_WF(Content router CR);

3 Construct WFT_{N}

4 INPUT: Content router N_i gets a request message $RMessage_c$

5 OUTPUT: Outgoing Interface named IF to content router selected by proposed protocol

6 $RMessage_c$= Request message to retrieve data chunk c

7 $DMessage_c$= Data message for $RMessage_c$

8 BEGIN

9 If $DMessage_c$ in $Cache_N$ then

10 Send $DMessage_c$ towards consumer

11 end if

12 Else

13 Search N_i having max (FR_{wf} (t)) in WFT_{N}

14 Send $RMessage_c$ to that N_i

15 if $DMessage_c$ in $Cache_{Ni}$ then

16 Send $DMessage_c$ towards consumer

17 end if

18 Else

19 Redirect to step 13 and repeat the steps till CS hit occurs.

20 END

Appendix 1). Consider a timeframe when consumer generates a request message $RMessage$ to retrieve data chunk *'courses/guidelines.txt'*. It then forwards request to router called *R1*. As per proposed forwarding protocol, before taking request forwarding decision it will first check inside its own cache for content availability. If desired data is present inside cache of *R1*, it will simply send relevant data message back to consumer. Upon cache miss, *R1* will refer weight fact table and identifies the router having maximum weight value. It will then forward interest to *R2.* In case if multiple routers have same maximum weight values, the protocol chooses the one with higher $DM_{\mathrm{N}}(t)$ count. We have also assumed that the desired data chunk is already available at *R4*, *R11* and custodian or origin server. On receipt of request message, *R2* will first verify within its own cache for availability of desired content. On cache miss, it will refer its weight factor table and recognize *R4* as one with highest weight value. So, the request is then forwarded to *R4.* The router *R4* will first look up inside its own cache which results in cache hit for given request message. The router *R4* will then send related data message *DMessage* back to consumer by following reverse route of request propagation. Hence, the request forwarding path returned by our protocol is *Consumer→R1→R2→R4.* In contrast to this, the traditional shortest path forwarding mechanism will forward request using shortest path to custodian that is *Consumer→R1→R5→R10→R9→R11→ Custodian.* Request packet will follow this path by referring forwarding information base maintained at each content router. Upon following this path, the cache hit will happen at *R11* as desired content is already cached at that router. So, the request forwarding path as per traditional approach is *Consumer→R1→R5→R10→R9→R11.* This path includes a greater number of hops compared to proposed approach which directly results in increased data discovery latency. Proposed protocol achieves lesser delay and perform superior due to adaptation of weight based forwarding mechanism that covers three important parameters for request forwarding decision process.

4. Performance investigation

We have investigated the performance of proposed protocol in simulator named ndnSIM 2.0. The comparative evaluation of proposed protocol over existing caching protocols (CL4M [19], LCD [20], ProbCache [21], LCE [22]) and recent forwarding schemes (IF-ICN [9], BF-ICN [23]) has also been extensively carried out in simulator. A copy of required content chunk is kept within every content router along the delivery path of data packet.

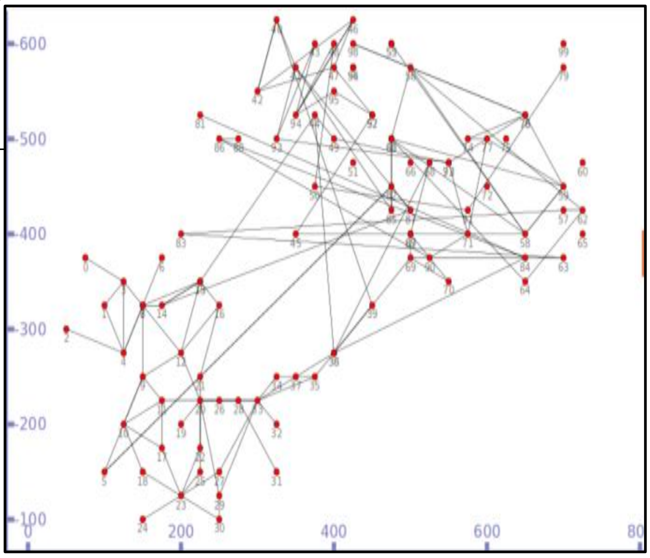

Fig. 2. The Random100 network scenario distributed over an area of 600 m × 600 m.

The LCD protocol copies asked data in cache store located at one hop distance from consumer whenever cache hit happens at given router. The CL4M protocol takes decision related to caching with the help of centrality value of router. This approach helps to minimize duplication in caching for network. If the content is cached in router having greater centrality measure, the data will become more accessible to different consumers. It saves content within particular routers on its way back to consumer. The ProbCache protocol relies on the probability of content retrieval request. The protocol considers two key factors namely on-route caching capability as well as forecasted traffic frequency to formulate the required likelihood of awaited interest messages relying on popularity of content. It directs the caching of content with higher popularity within interior content routers. It also predicts about caching decision through selection of content based on probability of future needs. The protocol introduced in [9] focuses on effective request forwarding mechanism for quick data retrieval. They have conceptualized forwarding strategy using single player game with assumption of consumer as start state and data

source as end state. The authors have adopted a monte carlo tree search method for building optimal path between data source and consumer. The problem of request forwarding is considered as bargain game by researchers in [23] with objective of minimizing overhead and data discovery delay. Based on the norms of game, the credit score will be assigned to in-between content routers depending on their potential for satisfaction of requests as well as their assistance while building path for data transfer. This analytical study has helped us to realize the effectiveness of proposed protocol in forwarding data requests to the nearest data holding cache. This has led us to compare the performance of proposed strategy over traditional and more recent existing approaches.

4.1 Simulation environment

The simulation run of proposed forwarding strategy is carried out within ndnSIM [24]. The performance of strategy is tested for two distinct topologies namely GEANT scenario comprising of 40 CRs and random network topology with 100 CRs (Fig. 2). These network nodes are placed on an 600m × 600m area. The adopted caching method and cache replacement method for proposed protocol is LCE and LRU respectively. Every simulation run is given 500 seconds of execution time. Content requests adhere the Zipf dissemination standard and data popularity skewness value $\alpha \epsilon [0.1, 1.5]$ as real-time factors for consumer produced data. The simulation variables and related values are depicted within Table 1. A set of 12000-18000 unique content pieces with each of size 1500 Bytes are considered. The cache capacity varies between 50-250, with a mean of 80 content pieces. The weighting co-efficients used for computing total weight factor of content router with respect to equation (1) are assumed as $w_1 = 0.6$, $w_2 = 0.2$, and $w_3 = 0.2$ by considering their influence in taking correct request forwarding decision (cache hit). The custodian capacity S=600 MB, bandwidth=100 Mbps, as well as request arrival rate R=25 interests/sec are assumed for simulation runs. The authors believe the fact that the protocol shows the same behaviour in realistic NDN testbed as it showed during extensive simulation runs.

Table 1: Simulation variables

Simulation variables	**Mean Value/Domain**
Network scenario	Random100
Simulation area	600m × 600m
Method of caching	LCE
Method for replacement of cached data	LRU
Simulation duration (T)	1200 secs
Popularity distribution for content chunks	Zipf law
exponent α for popularity dissemination of content chunks	[0.2, 1.2] for UGC
Total count of data chunks (N)	N=5000
Size of data chunk	2000 Bytes
Cache store potential	50-250
Data interest model	IRM (Independent Reference Model)
Capacity for custodian (S)	500 MB
Interest arrival frequency (R)	20 interests/sec
Network bandwidth	100 Bps

4.2 Simulation outcomes

4.2.1 Content retrieval latency

The data retrieval latency denotes the quantity of duration needed to search desired content and forward it again to the requestor node. The objective of any ICN routing protocol will be to minimize the delay for retrieval of asked content. We have investigated the strategy performance in terms of delay for Random100 network. We have compared proposed protocol with existing caching integrated shortest path routing protocols and recent forwarding proposals.

The simulation outcomes from Fig. 3 and Fig. 4 show that the proposed approach remarkably performs superior than existing methods and minimize delay approximately 10-42% for Random100 scenario. The fall in delay also slowly increases with content store size and data popularity skewness. The BF-ICN and IF-ICN protocols nearly follows proposed method for α ϵ [0.6,1.1]. The reduction in latency becomes 5-10% for α values in this domain. As per experimental results, the proposed approach behaves superior compare to existing approaches. Proposed protocol manages to minimize delay approximately by 14-38%, 16-26%, 12-39%, 21-49%, 7-12% and 5-11% compared to shortest path integrated CL4M+SPR, ProbCache+SPR, LCD+SPR, LCE+SPR, IF-ICN and BF-ICN respectively. In general, for Random100 network, LCE+SPR approach had highest delay to fetch requested content as LCE protocol stores each propagating content chunk inside each content router. The IF-ICN as well as BF-ICN protocols behaves superior to remaining existing mechanisms as it aims to reduce content discovery delay with the use of data location information inferred through their respective caching methods. The BF-ICN mechanism outperforms IF-ICN mechanism as it builds FIB through its own content advertisement strategy.

The principal rational behind superior behaviour of proposed approach over other mechanisms is the fact that it exploits content location information for interest forwarding process. It has the motive of fetching content via visiting minimum number of CRs in given topology. The factors such as PIT size of CR, Request message forwarding ratio and count of data messages produced by router are utilized, for sending interest towards router with greater probability for having requested content. This results in noticeable fall for delay. The ICN forwarding plan exploits weight factor table to locate content router that has highest probability of cache hit for given request message. Therefore, proposed protocol attains cache hit by traversing least nodes instead of following shortest route to custodian. In oppose to this, majority of state-of-the-art approaches constraints themselves for shortest route forwarding mechanism.

4.2.2 Network overhead

This is a key measure while calculating efficiency of forwarding protocol in ICN. It is considered as an overhead for network due to subsequent cache store misses at chosen router through proposed mechanism. The simulation outcomes for network load values updating over content interest arrival rate is shown within Fig. 5. This measure can be denoted using a ratio of cumulative requests turned in cache store misses at chosen CR over cumulative number of interests produced in past averaging timeframe.

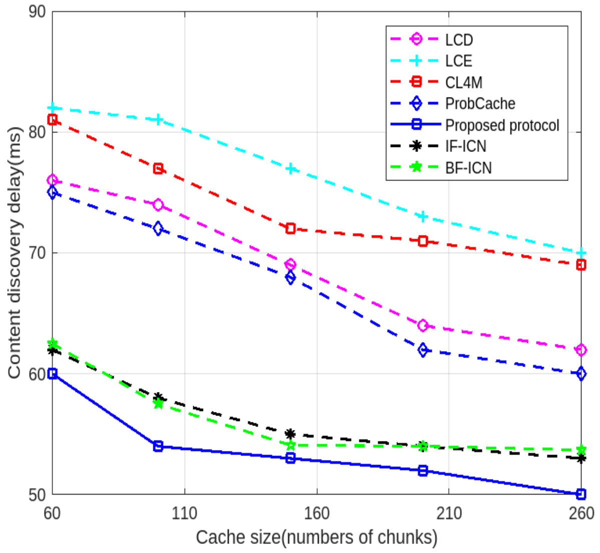

Fig. 3 Cache size vs. content discovery delay for Random100 network scenario

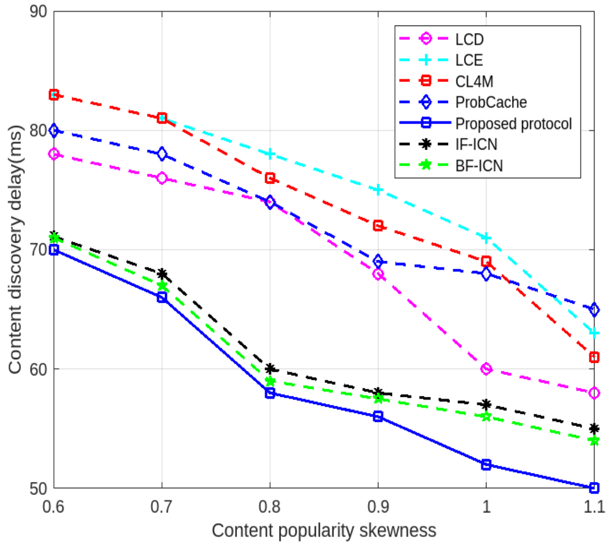

Fig. 4 Content popularity skewness vs. content discovery delay for Random100 network scenario

The rise in this ratio denotes the rise in cases of cache store misses at chosen router. Because of this, an unsatisfied interest needs to traverse till content producer to fetch asked content. This leads to rise in the distance traversed by interests and it ultimately produces an extra amount of overhead. For computation of this measure, the protocol saves the number of hops travelled by every request corresponding to which cache store misses have occurred at selected router. As shown in Fig. 5, the outcomes for network overhead are proportional linearly with interest arrival rate. Network overhead can be used to express the extra load produced due to cache store misses' events at selected router by proposed strategy. As the count for cache miss increases at chosen router, the overhead ratio also increases. This results in additional traversal of nodes till custodian for unanswered requests to retrieve asked data. Therefore, total distance travelled by every request also rises as the request message has reached to selected router but asked data was unavailable.

The comparative analysis of our mechanism over state-of-the-art CL4M+SPR, LCE+SPR, ProbCache+SPR, LCD+SPR, BF-ICN as well as IF-ICN protocols in context of overhead. The experimental results depict the mixed performance for each stated mechanism. Our strategy outperforms existing mechanisms for distinct cache store size as well as popularity skewness values. Till request arrival rate R =30 requests/sec, our mechanism performs superior than CL4M+SPR, LCE+SPR, ProbCache+SPR, LCD+SPR, BF-ICN and IF-ICN mechanisms by 8-16%, 6-14%, 10-22%, 9-18%, 4-11% and 7-13% in order. The performance behaviour of LCD+SPR is worst. On the other hand, ProbCache+SPR and LCE+SPR shows a comparative reasonable behaviour up to R=30. The overhead values for BF-ICN as well as IF-ICN with respect to request arrival frequency R nearly approaches the performance of our mechanism. The rationale for good behaviour of BF-ICN compared to LCE, LCD, CL4M and ProbCache methods is that it sends request to closest router with greater likelihood for having asked content. When R value exceeds 35 requests/sec, the behaviour of these protocols also changes. The LCE+SPR strategy outperforms ProbCache+SPR, LCD+SPR and CL4M+SPR. The cause is that LCE protocol follows dense caching approach in topology. While in ProbCache protocol, due to inaccurate likelihood forecast, the cache store misses also occur periodically and produces higher network overhead. The BF-ICN strategy closely approaches the proposed strategy for distinct interest arrival rates. This protocol uses the closest off-path saved encoded pieces and preserves the reachability data for off-route stored data during generation level of detailing. For the case R>35 requests/sec, our protocol performs superior than ProbCache+SPR, LCD+SPR, CL4M+SPR, LCE+SPR, BF-ICN as well as IF-ICN mechanisms by 10-22%, 11-18%, 7-24%, 9-15%, 7-13% and 12-23% in order. The BF-ICN mechanism generates lesser volume of overhead over proposed mechanism till R becomes 48 interests/sec. The mechanism produces remarkable rise in volume of overhead by 13-22% after this duration because of utilization of the additional content advertisement strategy responsible to FIB construction.

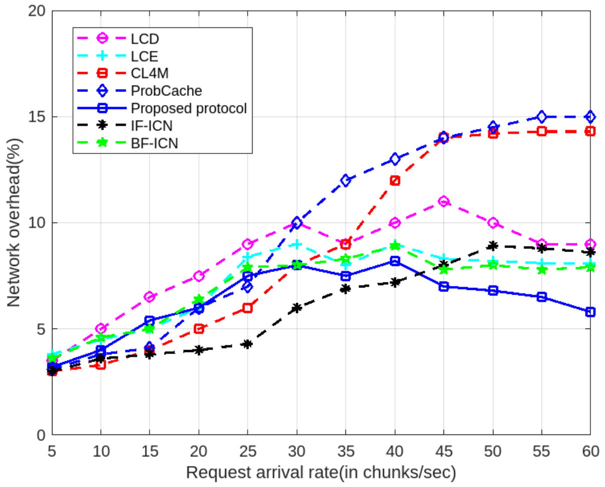

Fig. 5. Request arrival rate vs. network overhead for Random100 network scenario

4.2.3 Content store hit ratio

We have also investigated the protocol performance in terms of content store hit rate over request arrival rate. The simulation outcomes of the same is represented in Fig. 6. The protocol declares cache hit event when interest is fulfilled by intermediate routers and cache miss event when interest is answered by data producer. The results are derived by taking into account mean content hit ratio with varying cache size from 50 to 250 content pieces. We have inferred the fact that our protocol outperforms existing approaches in context of data hit ratio. The rational behind reduced delay of proposed mechanism is that it aims to fulfil interests by interior content routers in place of data producer. Hence, to achieve greater value for content store hit ratio is desirable evaluation metric for content centric networks. This can be well justified if base interest routing mechanism routes interest message efficiently and if this can be done properly, interest does not require to traverse up to data producer. It can be the case given that minimum single copy of data chunk is available inside interior content store.

The simulation outcomes of content store hit ratio for real-time Random100 topology with respect to interest arrival frequency is presented in Fig. 6. The content store hit ratio increases in linear proportion as interest arrival frequency increases in case of each mechanism. The shortest route forwarding joint Probcache variant performs better in range of 10-17% and 8-16% compared to shortest path routing integrated variants of CL4M and LCE methods respectively. The IF-ICN strategy and shortest path routing integrated Probcache behaves identical up to request arrival rate R = 35 interests/sec. In case when frequency becomes greater than 30 interests/sec, the BF-ICN and IF-ICN strategies closely approaches the behaviour of proposed mechanism followed by good performance, a remarkably good content store hit rate over remaining strategies. The rationale for better behaviour of IF-ICN except proposed mechanism and BF-ICN is as follows.

The strategy exploits monte carlo tree based search strategy for building optimal path between consumer and content source in network. The performance of BF-ICN mechanism beats the performance of IF-ICN mechanism in range of 7-18% for case of R > 36 interests/sec because it tries to fulfil interests through in-between nodes first by exploiting its data gradient based effective routing mechanism. It leads to noticeable rise for content store hit ratio of the strategy. The performance of proposed routing mechanism beats the performance of shortest route routing integrated variants of ProbCache, CL4M, LCE, LCD, BF-ICN and IF-ICN in range of 10-16%, 8-17%, 7-20%, 12-23%, 8-12% and 7-14% in order for content store potential ϵ [50,250] and distinct α values between 0.3 and 1.6.

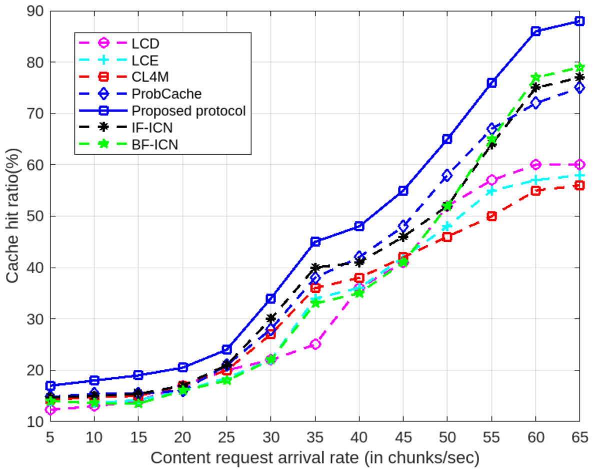

Fig. 6 Content request arrival rate vs. cache hit ratio for Random100 network scenario

5. Conclusion

The research work introduced in this paper contributes a weight-based request message forwarding strategy for ICN with key focus on minimizing the data discovery delay and maximizing the content store hit ratio. In order to accomplish this objective, the protocol exploits important factors such as request message forwarding ratio, PIT size of content router and total count of data messages produced by content router with different weighting co-efficients related to each one. These parameters all together assists forwarding plane of ICN in taking optimal interest forwarding decision such that request can be routed to node with greater likelihood of having needed data chunk. This can significantly help data retrieval process to fetch required data with least latency and overhead. The simulation analysis of proposed strategy has been done in ndnSIM for Random100 and GEANT realistic network scenarios. The extensive comparative analysis has been done to compare performance of proposed mechanism against traditional caching protocols integrated to shortest route routing as well as recent existing forwarding protocols of ICN. The proposed mechanism outperforms existing mechanisms approximately by 10-42% for performance metrics such as network overhead, content store hit ratio and data discovery latency. In future, we will investigate the feasibility of coupling machine learning driven models within process of request message forwarding in ICN.

CRediT authorship contribution statement

The corresponding author has contributed in problem formulation, algorithm design, implementation as well as testing and investigation.

Declaration of competing interest

The author declare that she has no known competing financial interests to affect the research work presented here. The author has not obtained any funding support for the reported contribution. The data generated while implementing proposed work are with author and can become accessible based on request.

Data Availability Statement

The data produced or used during research work will become accessible on request to corresponding author of manuscript.

References

[1] M. Aggarwal, K. Nilay, and K. Yadav. Survey of named data networks: future of internet. *International journal of Information Technology (Singapore)* 2017; 9:197–207.

[2] H. Jin, D. Xu, C. Zhao, and D. Liang. Information-centric mobile caching network frameworks and caching optimization: a survey. *Eurasip Journal on Wireless Communications and Networking* 2017; 33:1-32.

[3] G. Xylomenos *et al.* A Survey of information-centric networking research. *IEEE Comm Surveys and Tuts* 2014; 16:1024-1049.

[4] F. Khandaker, S. Oteafy, H. S. Hassanein, and H. Farahat. A functional taxonomy of caching schemes: Towards guided designs in information-centric networks. *Computer Networks* 2019; 165:106937.

[5] Lan Wang *et al.* OSPFN: An OSPF Based Routing Protocol for Named Data Networking. *NDN Technical Report NDN-0003, July 2012.*

[6] K. M. Mahmudul Hoque et al. NLSR: Named-data link state routing protocol. In Proceedings of the 3rd ACM SIGCOMM workshop on Information-centric networking. China 2013; 15-20.

[7] J. V. Torres, I. D. Alvarenga, R. Boutaba, and O. C. M. B. Duarte, "An autonomous and efficient controller-based routing scheme for networking

Named-Data mobility", *Computer Communication.*, 2017;103:94-103.

[8] C. Ghasemi *et al*. MUCA: New Routing for Named Data Networking. *In IEEE IFIP Networking Conference (IFIPNetworking) and Workshops*, Switzerland, 2018; 289–297.

[9] N. Dutta. An approach for FIB construction and Interest packet forwarding in information centric network. *Future Generation Computer Systems* 2022; 130:269-278.

[10] J. J. Garcia-Luna-Aceves. Name-based content routing in information centric networks using distance information. *Proc. 1st ACM Conf. Inf.-Centric Netw.*, France, 2014; 7-16.

[11] Banerjee, B., Seetharam, A., Mukherjee, A., & Naskar, M. K., "Characteristic time routing in information centric networks", *Computer Networks*, 2017;113:148–158.

[12] N. Dutta *et al*. Deep learning inspired routing in ICN using Monte Carlo Tree Search algorithm. *Journal of Parallel and*

A. *Distributed Computing* 2021; 150:104-111.

[13] Narayanan et al., "DEEPCACHE: A deep learning based framework for content caching", *In Proc.of ACM SIGCOMM Workshop on Network Meets AI & ML*, Hungary, 2018; 48–53.

[14] R. Boutaba et al., "A comprehensive survey on machine learning for networking: evolution, applications and research opportunities", *Journal of Internet Services and Applications, 2018;* 9:1-16.

[15] N. Dutta et al. SVM-based Analysis for Predicting Success Rate of Interest Packets in Information Centric Networks. Applied Artificial Intelligence 2021; 36: 2020488.

[16] K. Delvadia, N. Dutta, and R. Jadeja. CCJRF-ICN: A Novel Mechanism for Coadjuvant Caching Joint Request Forwarding in Information Centric Networks. *IEEE Access* 2021; 9:84134 - 84155.

[17] X. Chen et al. Improving NDN forwarding engine performance by rendezvous-based caching and forwarding. Computer Networks 2018; 145:232-242.

[18] G. Carofiglio et al.,"Joint forwarding and caching with latency awareness in information-centric networking," *Comput. Netw*., 2016; 110: 133-153.

[19] W. K. Chai *et al.* Cache 'less for more' in information-centric networks (extended version). *Comput. Commun.* 2013; 36:758-770.

[20] N. Laoutaris, H. Che, and I. Stavrakakis. The LCD interconnection of LRU caches and its analysis. *Perform. Eval.* 2006; 63:609-634.

[21] Psaras,W. K. Chai, and G. Pavlou. Probabilistic in-network caching for information-centric networks. In *Proc. ACM SIGCOMM ICN Workshop Inf.-Centric Netw.*, Finland 2012; 55-60.

[22] Y. He *et al.* A caching strategy in content centric networks based on node's importance. *Inf. Technol. J.* 2014; 13:588-592.

[23] N. Dutta. A bargain game theory assisted interest packet forwarding strategy for information centric network. *Journal of Network and Computer Applications* 2023; 209: 103546.

[24] R. Chiocchetti, D. Rossi, and G. Rossini, ''CcnSim: A highly scalable CCN simulator,'' in Proc. IEEE Int. Conf. Commun. (ICC), Budapest, Hungary, Jun. 2013; 2309–2314.

Author's Biography

Krishna Delvadia, is currently working as an Assistant Professor in Computer Engineering Department at Swami Atmanand Saraswati Institute of Technology, Surat, Gujarat. She completed her Ph.D. (Computer Engineering) in the field of information centric networks from Marwadi University (2021), Gujarat, India. She completed her BE degree in Information Technology from Marwadi Education Foundation Group of Institutions (2013), Gujarat, India. She received her ME degree in computer engineering from Marwadi Education Foundation Group of Institutions (2015), Gujarat, India. Her current area of research includes Information centric Networks, Mobile Adhoc networks, Wireless Networks, Internet of Things and Distributed Computing. She has published several research articles in the conferences as well as journals of repute of computer networking domain.

Email id: krishnadalasaniya10@gmail.com

Appendix 1

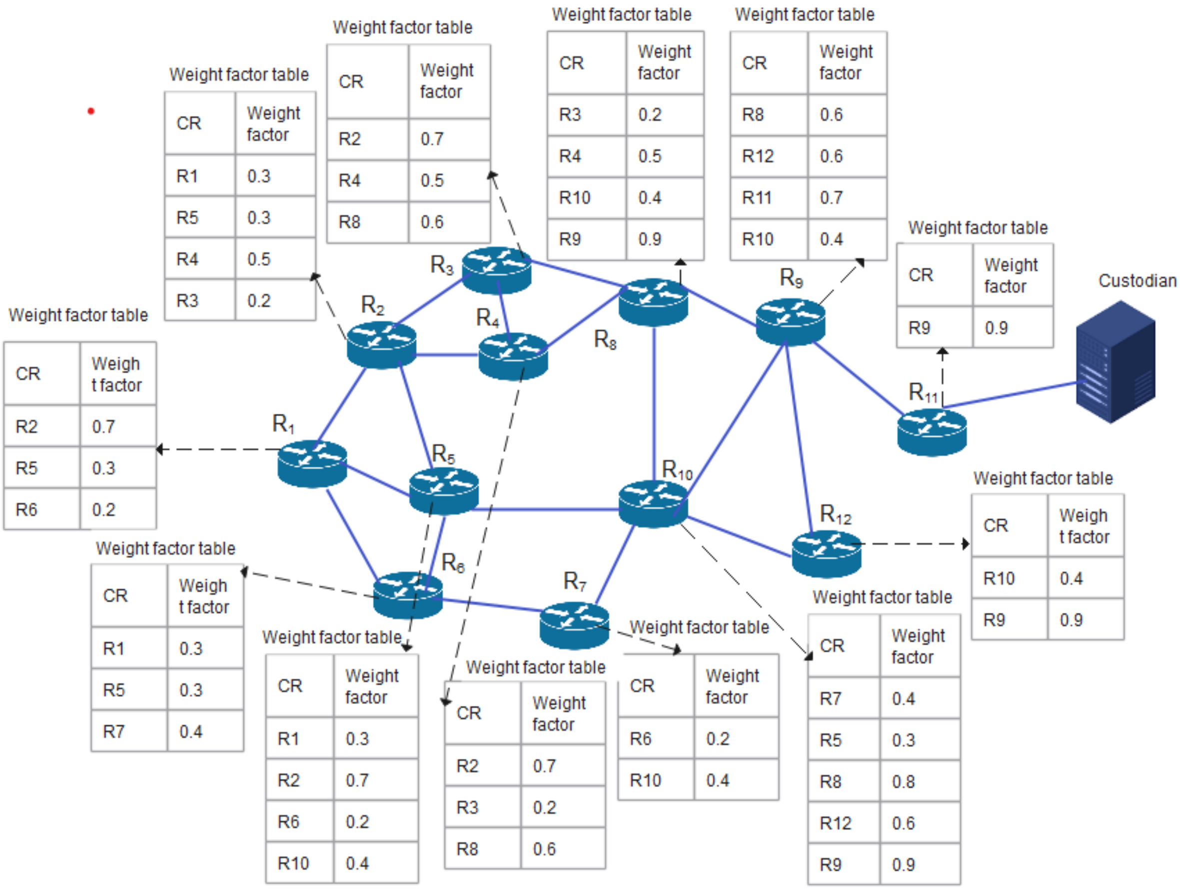

Fig.1 an illustrative network scenario for proposed weight-based interest forwarding protocol