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Global Cooperative Image Prefetching and GSA in Mobile Ad Hoc Networks

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Abstract: Prefetching the data is a popular technique that improves data accessibility in wired or wireless networks. In mobile ad hoc networks(MANET), the possibility to improve the access latency and cache hit ratio may reduce due to the mobility of nodes and only limited cache space available in mobile hosts (MHs). To eliminate this problem in wireless networks, Global Cooperative Caching(GCC) with Image Prefetching (IP) algorithm is proposed that pre-fetches the image based on similarity measurement between data items and integrated with Gateway Selection Algorithm (GSA) for increasing throughput and reducing delay in the networks. Design implementation and analysis are done using Network Simulator 2(NS2) and MATLAB tool used to calculate the performance parameters of the proposed algorithm and also the parameters are compared with GCCIP to prove that proposed GCCIP-GSA algorithm have greatly improved the system performance in terms of packet loss, delay, throughput and resource utilization compared to existing schemes. Throughput analysis shows that GSA GCCIP results 13.63% higher throughput and 31.25% reduction in latency than conventional GCCIP. The Mean Square Error(MSE) and Peak Signal to Noise Ratio (PSNR) has been evaluated for different kind of images such as cameraman, lena, and baboon. In Proposed GCCIP-GSA, 28.8%, 23.75%, and 18.66% of MSE has been reduced compared to GCCIP for three different images respectively. At that same time, 60%, 55.6%, and 50% of PNSR has been improved in proposed method than conventional method.

Keywords: Prefetching, Cooperative caching, Mobile ad hoc networks, Data mining, Association rules, Global cooperative caching with image prefetching.

1. Introduction

MANET is a continuous auto-configuring and infrastructure-less network which consists of several mobile nodes that are connected wirelessly. In MANET each node is allowed to move individually in any direction and it can change its connection to other nodes frequently in any direction. Every node in the cluster must forward traffic to other nodes even distinct to its use and therefore it acts as a router sometimes depends on network routing protocol [1]. Cache prefetching is a general technique used by most general purpose processors to increase processing speed and performance by fetching required instructions earlier or read data from their local storage from slow speed memory to a high speed local memory before it is needed for processing [2]. Most modern computer processors are provided with a fast and local cache memory in where the pre-fetched data is hold in cache memory until it is required for post-processing.

If mobile nodes in ADHOC networks perform common tasks, then the cooperative caching is a better technique [3], which allows coordination and sharing of cached data between multiple nodes which leads the way to reduce the bandwidth and energy consumption in wireless networks. Even both

caching and prefetching are well recognized for improving client perceived response time in clusters, the integration of both strategies may be exploited to improve the system performance in terms of power, energy and resource utilization. In MANET, cache missing is not an isolated events and if a cache miss occurs, that leads to more number of cache misses [4]. Due to this scenario, data mining based association rules are applied to find relationship between cached data items and hence execute the prefetching process. In the prefetching process, access to requested data is granted and the data cache is fetched before it is required. In this paper, a Global Cooperative Caching(GCC) with Image Prefetching (IP) is proposed that prefetches highly related image data based on relativity among image data items. To increase the caching performance in GCCIP, the generated caching rules are used to prefetch the image data item(s) from the client node. Mobile nodes will select the neighbour gateway for communication without considering the amount of load on the network [5-7].

The gateway buffers the data packets and increases more traffic that generates unbalancing network routing, which causes degrading network throughput performance and affect quality of service(QoS). Hence, the gateway selection method is introduced to increase the QoS performances in networks [8, 9]. Simulation is performed using both NS2 and MATLAB for evaluating the performance of this proposed algorithm under several circumstances.

Based on caching rules definitions, prefetching is performed and confidence value along with other caching parameters are used during prefetching. The remaining part of this paper is organized as follows. Section 2 briefly reviews the related studies on cache replacement and prefetching in mobile ad-hoc networks and mobile environment. Section 3 describes the proposed system. Section 4 describes the results. The conclusion of this paper is given in Section 5.

2. Related works

J Chandrashekar and A Manoharan [10] developed a routing technique, namely, Identity Based Key Management (IBKM) for providing a secure communication in MANET by implementing an efficient key generation, distribution, and verification processes. IBKM based routing mechanisms uses following stages. 1. Node registration, 2. Routing path validation 3. Key generation, distribution, and validation 4. Signature generation and verification. The routing path is authenticated in order to confirm the reliable communication between source and destination based on least hop distance. If failure occurres in the primary path, then the secondary path was selected as communication channel. The routing path is also validated by checking the link stability of the transmission path between source and destination.

M Siekkinen and A mehrabi [11] proposed the joint traffic optimization with collaborative edge caching technique based on the analysis of collaborative mobile edge caching backhaul data traffic parameters. backhaul/fronthaul traffic ratio (BFTR) parameter is introduced for routing path optimization which is adjustable by the mobile network operator. Also a bitrate selection algorithm is proposed with low complexity to solve the cache optimization. This threshold can help the edge-assisted system developers to design an efficient collaborative edge caching mechanisms for 5G mobile networks.

Wu Zhao and Zhiyong Chen [12] proposed two transmission schemes, namely Symbol-level scheme and Bit-level scheme in wireless sensor networks to improve physical layer security by utilizing the content property of cached files. In Bit-level scheme, the BS encodes the requested file with a pre-cached file to fully resist the overhearing of eavesdroppers in bit level. This significant security advantages of the proposed schemes characterize the impacts of the cache ability and network resources on the security performance.

K. Shanmugavadivu and M. Madheswaran [13] proposed a new group data caching scheme to improve data access time in MANETs called Neighbour Group Data Caching. By combining local resources of mobile nodes, data availability and data access time are improved. Cooperative caching has two major complications namely Cache resolution and cache management(CRM) in cluster. However, that does not investigate the integration of broadcasting and cooperative caching.

Chao-Chin Chou, David S. L. Wei, Jay Kuo and Kshirasagar Naik [14] proposed anonymous communication protocol called MANET Anonymous P2P Communication protocol for P2P applications in MANET. Even under selective attacks, this anonymous communication protocol maintains a high packet delivery ratio(PDR) and also it is designed as a middleware protocol between network and applications layer routing protocols. Due to cache miss, there is possibility for packet loss under selective attacks.

Sunsook Jung, Nisar Hundewale, Alex Zelikovsky [15] introduced a new approach to constraint route request broadcast that is based on

node caching. Node caching is a process where a node that involved in data forwarding and contains more recent reliable information about its neighbours than other nodes in terms of data cache and has better routing locations (e.g., intersection of multiple data routes inside clusters) than other nodes. But node caching leads to increase overall system latency.

Guohong Cao, Liangzhong Yin and Chita R. Das [16] proposed a cooperative cache-based data access (CCDA) scheme that allows mobile nodes to cache the data to reduce request delays and reduce data accessibility time. If neighbour nodes are busy, cooperative caching cannot be performed.

Dan Hirsch and Sanjay Madria [17] proposed a novel scheme that looks for distributing the storage, increased bandwidth and less energy consumption using an efficient adaptive resource caching scheme for MANET. Based on this technique, the performance analysis shows that this scheme can reduce bandwidth utilization by 36% meanwhile 79% increase in energy efficiency and a 53% reduction in memory usage. However, distributed storage requires more hardware optimization algorithms for efficient resource utilization. Bhat [18] proposed an Efficient Cache Management system using Adaptive Buffer Mechanism in mobile ad-hoc networks. In a mobile environment, consider a mobile node moves from one point of cluster to another during an ongoing application, this process leads to packet loss due to insufficient network and storage capacity which is defined in [19]. Nayyar [20] has proposed a Cross-Layer System for cluster based data access(CBDA) scheme in mobile ad-hoc networks. This new cross-layer technique is introduced to increase the performance of hybrid cooperative caching and prefetching(HCCP) schemes [21, 22]. For future research there is a necessity to introduce an efficient prefetching technique which can further improve the data accessibility time and reduce query request delay to make cooperative caching scheme better. Waleed et al., [23] proposed a survey of web caching and prefetching(WCP) techniques that play an important role in improving speed and query processing performance by monitoring web objects that to be required near future to the client. Also, Web caching can work independently or integrated with the web prefetching [24-26] has proposed a cooperative traffic transmission algorithm in a joint vehicular ad hoc Network-Long Term Evolution Advanced (LTE Advanced) hybrid network architecture that elects a gateway to connect the source vehicle to the LTE Advanced infrastructure under the scope of vehicle-to-infrastructure (V2I) communications.

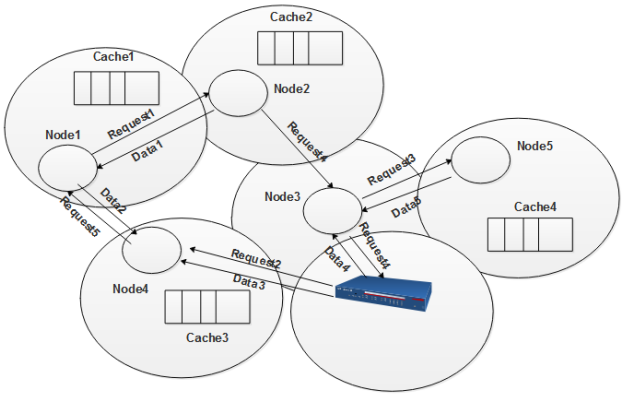


Figure.1 Caching framework in MANET

3. Proposed system

MANET consists of autonomous mobile nodes, where these nodes cooperate to exchange data by multiple-hop communication. Although each node can transmit data within a particular range, some nodes act as routers that can forward data to other nodes or receive data from other nodes. Caching can be performing individually on each node or on selective nodes to leverage cooperation. Fig. 1 shows typical model of caching framework for MANETs, in which caching nodes are controlled by server to cache contents and recover requested contents in a multiple-hop manner. A global cooperative caching(GCC) with image prefetching framework for mobile nodes is proposed in which the buffer storage of each mobile node is allocated for prefetching the data from other nodes. Each cache node has the ability to stores or log its most frequently processed image data items in their buffer.

There are some problems occurred during Caching and Prefetching in MANETs. Those are as follows. Degradation of data access or latency in query processing is due to the following reasons concerning to caching and prefetching problems:

1. Cache Access: Slows down in accessing the cache memory due to network congestion.
2. Memory constraint to store data: Memory is fixed in size, memory should be utilized efficiently to manage the data communication
3. Data overflow in prefetch memory: Data overflow from prefetch memory may occur due to prefetch memory limits leads to packet loss.
4. Cache Overflow: The contents are not stored in the cache memory due to cache memory limit.

5. Cache Data Recovery: Data loss from the cache due to vulnerable attacks to be recovered.
6. Data consistency in cache and prefetch memory: Due to huge amount of data traffic in networks, consistency should be maintained between the cache and the prefetch memory.
7. Data time stamp record: In prefetch memory, data will be discarded if the data is not utilized for certain period of time.

The proposed GSA-GCCIP scheme pre-fetches only the highly correlated data items from the local cache and considers the reliability of association rules in each node for data security. Whenever a mobile node sends a request to the server, the cache request processing(CRP) module process the request and store this request into a time stamp record and verify whether the requested data is existing in local cache of Mobile Node (MN) or in any other Mobile Node of the cluster. If a cache hit has occurred, still the cache manager has to validate the reliability of the cached item with the original copy at server. To check the validity of the cached item, CRP module checks the validity of data item presented in its local cache and if requested data item is up to date while verification, it is reverted to the requester mobile node immediately. In case, if a cache hit occurs with outdated values, the cache manager discards existing cache content from memory and sends another request to the server and waits to receive obsolete data from the particular node. When the requested data item is received from server, the cache manager forwards this data to the requester node and maintains a copy in the local cache. Due to infrastructure-less network and non-centralized control, ad-hoc network can be easily deployed in disaster areas even network has been collapsed. The GCCIP algorithm prefetches the image data that upgrades the performance of the networks without affecting QoS and throughput.

Network simulator cannot directly process image formats like JPEG, PNG or GIF. In-network simulator tool the images can be processed as hexadecimal values. For image prefetching during simulation, the image must be converted into equivalent hexadecimal values using MATLAB R2012a. These converted values are then stored in a text file and given as input in network simulator tool to perform image prefetching process. The flowchart of the global cooperative caching with image prefetching is shown in Fig. 2.

Whenever a mobile client issues a request for image data to control-server, the control-server process the request and search the requested image data into its record and checks whether the desired image data item is available in its local cache or any other mobile client in the cluster as explained earlier. When the requested image data appears, the cache manager returns it to the requester and retains a copy in the cache. In that case, if the searched image data miss occurs, the client cache manager checks the caching rule depository to derive the prefetching rules corresponding to the requested item. If this request triggers some prefetching rules, the identity of the item implied by these prefetching rules will also be piggybacked to the server along with identity of missed cache item.

2.1 Proposed algorithm

2.1.1. Global cooperative caching with image prefetching

Step 1: Cache process the request from the mobile node. The Cache will check whether the requested data is available in local or within a cluster.

Step 2: If the requested data is available then check the confidence (originality of the data such as validity) and send it to the requested mobile node

Else if the requested data is available but the validity is not satisfying the threshold level means the cache manager sends the uplink request to server. After getting the data from server it will return the data to the requested mobile node and keep that copy of data

Else

Step 3: If data is missing in the cache manager, it checks the caching rule to derive original data from the related node. Assume that the client has a cache miss, the proposed algorithm finds out the rules to find existed content in cache. Consequent of each prefetch rule along with the confidence value in a linked list of such tuple is stored. The tuples of this list are then sorted in descending order of their confidence values. If cache miss happens, the prefetch rule set is applied to generate missed cache.

Step 4: Instead of only requesting the cache miss item, the client also requests the items which are indicated in the prefetch set. When a cooperating node or server receives the request, it transfers the requested items over the wireless channel. The client downloads the items and stores them in its cache. By prefetching the items, the client can save future requests and reduce query latency.

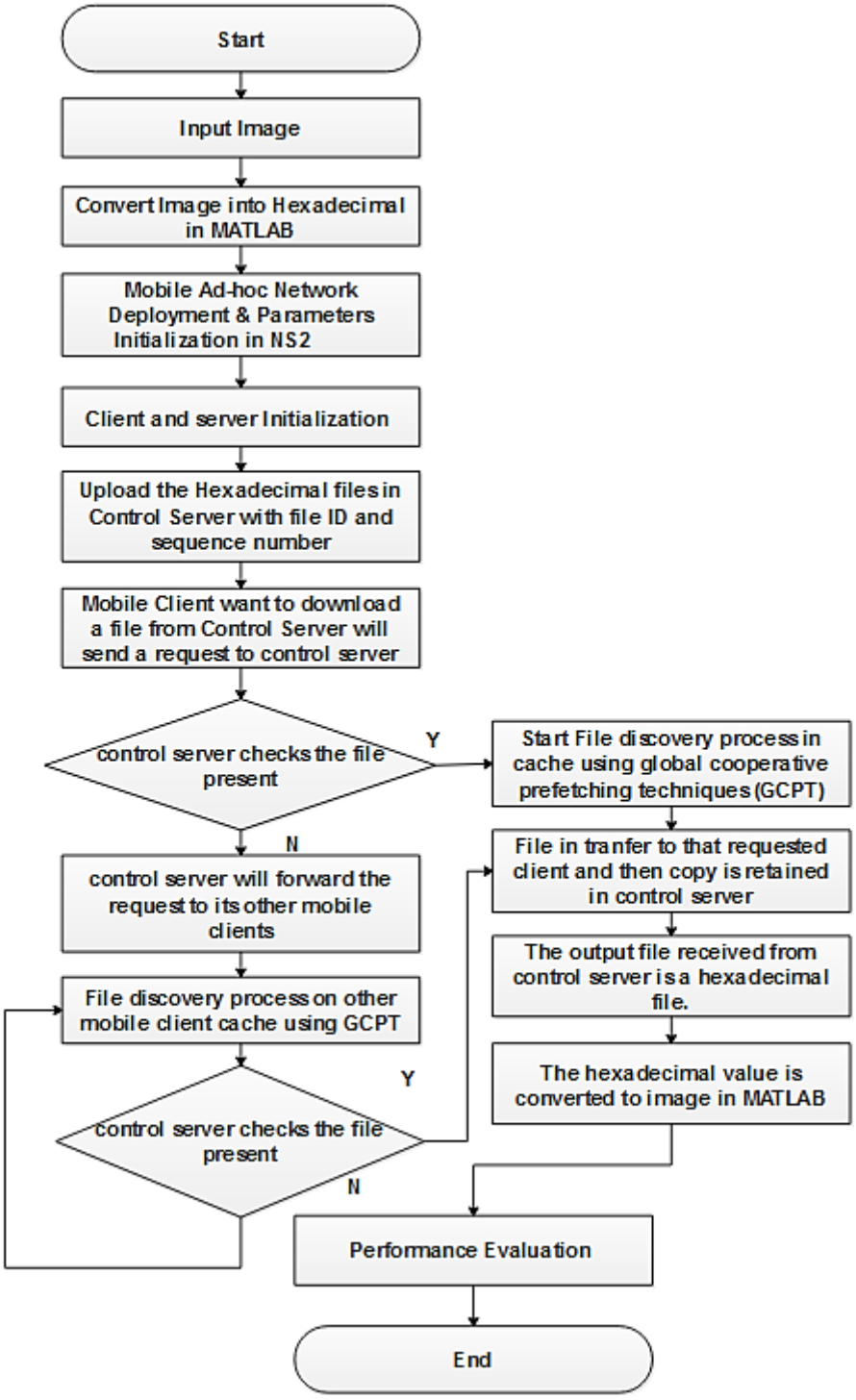


Figure.2 Flowchart of image prefetching algorithm

2.1.2. Gateways selection algorithm (GSA)

Each gateway sends a notification and advertisement message to all mobile nodes within coverage area instead of flooding packets in MANET. Therefore, mobile nodes store information in routing table about nearest gateways. When gateway exceeds threshold limit it is called heavily loaded gateways it sends a notification message to neighbour for intimate the status of gateways. After receiving notification message, mobile nodes not sending packets to same gateway and select alternate gateway for packet transmission. Also, such heavily loaded gateway not advertising for a certain period. By this way the packet loss can be reduced and it increases throughput for avoiding congestion. The selection of gateway scheme is based on the following Eq. (1).

$$Q = \beta_b B_i + B_R R_i + \beta_l L_i \quad (1)$$

Where Q indicates link quality and β denotes coefficient based on QoS metrics. B is a bandwidth for path and L is latency and R refers a reliability of the node. The maximum capacity of the gateway is Gmax and the current traffic of the gateway is represented by Gct, then the available capacity of the gateway λ_A can be calculated from Eq. (2) as,

$$\lambda_{A=} G_{max} - G_{ct} \quad (2)$$

Mobile nodes that are far away from the gateway will not directly send packets to gateways, so that the neighbour mobile node act as relay and pass the packets up to gateways. The gateway based route selection scheme exponentially increases the packet delivery ratio and reduces delay. Due to the improvement on the network the load is equally distributed and the congestion is avoided. For gateway selection in GCCIP based MANET, gateway nodes are selected from the border nodes in cluster. A border node is a mobile node that has one or more neighbours belonging to different cluster.
In Clusters, nodes are classified into four states such as

1. Clusterhead
2. Member node
3. Gateway node
4. Free node

Each node in cluster maintains a table to store details of neighbour nodes and neighbour cluster.

When a source node need to send Image data to the destination it stores the identity of that image in cache memory and send it directly to the destination if that destination node is found in its neighbour table. Otherwise the routing process is triggered to search requested image in caches of clusters globally to find the node which is pre fetched the image in its own cache.

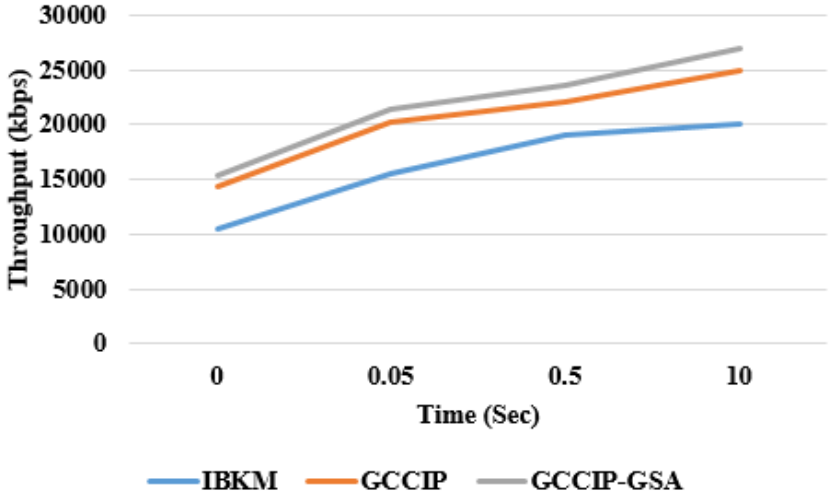
3 Results and discussion

The simulations are done using a built-in random generator in Network Simulator 2 (version NS-2.34). The protocol evaluations are based on the simulation of 50 wireless mobile nodes generating Mobile ad hoc network with mobility speed of 5m/s. For the experimental setup, the communication range between mobile node is set to 300m. The media access control layer used in this simulation is 802.11 MAC protocol and all the node movement scenarios are generated using set dest command in NS2. Initially, the images are converted into hexadecimal values using MATLAB, because in NS2 the images can be processed only in hexadecimal value format. After the conversion of image to a hexadecimal value that will be used to prefetching the data to a mobile node. Initially, a mobile node sends a requests to control server to access image data. After receiving request, the control server first checks its cache and if the requested image data is not present in the cache means it will forward the request to nearby mobile nodes. After the image data is available it will transfer to the requested mobile node and keeps the copy of that image data. The simulation parameters are tabulated in Table 1.

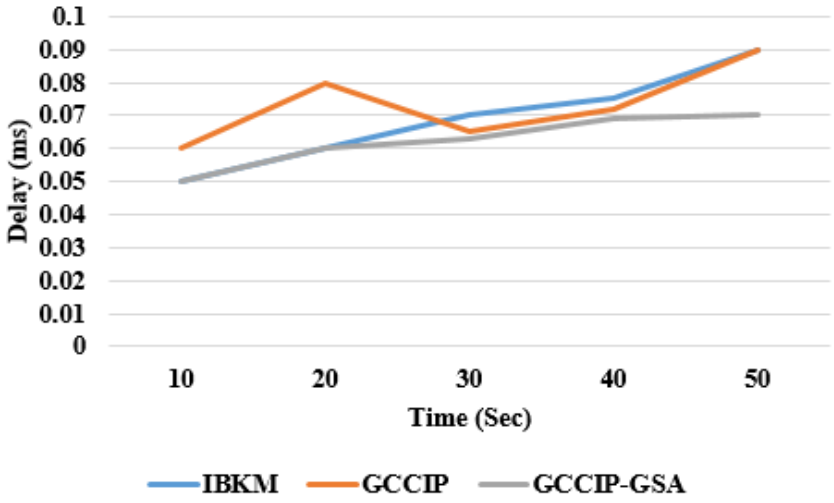
Figs. 3 (a) and (b) show the screenshot of throughput and delay. Throughput is defined as the amount of the bits received at the receiver side after the data transmission. It will be measured in bits per second(bps). The proposed prefetching technique increases throughput gradually with minimum delay because searching image data from cluster requires more time compared to binary data searching time. The proposed approach can achieve throughput of 2700Mbps whereas existing GCCIP achieved only 2300Mbps and existing IBKM algorithm achieved1700Mbps [10]. Delay is the amount of time taken to transfer the image data between the client and the server node. The proposed image prefetching technique requires 0.06ms time to transfer the data than previous cooperative caching scheme and IBKM [10] which requires 0.08ms. Fig.3(a) shows that the throughput and delay of GSA based GCCIP design is better than conventional GCCIP.

Table 1. Simulation parameters

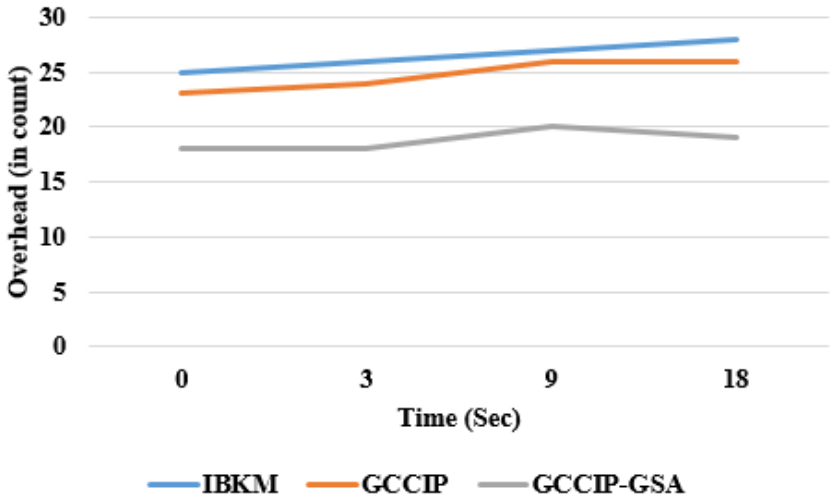
Parameter	**Value**
Channel Type	Wireless
Routing Protocol	AODV
Queue Length	50 Packets
Number of Nodes in Topography	50,75.100
Node Placement	Random
Simulation End Time	50 sec
MAC Protocol	IEEE 802.11
Packet Size	512 bytes
Traffic Type	CBR
Path Loss Model	Free Space
Energy	500J
Transmission Power	0.75
Receiving Power	0.5
Mobility	5m/s
Frequency	912mhz
Communication Range	300m



(a)



(b)



(c)

Figure.3 Simulation results: (a) throughput, (b) delay, and (c) overhead

Fig. 3 (c) shows that snapshot of overhead. Overhead means excess consumption of resources that are required to perform a specific task. The proposed image prefetching has less overhead than existing.

Figs. 4 and 5 show that comparison graph of mean square error and PSNR. MSE is computed by averaging the squared intensity of the original (input) image and the resultant (output) image pixels. The mean square error can be calculated using the Eq. (3).

$$MSE= \frac{1}{NM}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} e(m,n)^2 \quad (3)$$

Where $e(m,,n)$ is the error difference between the original and the resultant images. PSNR describe mathematical measurement of image quality based on the pixel variations between two images. The SNR is the process of estimating the quality of reconstructed image from the original image. PSNR is defined in Eq. (4).

$$PSNR=10\ log\ (\frac{s^2}{MSE}) \quad (4)$$

where s = 255 for an 8-bit image.

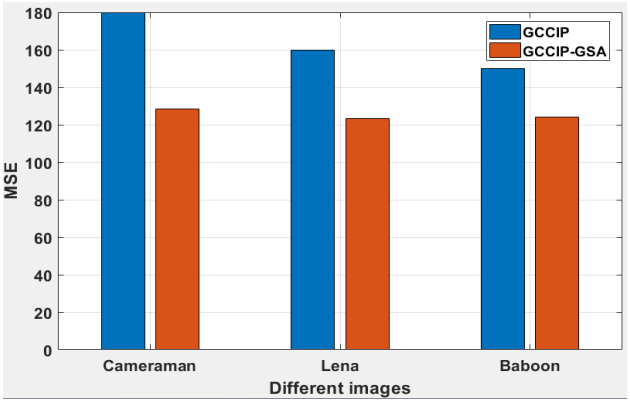


Figure.4 Mean square error (MSE)

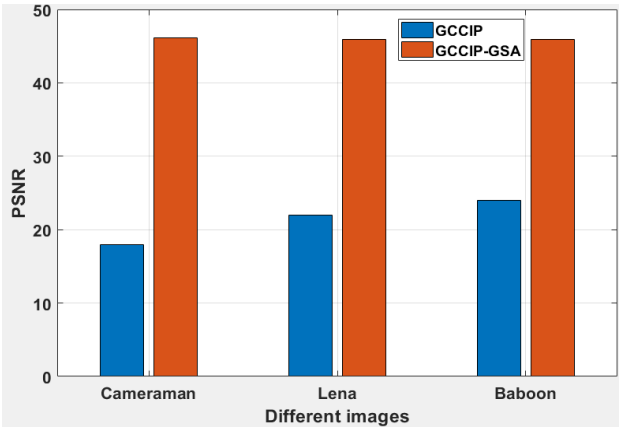


Figure.5 Peak signal to noise ratio (PSNR)

In this paper, image is transferred between nodes and it is the key element for caching and prefetching, it is required to measure image quality at receiver nodes. Here analysis of different images has been done in the MATLAB to find the values of the PSNR & MSE. Three images such as Baboon, Lena, cameraman are subjected for analysis by transmitting and receiving in MANET. From the above graphs, it is clear that MSE for GCCIP is 180 whereas it is 122 for GCCIP-GSA method for cameraman image. Also PSNR is higher in GCCIP-GSA compared to GCCIP for all the images.

4 Conclusion

From the results discussed in section 4, its showed that the Caching and Prefetching technique provides better system performance in mobile ad hoc networks by increasing throughput and reduction in delay. However, caching and image prefetching consumes more system resources such as storage, power consumption and energy. And, gateway selection process also increases throughput and decreases the delay in the networks. Thus it is very important to only prefetch the right data. In this paper, global cooperative caching and image prefetching algorithm with the selection of gateway method is proposed which improves performance and security due to caching and gateway selection in mobile ad hoc networks. Throughput analysis shows that GSA GCCIP results 13.63% higher throughput and 31.25% reduction in latency. The MSE and PSNR has been evaluated for different kind of images such as cameraman, lena, and baboon. In Proposed GCCIP-GSA, 28.8%, 23.75%, and 18.66% of MSE has been reduced compared to GCCIP for three different images respectively. At that same time, 60%, 55.6%, and 50% of PNSR has been improved in proposed method than conventional method. The proposed techniques will lead to further research work in several areas related to cache management and security against vulnerable attacks in mobile computing environments.

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