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Group Mobility Aware Video Caching in Information Centric Networks for 5G Network

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Abstract: *The increased demand for video from mobile users has caused much pressure on cellular networks. In 5G networks, a millimeter-wave technique provides high bandwidth by using this technique. We can satisfy the need for high definition mobile videos and reduce the traffic load. While 5G networks have a slight tradeoff, although they provide higher bandwidth but base stations (BS) have a shorter range, frequent handoffs will occur when the user is mobile. So mobile video quality will suffer due to these frequent handoffs. Information centric network provides better mobility support than a typical IP procedure and is a promising new paradigm to alleviate the challenge mentioned above. This paper proposed a 5G-ICN caching approach in which we considered both user group mobility and video popularity. We have exploited the user's group mobility to reduce video retrieval delay as low as 6ms which were caused by handoffs. In terms of frequent handovers, retrieval delay is reduced group of mobile users will get videos directly from CR rather than the original content provider, while group handover will reduce handover delay as compared to single user handover. As the results showed that 5G-ICN group mobility caching approach performed 40% batter than typical CDIC and CAMV in terms of network load reduction, Improved QoE and lessen retrieval delay time.*

Keywords: *Information Centric Networks, Group Mobility, 5G-ICN, ICN Caching.*

Introduction

Video streaming became a crucial part of mobility when handoff will occur how to maintain the quality of experience. According to figures of cisco visual network index mobile data traffic will increase by 46% in 2021, and in which 78% is video streaming. Much research has been done on mobile multimedia content, such as [1]. Most researchers focused on cache placement by taking count of individual mobility such as[2][3]but not group mobility. The present Internet design was established upon a host-driven communication model. In that model, packets were used and exchanged between sender to receiver, a path has to be created between them for communication, which results in delay because data has to be accessed all the way from the provider and that was proper for adapting to the requirements of the early Internet users. Internet utilization has advanced, but most users are basically keen on accessing (Large set of) Information independent of its physical localization[4].A new paradigm Information Centric Network is introduced to cope with the above mention problem.ICN provides flexibility in the network in terms of putting the content as near to the user as possible rather than the typical IP-based retrieval process in which content is retrieved from the Content Provider that degrades the QoE[5]. ICN enables Named Data Network and In-networking strategies, which supports mobility in 5G networks.NDN supports named based routing, In which accessing the content relies on the name of the data; it doesn't rely on the location/server[6]. Name data networking has the following components Content store, pending interest table, and Forwarding interest-based. When the interest packet is generated, it goes through these ndn components there working is defined in below figure 4.In-networking enables caching of the content, which means routers and base stations in the 5G-ICN architecture can store (cache) the content [2]. When the user generates a request, a path is created along that path; if routers have no content according to a user request, they are forwarded to the content provider. Packets will return to user along the same path that packets were forwarded means along forward path also reverse path will be set. Along that reverse path all routers and base station will cache the content.

Mobility is one of the challenges in the wireless networks, and ICN provides a better approach towards handling mobility. Typical IP networks use anchor-based strategies in which the mobile node is connected to the content provider through an access point (AP) or base station (BS); when a handoff occurs, only link changes, but data is fetched from the content provider which puts congestion on the backhaul. While ICN provides a Request and Reply content mechanism in which mobile nodes request the content, the nearest nodes check local storage if there forwards the content [7]. Mobility in ICN is the hottest research area;much research is taken place, but most of them consider individual mobility. In [2] mobility patterns are identified through Janson density, but the consideration of pattern is only for the individual mobile node. Group mobility in ICN can improve QoE and delay, while group mobility has been considered in Adhoc, WiMAX networks to increase routing protocols' performance and shortened handover delays [8].

Due to the increased demand for multimedia content, videos have the highest request factor of 78% traffic on the network until 2021. The huge demand for videos can create extensive traffic load and congestion on the network core and backhaul. Some strategies and techniques can deal with these problems. ICN provides an in-networking caching mechanism that is a better way to handle these issues[9]. On the other hand, 5G-ICN architecture in [2] provides higher bandwidth to support higher quality video streaming, which utilizes the (mmWave) techniques and supports mobility. In contrast,a 5G network can impose longer connection delays due to frequent handoff causes of shorter transmission between the base station, which can degrade the QoE for mobile video users. Group mobility into 5G-ICN architecture hasn't caught the researchers' attention; only individual node mobility has been taken in to count[2][3].

The main contributions of our work are as follow:

1. The objective of our work is to explore the QoE of videos in 5G-ICN architecture under group mobility.
2. The 5G-ICN architecture was built using ndnSIM;our work presents the performance evaluation of QoE of videos under group mobility in a name data network.
3. To evaluate the impact of group mobility on QoS in 5G-ICN, several experiments were designed. We used bonmotion to implement group mobility in ICN.

The rest of the paper is organized as follows. Section 2 described the Proposed schemerelated work about Information centric networks, Caching in 5G,andgroup mobility methods in 5G-ICN. Section 3describes the problem modeling of the proposed problem statement.Section 4 reviews the implementation details and the evaluation measure that was taken to calculate the results. Conclusion and Future work is described in section 5.

1. Related Work

This section of the proposed scheme describes related work about the proposed research problem statement. We have divided the related work into three sections. The first section gives an overview of caching in ICN. In the second section, video caching in 5G and ICN. In the third section, mobility methods and group mobility in information centric networks are discussed.

Due to the increased mobile traffic, mostly multimedia demand, which includes Audio, video, and gaming are produced by smartphones, or other end devices can produce much congestion on the core network. Typical IP protocols will not work efficiently in terms of QoE, delay, and throughput. ICN can efficiently provide these services. It supportsa naming scheme in which the users are transparent to the underlying processes (e.g. location of processes/server) is concerned with high-level names [7]. ICN is a vast field, so we classified ICN according to our problem statement following fig 6 defines our proposed work classification.

Caching is one of the prominent solutions to reduce the load from backhaul. So, information centric network provides an in-networking caching mechanism to reduce the load from the core network. Following are the techniques used in ICN: In[10], they used a cluster caching approach in ICN, which reduced the packet loss ratio and increased the transfer time ratio.A smart caching mechanism in [1] used an edge environment over an ICN architecture in which they used 1) Location prediction 2) Smart cache using machine learning method for the placement of mobile multimedia content on the edge nodes and at the end, a smart cache replacement algorithm and there result showed that there proposed algorithms performed well against the comparative techniques which include increased hit ratio and reduced access time.

As video streaming is becoming more and more popular as time passes, the QoE of video caching techniques is used. The following are the video caching techniques of our related work: A popularity prediction caching is proposed by leveraging ICN architecture. They designed a chunk level cache eviction policy that predicts video chunks future popularity. This strategy analyzedthe early behavior and user request behavior relationship between the same video files neighboring chunks; by doing this, they monitored the user viewpoint behavioral aspect and chunks relationship. Suppose the predicted chunk popularity has the highest count. In that case, that chunk will be placed, and whose predicted count is outdated will be evicted from the cache, and their model increased the efficiency over LFU and LRU[11].Three types of Adaptive Bit Rate (ABR) algorithms are rate-based, buffer-based, and hybrid-based, for adaptive video streaming have been tested in [15] under QoE's influence in an ICN environment. Their evaluation confirmed that rebuffering happens in throughput-based approaches due to the factor of hit ratio. Rate based algorithm bitrate decreased due to throughput, but QoE is better than hybrid based vice versa but buffer based QoE and bitrate are low because of its strict policies and no rebuffering state. Their work concluded that ABR performance depends upon user preferences, but tested algorithms do not work in different situations.Caching the videos at the edges of the networks can reduce congestion at the backhaul. The author in [12]introduced a proactive caching technique by leveraging the 5G-ICN approach. In their smart caching technique, they used non-negative matrix factorization to predict the future rating of consumer preferences of videos, but the shortcoming of this technique is inaccurate for unpopular videos. So, they also used historical prediction to cope with this problem, there works increased the hit ratio and the retrieval video delay, but under the mobility, their techniques do not perform well.K.Hasan et al [13] proposed a lightweight collaborative cache scheme by leveraging ICN perspective in which cache placement is dependent on the position of the router, and the popular videos have to be cached at the routers which are closer to the user and this scheme adaption isn't dependent on the prior knowledge about popular videos, but its adapts according to a user request. Video placement on the cache of a router is dependent on the router threshold because different routers can have different threshold due to their different topologies. Results showed that their scheme reduced no hop count and publisher load, but their approach's drawback is the large amount of redundancy across the network.

Mobility is one of the key challenges in networks and ICN. At the same time, ICN can provide better mobility support than IP protocols because ICN content is not dependent on the location. Following are the mobility techniques in ICN: In[2], they considered a 5G-ICN architecture to cache videos on the base station by taking count of user mobility. Their works focus on reducing the average delay and buffering (choppy playback). Their cache mechanism involves 1) caching the popular content at the base station for those users who are slow movers inside the base station range and 2) for high mobility user's they involve an entity that is a content router. High mobility users are forwarded to the content router for retrieving the videos in this way when high mobility users are under frequent handovers, retrieval performance is improved, and choppy playbacks are reduced than other approaches such as radio access networks; however, there research only consider single user mobility and preference-based model for video caching. An Optimal Information Centric Caching is proposed [3] in which they created a mobility aware 5G-ICN architecture in a device to device environment and formulated an optimal cache placement policy in which they demonstrated a replication was spreading process which catches the dynamic connection between replication and user activity conducted under controllable caching tasks. Their optimization technique minimized system load and caching.Furthermore, they created a cache algorithm named OCP. They integrated with their time threshold-controlled cache technique result shows that increased cache hit ratio and controlled redundancy in the network.

Group Mobility in information centric network is not fully explored yet as it is challenging in terms of how groups will be formed based on what parameters should be used. Some of the group mobility techniques are implemented in ICN are as follow: Author in [14] adopted an ICN approach content-centric network, In which groups were made when a specific mobile node request for content a group is created around its 10m range and the content that is requested if local storage available locally placement if not distribute the content into respected group members. They used Zipf distribution for content placement, and for corporative group caching, they used the “Hello” message mechanism to periodically check its local table, group table, and neighboring nodes; due to this mechanism, there is a communication overhead on the ad hoc network, but the Hit Ratio probability increased. X. Liu et al [15] grouped the mobile nodes in MANETs under ICN environment and investigated the impact of group mobility on the delay and throughput performance main concern of their research is to investigate content retrieval from the neighboring nodes that are stored (cache) there based on the instinct of correlation between the nodes in the same group or between groups. They considered two arrangements cluster dense and cluster sparse and investigated both under fast mobility and slow mobility. There result showed that under fast mobility, throughput is degraded, and there is an improvement in the delay performance and under slow mobility,a correlation among nodes had a negative impact on delay and throughput. Their cache allocation did not consider time and location, which means they used the static cache allocation technique.

Mobility prediction has been one of the key challenges in wireless networks. Many research pieces in the last generations (3G and 4G) networks have been done on mobility but their methods focused only on predicting mobile node patterns but not caching the content. While ICN decouples the location’s content, the paradigm provides name data access from the nearest access point rather than typical IP-based retrieval from a content provider; therefore, ICN can provide better mobility support. Mobility has been considered in ICN by many researchers, such as [4], but these works only focused on individual mobile nodes pattern. Some works like [11][12] also considered mobility under ICN environment; their works were in MANETs and device to device. Focus of their research is how to cache the content on the mobile nodes and how to retrieve content from a neighboring node

Table 1. Summary of Related Work.

Paper no.	Research Methodology	Eviction policy	Prediction Method	Content Type	Advantages	Disadvantages	Technology	Limitations	Parameters
[1]	A smart caching mechanism for mobile multimedia inICN	OCRS	Historical traces	Mobile multimedia	Increased hit ratio and reduced access time	Cache size small OCRS has a lower hit ratio	N/A	Prediction accuracy of the week’s half days is lower than the other half days	Hit ratio and Average access time

[2]	ICN-based caching approach for mobile video	LRU	Zipf	Video	Reduced video choppy playback time	Different video preference is not considered	5G	Cache strategy only considers popular videos	Average retrieval delay and Miss ratio
[3]	Optimal Information Centric Caching in Device-to-Device Communications	N/A	No	N/A	Minimized system load and controlled redundancy	Caching tasks were static	5G	Dynamic behavior is only considered between replication and user only	Caching cost, Average download time, and Average hit ratio
[14]	Cooperative Group Caching Strategy in Content-Centric Networks	Time aware least recently used	Zipf	N/A	Cache hit ratio probability increased	Communication overhead on the network	Ad Hoc	Neglected the impact of the "Hello" mechanism on the performance of the proposed strategy	Cache Hit Probability, Average Number of Successfully Served Requests, and Content Caching Probability
[15]	ICN with correlated mobility	N/A	No	N/A	Improved delay performance	Static cache allocation	MANETs	Time-dependent and location-dependent content popularity is not considered	Cluster Sparse Regime with Fast Mobility

[10]	Efficient Caching for Delivery of Multimedia Informatio n with Low Latency in ICN	N/A	No	Multi media	Reduced the packet loss ratio	Redundanc y throughout the path	N/A	Limits the cache hit ratio	Conten t transfer time
[11]	Popularity Prediction Caching in ICN	Least Futur e popul arity	Zipf	Video	Increase d efficienc y of eviction policy	Popularity prediction is limited to chunk level	N/A	Popularity between videos should also be considered	Average delay, Average cache hit ratio, Average server load, and Average cache hit ratio
[16]	Adaptive Video Streaming in ICN	N/A	No	Video	Shorten playback time	The approach is scenario dependent	N/A	Only throughput -oriented algorithms are considered	Rebuffe ring time
[12]	Smart Caching in ICN	N/A	Non-negative matrix factoriz ation	Video	Increase d hit ratio and reduced video retrieval delay	Under mobility, smart caching does not perform well.	5G	Content popularity with user mobility should also be considered	Hit ratio, Average Video Retrieva l Delay and Average Rating of Cached Videos
[13]	Router Position-	LRU	N/A	Video	Reduced no of	Redundanc y across the	N/A	Works only when cache	Reduce d

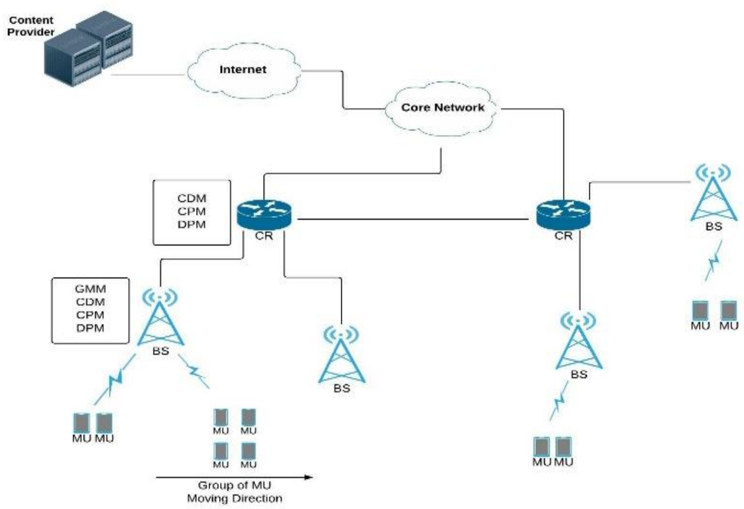
Based Cooperative Caching for Video-on-Demand in Information-Centric Networking		hop count and publisher load	network		size of routers is relatively small	publisher load ratio and Average number of hops

2. Proposed 5G-ICN Scheme GMAVC

In this section, we will explain how the proposed technique is modeled. The Athematic modeling of our proposed models Group Mobility Model, Content Popularity Prediction Model, Group handover and Different Preference Model and evaluation metrics Average retrieval delay, Average Number of Choppy playback Time and Average miss ratiois discussed.

2.1. Overview of GMAVC

Video streaming has become more popular over the past couple of years and due to the huge amount of videos request put a load on the backhaul, ICN provides in-networking caching to cache videos near to user by considering user mobility to decrease load at backhaul. In our approach, we are considering group mobility under 5G-ICN architecture to improve QoE. We placed a group mobility model on the base station to capture mobile users' speed and direction and predict whether a handoff will occur



during video playback time. Users moving with similar speed and direction will form a group with high mobility will have a link to a content router, and low mobility will get their videos from the base station. The preference model contains Zipf distribution to predict popular videos named as content popularity model, and a kernel function is used for group members whose preference is different. Then cache decision model will predict where to cache video at the base station or the content router.

Fig. 1 –Illustration of the Architecture of Proposed GMAVC 5G-ICN Approach.

2.2. Logical View of GMAVC

The proposed technique GMAVC is overlaid on the 5G-ICN architecture; it divides the video storage and video caching functionality into edge nodes, which are BS/CR. The system has three components users, nodes (BS/CR), and content providers. Firstly, users' components have all the information about the user's request, and the configuration part has the ability to pass user requests to center nodes. The

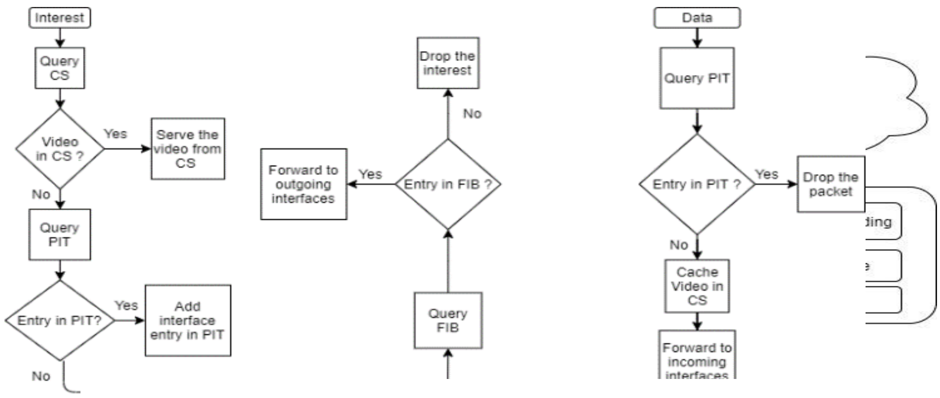


Fig. 2 - GMAVC Logical View.

second component is Nodes (BS/CR), BS can locate the users and form a group on the other hand, nodes have the ability to cache videos, routing strategies, and updating the content based on popularity prediction. The third component is the content provider, which has the storage capability to store video and provide the requested video or forward it to between nodes for caching.

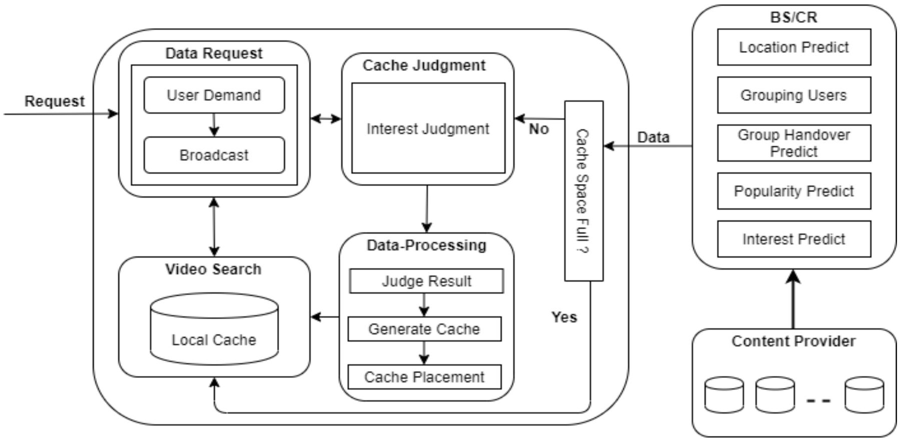
2.3. Edge Nodes and Interfaces Interaction

In 5G-ICN, BS and CR are content-centric nodes in which three components are being used FIB; it is similar to IP forwarding protocols, and PIT keeps the information about the requests which had no response, and CS keeps track of the cached content.When interest comes to the BS, it checks its CS. If the video is available, it is forwarded back to the interest path and that interest packet will be discarded. If the video is not in the CS then interest is checked in PIT. If interest in PIT is the same as an interest that interface is added in the response entry in PIT table and cached at the desired interface, then that interest is discarded. If interest is not in CS and PIT than FIB is searched, and interest is forwarded to the matching interfaces. If the matching interface has the video, it is added to the PIT response request, and the interest packet is discarded.

Fig. 3–(A) Flow of Interest Packet; (B) Flow of Data Packet.

2.4. Workflow of GMAVC

The user will generate a data request, then the user demand is checked at (BS/CR). Then (BS/CR) local caches are checked for videos; if not present,the request is forwarded to the connected (BS/CR) throughout the system. The connected (BS/CR) responds to whether the forwarded request is present in the local cache. Otherwise, if not,a present request is forwarded across the system until the corresponding video is returned. If the cache is full, content popularity calculation and eviction policy



performance will be measured based upon the above outcome. For the (BS/CR) nodes that are connected to requesting users, the location prediction for the grouping of the users, popularity prediction, Group handover prediction, whether the handoff will take place or not, and interest prediction are determined. According to the calculation of these predictions, the edge node (BS/CR) decides whether to cache the requested video and where to cache the requested video.

Fig. 4–Workflow of GMAVC.

2.5. Proposed Architecture

In this segment of the paper, the proposed 5G-ICN based system model is described. It comprises four different models: a group mobility model, Content popularity prediction model, Cache decision model, and Different preference model. GMM is only placed at BS, while CPPM, CDM, and DPM are placed at BS/CR. The architecture of the proposed group mobility aware video caching 5G-ICN is explained in Fig. 5.

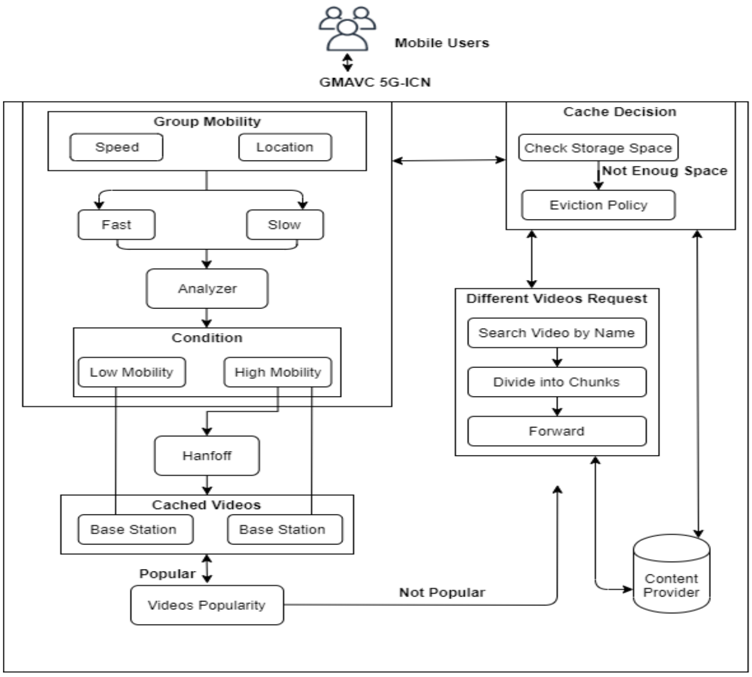


Fig. 5– Architecture of Proposed GMAVC 5G-ICNApproach.

2.5.1. Group Mobility Model

The GMM is used to compute the mobility and group the mobile users according to spatial and temporal features. Also, to predict handoff during a playback session in the proposed technique, there will be a number of mobile users in a group; only one member of the group will handoff on behalf of others. While 5G networks have prediction accuracy with one-meter deviation location information of mobile users.

Table 2 -Symbols Used in GMAVC Modelling.

Symbols	Definition
t_{ij}	Euclidean distance between user i and j
t_{max}	Transmission range between user i and j
s_{ij}	Relative velocity vector between user i and j
s_{max}	The total speed that the network can track
$JSD_{i,j}$	Finding temporal locality
γ_{DLR}	Tuning parameter
$\hat{P}_i\|\|\hat{P}_j$	Probability between mobility

	patterns
$Up_{i,f}$	User preference of user i in group Gr_n

Spatial locality (SL) and Temporal locality (TL) are group mobility metrics. SL can give information about speed and direction; similar users moving with the same speed in a similar direction.$s_{i,j}$ are the relative velocity and euclidean distance which means relative speed and distance between user i and j. The maximum transmission range is denoted by s_{max} and maximum speed is denoted by t_{max}. When a condition $0 \le t_{i,j} \le t_{max}$ and $0 \le s_{i,j} \le 2s_{max}$ satisfy between two neighboring nodes commonality is set between these nodes and resultant v$\sum_{K=1}^{M} g(C_k, D_f)\, v$alues are normalized between $[0,1]$. A group will be formed when this condition will be satisfied $SL_{i,j} > SL_{th}$. $SL_{i,j}$ is used to find relativity among neighboring nodes. Following equation (1) for finding spatial locality of mobile users.

$$SL_{i,j} = \frac{1}{1+\sqrt{\left(\frac{t_{i,j}}{t_{max}}\right)^2+\left(\frac{s_{i,j}}{2s_{max}}\right)^2}} \quad (1)$$

TL will provide a similar user at a given time slot existing at the same location, and groups will be formed when $TL_{ij} > TL_{th}$ condition will be satisfied. Jenson-Shannon Divergence is used to find TL of mobile users. When a condition $0 \le TL_{i,j} \le 1 \; and \; TL_{i,j} = 1 \; only \; if \; \hat{P}_i = \hat{P}_j$is meet users with the strongest mobility pattern are grouped together. Following equation (2) is for extracting temporal locality.

$$TL_{i,j} = 1 - JSD(\hat{P}_i || \hat{P}_j) \quad (2)$$

While combing both will provide us a complete set of information location and direction from which observation about group mobility can easily extract. Dual locality Ratio (DLR) combines SL and TL and investigates group mobility impact on network performance, and following equation (3)is for findingDLR. For different scenarios, SL and TL effect can be controlled by using tuning parameter γ_{DLR}. If the value of the tuning parameter γ_{DLR} is higher changes will be controlled by TL of DLR on the other hand γ_{DLR} is small SL can control DLR. When $DLR_{i,j} \ge DLR_{th}$the condition will be satisfied virtual groups profiles will be formed $Gr = \{Gr_1, Gr_2, Gr_3 \dots Gr_n\}$.

$$DLR_{i,j} = (1-\gamma_{DLR})(SL_{i,j}) - (\gamma_{DLR})(TL_{ij}) \quad (3)$$

Thus, for forwarding the videos to the users inside the group with the user preference in mind. Where $Up_{i,f}$ defines user preference among other group users and$\sum_{j\epsilon \frac{Gr_n}{(i)}} Pr_{j,s}.F_{j,s}$Provides the videos from BS/CR to group members.

$$V_i = \sum_f^N \left(\sum_{j\epsilon \frac{Gr_n}{(i)}} Pr_{j,s}.F_{j,s}\right) Up_{i,f} \quad (4)$$

Algorithm 1: GMM

Input: 1) Euclidean distance between user i and j.

2) Relative velocity vector between user i and j.

Transmission range = Pre-defined value

1: **for** n = 1: for number of users to compute spatial locality
2: Compute max transmission range → s_{max}
3: Compute max speed → t_{max}

if (SL_{ij}>SL_{th})
$s_{ij} \leftarrow$ Set similar relative speed and distance between user i and j.
$\sigma_{s,0} \leftarrow [randome\ value \in [0,1]]$
Else
$s_{ij} \leftarrow$ Set no similar relative speed and distance between user i and j.
$\sigma_{s,0} \leftarrow [randome\ value \in [0,1]]$
Users with relatively same $\rightarrow SL_{i,j}$ are clustered in one set.
end for
for m = 1: for number of users to compute temporal locality
Compute mobility pattern trace between user i and j
Compute JSD at the time slot t $\rightarrow JSD(\hat{P}_i || \hat{P}_j)$
if ($TL_{i,j}$>TL_{th})
$\hat{P}_i = \hat{P}_j \leftarrow$ Set strongest temporal locality between user i and j.
$\partial_{p,0} \leftarrow [randome\ value \in [0,1]]$
Else
$\hat{P}_i = \hat{P}_j \leftarrow$ Set no strongest temporal locality between user i and j.
$\partial_{p,0} \leftarrow [randome\ value \in [0,1]]$
Users with relatively same $\rightarrow TL_{i,j}$ are clustered in one set.
end for
for x = 1: for number of users to compute dual locality ratio
Set $\gamma_{DLR} \leftarrow$ as a tuning parameter
Compute $\gamma_{DLR} \leftarrow$ value for particular time slot t
Set $TL_{i,j} \leftarrow$ value with similar weights
Set $SL_{i,j} \leftarrow$ value with similar weights
if ($DLR_{i,j}$>DLR_{th})
$(1-\gamma_{DLR})(SL_{i,j}) - (\gamma_{DLR})(TL_{ij}) \leftarrow$ Set dual locality ratio between user i and j.
$\gamma_{DLR,0} \leftarrow [randome\ value \in [0,1]]$
$(1-\gamma_{DLR})(SL_{i,j}) - (\gamma_{DLR})(TL_{ij}) \leftarrow$ Set no dual locality ratio between user i and j.
$\gamma_{DLR,0} \leftarrow [randome\ value \in [0,1]]$
Users with relatively same $\rightarrow DLR_{i,j}$ forms groups out of N-1.
end for

2.5.1.1. Group Handover

While the users are moving in a group, we have to compose a group handover strategy that will help lessen the ARD and CPT, but to that, only one member of the group has to perform the group handover. In equation (5) Gr_n no of virtual groups that were formed and VS_i represents the size of video *i*of user$u_i$in group Gr_n whereas VBR_i is the bit rate of video *i*of user$u_i$in group Gr_n. $s_{max}$is the max speed that the network can track while the users are moving in the network range and Set $\gamma_{DLR}$is the tuning parameter value to detect the angle between group Gr_n moving direction and base station.

$$H_i = \sum_{j\epsilon\frac{Gr_n}{(i)}} \left(\frac{\frac{VS_i}{VBR_i} \cdot s_{max}}{DGr_n} \right) \qquad (5)$$

Algorithm 2: Group Handoff

Form groups and get their mobility traces from → Eq (1), Eq (2), and Eq (3)
for Gr_n = 1:
Get VS_i→ size of video *i* of user u_i in group Gr_n
Get VBR_i→ the bit rate of video *i* of user u_i in group Gr_n
s_{max}→ max speed that the network can track
Set γ_{DLR}→ Parameter value to detect the angle between group Gr_n moving direction and base station
Generate a random delay D_i for user *i* of Gr_n
Sort random delay D_i for user *i* of group Gr_n into ascending order → *w*
  for *i* = 1:
  Select a user *i* from group Gr_n which has the smallest delay from → *w*
  Get the traffic information fromthe previous group Gr_n
for j = 1:
    Compute latency of network *j*
N_i→ network *j* has minimal latency
if ($H \geq 1$)
      Start the handoff process
else
Do not start the handoff process
    Send out network selection N_i when handoff is completed
end for
end for
end for

2.5.2. Different Video Preference Model

For the prediction of popular videos, we will use Zipfdistribution; it will calculate the frequency of how many times the video *f* is requested if the frequency is greater than other videos, that video will be considered popular and cached. While the video popularity will be generated locally by each node (BS/CR). Popularity depends on time; as time passes, video popularity drops, so the cache space is limited at nodes. When a node has a video that's popularity threshold drops and becomes unpopular, that video is removed using LRU.

$$p_{v_f} = \frac{f^{-\alpha}}{\sum_{j=1}^{F} j^{-\alpha}} \qquad (6)$$

2.5.3. Different Video Preference Model

A group will have different preferences membersto in each time slot *t* user *i* canprefer a file *f* in a groupcan be calculated by thefollowing equation (6). Based on the user interest *i* in file *f* at time *t* next file, probability can be calculated by the kernel function. To track the user demands for videos, the system will create a demand profile for each user to track particular users' personal preferences for videos to predict the whole system's average demand. Where these demand profiles are used in the caching process as a weighing parameter. The demand profiles for each mobile user in a group is defined as $Dp_i = \left\{up_{i,f}, \forall t \in \{1,2,3 \ldots, T\}, \forall f \in \{1,2,3 \ldots, F\}\right\}$.

$$up_{i,f} = p_{vf}\left(\frac{m(C_i, D_f)}{\sum_{K=1}^{M} g(C_k, D_f)}\right) \quad (7)$$

2.5.4. Cache Decision Model

CDM follows some decision principles, which are described below.

1) Group of mobile users who requested videos and moving with high mobility, their content will be cached at CR nodes.
2) Group of mobile users who requested videos and moving with low mobility, their content will be cached locally at BS nodes.
3) The eviction policy used in our approach is least recently used.

The CDM model is used in or approach to predict which video and where it should be cached. When cache storage is full and which video should be replaced is decided by eviction policy LRU.

CDM model is implemented as follow:

1) Every node in the system (CR/BS) checks its cache space locally; if space is available, cache the requested video directly on the node.
2) If cache storage space is not enough, then the user's group mobility information will be required. If a group of users moves with high speed, and group handoff will occur during the videos playback session, those videos should be cached at CR.
3) Otherwise, if there will be no handoff during the video playback session, those videos should be cached at BS.

3. Implementation and Results

In this section, we will discuss the results and the environment we used for the testing phase. As our approach is ICN based, we will choose IP-based RAN caching [17] that stores content at the base station, and also we took CAMV [2] that stores content according to the popularity at both CR and BS. The replacement policy that we used to compare the techniques is LRU. We used ndnSIM[18] for the evaluation of our 5G-ICN based technique. We performed the simulation 5 times and then calculated the average of those 5 runs.

3.1. Simulation Setup

In our implementation, we took a regular grid of 500×500m^2 in which 30 BS and 6 CR are connected to each other. Every CR is connected to 5 BSs each. Through optical fibers,neighboring CRs are connected to each other. There were 40 groups, and each contained maximum of 25 users. FirstlyReference Point Group Mobility model was applied to form groups than all the group members keep requesting video until they reach the end of the grid and walk out of it than group handover technique was applied so, only one member of the group takes part in the group handover. Each group moves in a random position with a random speed. Group speed ranges from 0 m/s to 20 m/s, and the videos request that were generated are 10000, in which the identical requests were 2598. For popularity, we implemented Zipf distribution, and we set the $\gamma = 0.7$.

3.1.1. Resource Modelling

Mobile user's wireless link capacities are assumed to be equally distributed. As we know,mmWave technology provides Higher bandwidths, and the maximum no of user's in a group are 25. A group contains multiple mobile users, so the latency between a mobile user and base station is considered 5ms [19], the latency between content router to base station is 10ms [20], and latency between content router to the content provider is 50ms [21]. Video is fragmented into chunks, and the size of those chunks is 4000 bytes, and all the chunks will be of the same size. The size of the videos can vary from 10 MB to 4GB. The protocol used in the simulation is the shortest path routing protocol, and we assumed that CR storage wouldvary and BS storage will remain the same.

Table 3–Parameters Setting.

Property	**Value**
Base Station Grid Layout	500×500m^2
Base station Radius	100m
Latency Between BS and Group of Mobile Users	5ms
Latency between CR and BS	10ms
Latency between CR and Content provider	50ms
Video Fragments Size	4000 bytes
Total No of BS	30
Total No of CR	6
Popularity Method	Zipf
Popularity Reset value	30mins
Ram	12 GB
ndnSIM Version	2.0
Group Members	10 to 25
Speed Ranges	0 ms to 20 ms

3.1.2. Application Modelling

While in the simulation first step is to form a group so, we used the reference point group mobility model as it has both spatial and temporal in the shape of speed and geographical manner as the members inside the group can freely move outside the group. When it goes into an area of other groups, it becomes a member of that group, and that feature is known as a dynamic grouping in RPGM; to use this feature, use a command -c <probability>. For the videos, we have gathered 10000 videos from YouTube, and they have unique names. When users inside a group request a video consumer who generates a request then goes to consumer class that is a reference class that is generating interest toward producer with the frequency of 10 interest packet per second and consumer is implemented on all the mobile nodes. BS/CR can cache the content that means they are ICN enabled,which hasa forwarding interest base (FIB), pending interest table(PIT)and content store (CS). When a request is generated from the request packet,the name prefix/com/youtube/Demo is checked if available in CS of BS/CR start sending data packets back to the user if no check PIT and add a PIT entry. Suppose no relevant entry found in PIT of BC/CR query to FIB will make an entry and will query to the video's content provider and save a video on reverse paths BS/CR. To reduce the congestion on backhaul popularity prediction Zipf is implemented on both CR/BS. Zipf maintains a table in which its record's the frequency of request per video and caches the video with high frequency.The content store has some policies last recently used (LRU) and first in first out (FIFO) to evict the videos that lost their popularity. We set 30 mins threshold for the popularity of a specific video. Requests checked at content store implements FIFO first request enters that request is responded in a queue. MPEG GASH is used to convert the video in a stream of fragments into a relevant sequence and pass it on to the producer class to convert in TCP segments to pass it on the network.

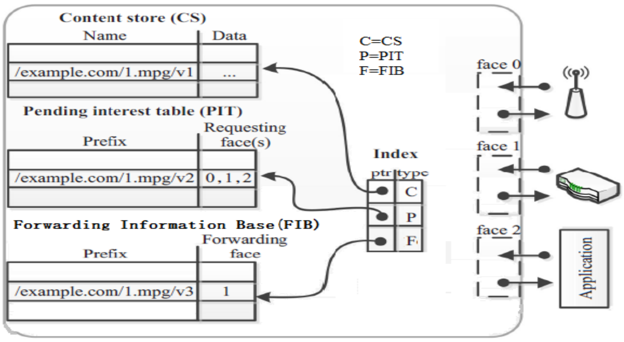


Fig. 6–Application Model.

3.2. Performance Measures

This section provides what measures were taken to check whether the given cache strategy works better than others.

3.2.1. Average Retrieval Delay

We will use this matric to evaluate how much faster a user can fetch the requested video. QoE can be affected if the average retrieval delay is high. Where r_i is the retrieval delay of video i, and N is the total number of requests. The average retrieval delay RD can be calculated by the following equation (7).

$$RD = \frac{\sum r_i}{N} \quad (8)$$

3.2.2. Average Number of Choppy Playback Time

By using this metric, we can observe the QoE of a mobile user. When a handoff occurs, this will lead to retransmission of packet due to lost packet if the newly connected content router or base station does not cache the video. Following is the equation for calculating the average number of choppy playback time. where p_i is the number of choppyplayback for mobile user *i*and *N* is total noof requests.

$$CP = \frac{\sum p_i}{N} \quad (9)$$

3.2.3. Average Miss Ratio

For calculating the efficiency of the proposed 5G-ICN approach, we will use the average miss ratio. Following is the equation for calculating the average miss ratio.Where m_i is a binary value, $m_i = 0$ if video i is not cached at a BS or a CR locally for a request; otherwise,m_i=1.

$$MR = \frac{\sum m_i}{N} \quad (10)$$

3.2.4. Backhaul Load Reduction Ratio

The proportion of chunk requests that have to traverse from the content provider towards the base station that propagated the content request.Following is the equation for calculating the Backhaul Load Reduction Ratio. Where c_i intensity of chunks propagated through the backhaul and N is the total intensity of the backhaul.

$$RR = \frac{\sum c_i}{N} \quad (11)$$

3.2.5. Redundancy Ratio Across Network

The intensity of a duplicate caching among neighboring base station nodes N, which can be calculated as the proportion of the overall cache capacities in GMAVC that hold duplicate data item.Following is the equation for calculatingRedundancy Ratio Across Network. Where r_i is the repeated video across the base stations and CR and N is the total no of videos across the network.

$$RR = \frac{\sum r_i}{N} \quad (12)$$

3.3. Result and Discussion

This section will assess how our 5G-ICN approach impacts performance when different cache sizes are considered. In our approach, BS/CR cache size ranges from 1GB to 100GB. In our approach, we use group mobility as a key factor in Implementation; when groups are formed, the key element is group handover. In our group handover technique, only one member takes part in the handover process while others stay static and follow that member's lead.

3.3.1. Cache Size Impact on Average Retrieval Delay

Average retrieval delay (ARD) plays a vital role in QoE. An objective of the experiment of ARD is to check how many packets were lost during transmission means that when packets are lost, retransmission will occur and will cause a delay, which will directly affect the QoE of the mobile user. The graph's y-axis is ARD shown in a millisecond and on the x-axis cache size that ranges from 1 GB to 100 GB. While working with the cache strategy, the graph's general trend shows that our strategy delay became less and less when mobile users were receiving the videos when we increased the cache size. When the range of BS cache size is changed between 1GB to 100GB pattern of average retrieval delay is described in Fig.6. When the simulations were performed, it showed us that the average retrieval delay of CAMV decreased when both CR and BS cache sizes were limited to 100GB. Due to our group handover technique, waiting time for each member's handover process decreases, and requests are fetched directly after the group handover process for all members, whichsignificantly improves our average retrieval delay performance. CDIC was using a base station to cache videos, there BSs were cooperating with each other to cache the videos but a flaw was due to excessive replication which caused cache memory to be full and eviction policy didn't remove the videos as their popularity among videos wasn't working considered popularity was considered between chunks. In the case of CAMV, its performance is affected by each members handover process, and also there is a limitation of storage in CAMV in which BS max cache size is 30GB considered due to small cache size of BS, so popular content may not be stored at it, and thus performance was too poor. However, the CAMV technique is simulated, and when its BS/CR cache size is varied from 1 GB to 100 GB its average retrieval delay decreased from 25 ms to 19 ms; on the other hand, when GMAVC is simulated, and cache size of both CR and BS is varied from 1 GB to 100 GB the minimum Average retrieval delay decreased from 7 ms to 5 ms with CR cache size of 100 GB

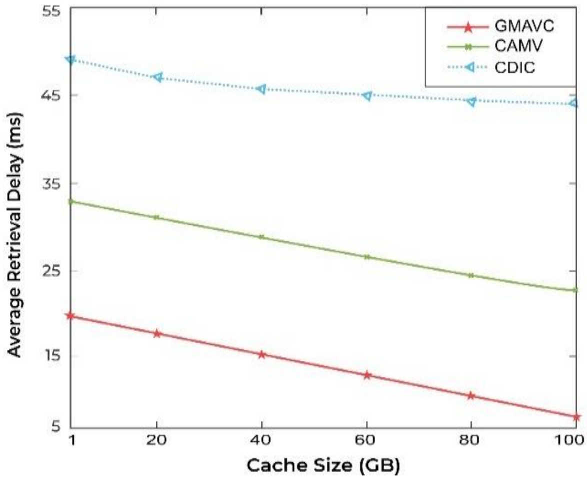
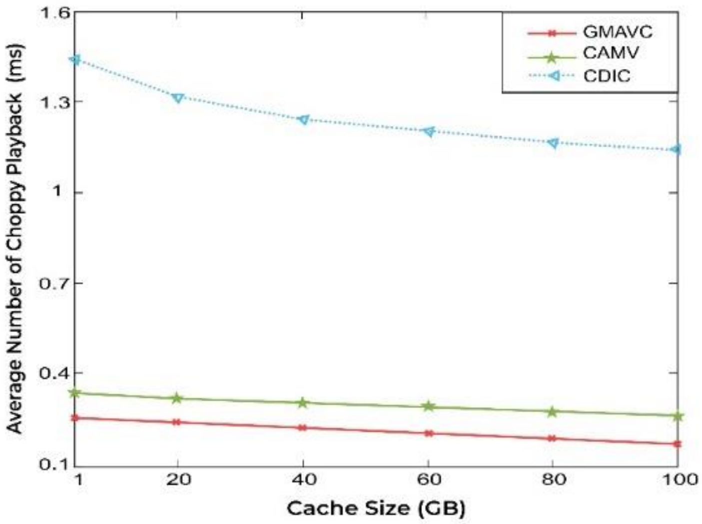


Fig. 7– Cache Size Impact on Average Retrieval Delay.

3.3.2. Cache Size Impact on Average Number of Choppy Playback

Average Number of Choppy Playback tells how adequately the approach is performing, and Fig.16 tells how average choppy playback is impacted by cache size. We used the average number of choppy playbacks (ANCP) to indicate the QoE for mobile users. We record the number of choppy playbacks each time a handoff occurs, which leads to retransmission due to packets lost if the newly connected BS does not cache the requested video; as ARD arises, it has a direct impact on ANCP. For choppy playback time, CR plays a vital role here mobile nodes; when handover occurs, nodes have to reconnect to other BS, so retransmission of packets has to start, but CR is directly connected to BSs, so packets are delivered by CR to mobile nodes. As y-axis shows ANCP, and the x-axis tells the range of cache size. If the size of the BS/CR is increased, ANCP ms will decrease. As the graph trend shows that CDIC ANCP decreased from 49 ms to 44 ms when cache size was varied from 1 GB to 100 GB, but its performance wasn't efficient due to the unavailability of CR in-between content provider and BSs As the CAMV techniques use probabilistic caching that lead to poor performance as CAMV average number of choppy playback is greater than 0.25 ms because of single-user handover technique in which when handover process occurs only one user take part in it thus packets are forwarded after the handover which causesa delay in packets and hence effects on choppy playback time. As in our approach BS cache size has not that of an impact because while handover occurs, packets are forwarded from CR. As our approach focuses on group mobility-based caching technique using ICN approach, which significantly reduced the choppy playback as in our approach, only one member takes part in the handover technique and CR cache size is increased more predicted videos can be cached. Our

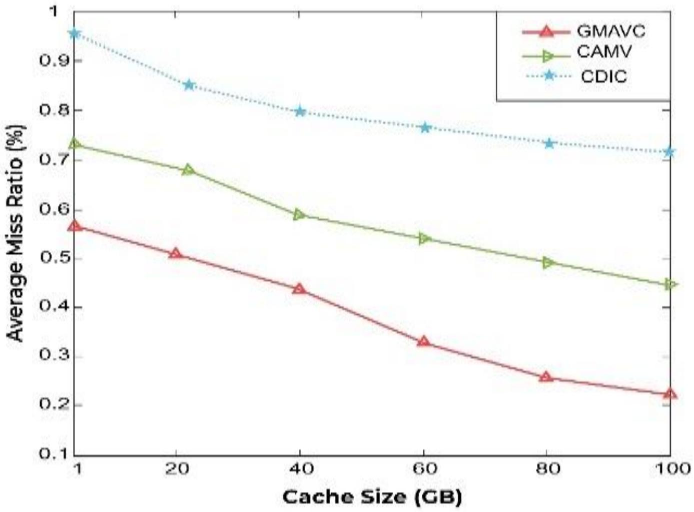


approach's minimum choppy playback time is 0.13 ms at CR cache size of 100 GB.

Fig. 8– Cache Size Impact on Average Number of Choppy Playback.

3.3.3. Cache Size Impact on Average Miss Ratio

We evaluate the proposed ICN-based caching approach's efficiency by measuring the average miss ratio (AMR). Our approach miss ratio percentage is lower than others.In Fig.17,the effect of cache size on an average miss, the ratio is illustrated. As the miss ratio shows how well the approach is caching the content and provides the content on the go for mobile users. As the graph in Fig.17 x-axis shows, the cache size in GB against the y-axis average miss ratio lower the AMR better. As the percentage decreases, the approach's efficiency increases as CDIC popularity prediction was among chunks, not the videos, so the videos' availabilitywas not good videos weren't available when requested. CAMV probabilistic functions came in the way of its efficient working and decreased its efficiency. When BS/CR cache size

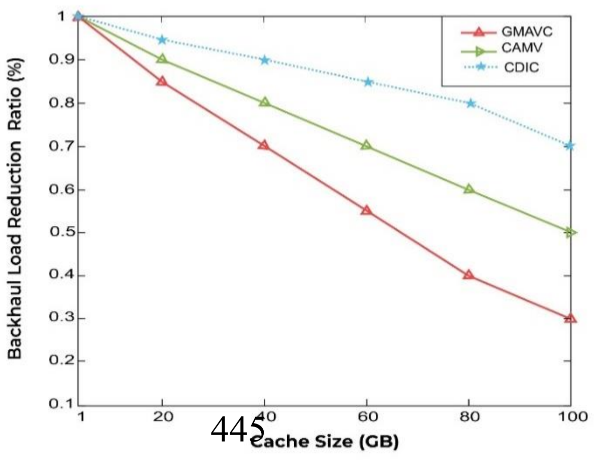


was 1 GB, the miss ratio was at 44%, but as the BS cache size increased to 100 GB it just decreased 2%, which means its average miss ratio was 44%. Increasing the size did not help too much for CAMV to perform efficiently. Whereas the 5G-ICN GMAVC approached allowed us to achieve less miss ratio and higher hit ratio rate. When GMAVC CR cache size is 1 GB average miss ratio decreased from 41% to 39%, and when Cr cache size is at 100 GB the average miss ratio decreased to 21% to 18% that means the GMAVC approach is 27% more efficient than CAMV as GMAVC feature were popularity among videos and CR to maintain QoE for a group of mobile moving between BSs and group handover to reduce the delay time.

Fig. 9– Cache Size Impact on Average Miss Ratio.

3.3.4. Backhaul Load Reduction Ratio

As ICN can reduce backhaul load, in Fig.18, the three approaches reduce load across the network. As the x-axis shows, the cache size ranges from 1 GB to 100 GB, and the y-axis shows how a particular approach has reduced much load ratio. The trend in Fig.18 shows that backhaul load was when at

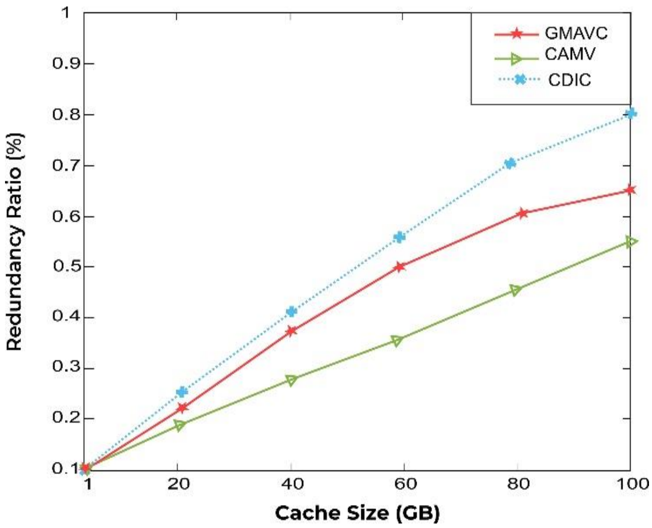


highest peak 100% CDIC load reduced 30% and it is the lowest among the techniques as its cooperation among base station wasn't doing much for the users with high mobility. When a mobile user was moving across the base station due to handover, they senta request directly to the content provider because the next base station could not cache the relevant video they wanted the historical traces and popularity threshold couldn't perform efficiently. The CAMV approach they were using least recently used so when the cache was at 1 GB to 60 GB was reducing load, but after that, the cache was caching videos but wasn't removing them because of which request was directly diverted to content provider congestion again started at the core network. As of GAMV, we used last recently in our approach, which reduced the load throughout the experiment. When the cache was being increased from 1 GB to 100 GB, congestion was being reduced throughout.

Fig. 10– Backhaul Load Reduction Ratio.

3.3.5. Redundancy Ratio Across Network

Redundancy show how many times the particular video is cached across network cache enable devices. In Fig.19 redundancy ratio of CDIC is least and GMAVC has the best performance. The Y-axis of the graph shows that the frequency of replicated content across the network, and the x-axis shows how the cache can affect it. CDIC replicated the content throughout the network because historical traces used to cache videos showed that the videos that were not needed at the current BSs were being cached at it.



CAMV's popularity threshold was too high because videos with low popularity were being cached at the CR/BS. GAMVC used a low threshold. Only videos with higher count are considered popular at the current router. Every router had its own independent popularity threshold calculator that why the redundancy of the proposed approach is better than others.

Fig. 11– Redundancy Ratio Across Network.

4. Conclusion and Future Work

4.1. Conclusion

In this modern world, video streaming is increasing day by day, and it has put a lot of pressure on the backhaul of cellular networks. So, the bandwidth required for the content is higher than ever. 5G networks have the capability to provide higher bandwidth, and in 5G networks, there is a millimeter-wave, which provides higher bandwidth inside, 5G networks and can provide high definition videos on demand. There is a slight drawback of 5G network because its base station has shorter ranges than typical 4G networks that mean there will be a lot of handovers when users are mobile. Though mobility is a critical challenge in networks, and due to this, how to maintain mobile users,QoE is also a crucial problem. Our approach is ICN based caching videos in 5G networks. In this approach, we considered user group mobility parallel to the popularity of videos to elevate the backhaul traffic load and to reduce average retrieval delay. While applying a group handover and caching videos for users who have high mobility can reduce choppy playback and average at the same time because when a user is experiencing frequent handoffs during its movement from one base station to another, it will affect the quality of video hence user's quality of experience can suffer. We evaluated our approach by performing simulations; the results showed that our 5G-ICN approach increased QoE by decreasing the average retrieval delay, choppy playback time, and average miss ratio as compared to CDIC, which is a RAN-ICN approach used in 5G networks.

4.2. Future Work

In future work, we can combine group mobility with the software-defined network to investigate further how they can affect the performance of the caching process of videos in a certain way—applying Machine or deep learning algorithms to deeply understand the popularity prospects of videos with user's mobility.

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Appendix A. An example appendix

Authors including an appendix section should do so before References section. Multiple appendices should all have headings in the style used above. They will automatically be ordered A, B, C etc.

A.1. Example of a sub-heading within an appendix

There is also the option to include a subheading within the Appendix if you wish.

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