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Using Multicast Data Dissemination to maintain Cache Consistency in Location-dependent Mobile Environment

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***Abstract*—This paper addresses the problem of efficient cache replacement for maintaining cache consistency in wireless networks by considering the network environment with a server and other nodes for accessing information stored at the server. To minimize access latency in a wireless communication network, caching the server information at some of the client nodes across the network is an effective strategy. Caching may incur extra overhead cost and also disseminating information incorporates intake of additional energy and increased bandwidth. But the wireless systems are constrained by scarce bandwidth and limited energy. Thus the caching strategies are designed optimally by considering the trade-off between overhead cost and access latency. We propose a replacement policy for cache objects that uses a heuristic approach based on different parameters that improve caching performance. In this paper, we show that the on-demand broadcasts can be minimized when multicasting is used. All the clients implement the Heuristic Cache Replacement Policy that is based on the frequency of the location affinity of the user along with several other factors such as the variable data object size, temporal data updates, limited client resources, scarce wireless bandwidth and mobility of the node. Finally we prove through the experimental investigation that multicast strategy for data dissemination to maintain cache consistency in location-dependent mobile environment performs better than broadcast approach.**

***Index Terms*—Broadcast Data Dissemination (BDD), Dynamic Transmitting Agent (DTA), Protocol Independent Multicasting (PIM), Multicast Data Dissemination (MDD), Cache Replacement Policy (CRP)..**

I. Introduction

The explosive growth of mobile networks during last few years have supported enormous multimedia traffic streaming and personal communication systems, providing potential for distributing content on mobile devices such as palmtops, laptops, etc. These devices have in turn facilitated access to mobile applications like location dependent information systems, airline reservation systems, weather forecasts, traffic information systems and many more. Wireless networks can be used to provide such services, any time and anywhere. Mobile networks enable users to access the services offered by the fixed network through the server. In order to provide high quality services at low cost to the network nodes, the technical challenges such as scarcity of communication bandwidth and limited energy resources at the nodes needs to be addressed while disseminating data on the network. Caching improves system performance without increasing the complexities and cost an overall system design in a location dependent wireless environment. The strategy of storing data items at the client's local storage increases the data availability for answering queries at the client side. The efficient use of the limited bandwidth of the wireless channel thus balances the instabilities of the wireless network. An efficient cache replacement policy can have a significant impact on global network traffic and local resource utilization. The cache will perform best if the data evicted is least likely to be referenced again in the near future in a location-dependent environment. The data dissemination strategy used in this paper is based on an exclusive node in the mobile network while multicasting data, which we name as Dynamic Transmitting Agent. The rules for designating a node as DTA in multicast data dissemination are based on factors such as access rate of the mobile node, stability, level of energy of the mobile node and network distance among the nodes in the network.

If the data on a wireless network is to be transmitted to a group of the mobile users then multicasting is a reliable and effective data distribution mechanism that can provide not only scalability but also timely content delivery on the mobile network. Since it is a wireless network the mobile nodes will enter and leave the multicast group and this problem is best encountered and adjusted by the DTA node whose selection parameters are given above. In this paper we use multicasting instead of push/pull in broadcast environment to study the performance of HCRP with multicast data dissemination and associated issues. For this purpose in the scenario all the peer nodes implement a multicasting protocol (PIM). The mobile devices can efficiently carry out data transmission given the resource constraints such as limited power supplies since most of the wireless devices are equipped with batteries that are dischargeable provided a new strategy of communication is employed that takes into consideration the coordination of nodes of a particular network. The anticipation in this strategy is that although as a single node it may not be possible to work that effectively when compared to in a group. Multicasting is best suited for this scenario where the multicast group maintains a dynamic node that is labeled as a dynamic transmitting agent for the multicast group. Since the nodes in the group are mobile the DTA is dynamically elected based on the selection criteria of rules given above. There is a tradeoff between the overhead of maintaining the dynamic node (DTA) and the advantages of multicasting

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such as scalability, reliability, security issues better addressed in multicasting when compared to other scenarios such as unicasting and broadcasting. This paper gives the performance details at various layers of communication when a novel policy based on the benefits of cooperative cache management strategy in wireless multicast environment called Dynamic Data Transmission is employed that uses H-CRP on every mobile node as replacement policy.

The proposed heuristic-based caching mechanism considers several characteristics of mobile distributed systems, such as disconnection, mobility, handoff, data item update and patterns of request from a user to achieve appreciable savings of energy in mobile devices. The results of simulation carried out have shown that the eviction policy used for wireless data dissemination when cache consistency must be enforced before a cached item is used performs better than LRU-CRP in multicast environment.

The parameters considered for proposing the policy are those that affect cache performance such as access probability, update frequency, data size, retrieval delay, and cache validation cost. Also the experimental evaluation shows the performance of the H-CRP algorithm in multicast scenario that makes no packet loss and therefore provides a better performance in comparison to the on-demand broadcast scenario. The performance improvement of H-CRP over the other schemes becomes more effective when the cache validation delay shown is more.

The rest of the paper is formed in the following manner - Section II describes the related works in this area, Section III discusses the proposed system, Section IV outlines the System Architecture, Section V describes the performance metric that has been used in MDD and gives the simulation details of the model, the. Experimental results depending on the simulation model for performance evaluation. Section VI concludes the paper.

II. RELATED WORKS

The development of satellite Systems and Cellular Systems in mobile computing has become a necessity for day to day life. The wireless environments face challenges due to various constraints such as limited bandwidth and resources. Client side caching is a famous policy for dealing with the complexities of data dissemination in mobile environment. Cache replacement policies for wireless data dissemination is studied in detail in [2] which proposes a new policy namely PIX where the cached data item that has the least value of data access probability having the same broadcast frequency gets evicted from the cache. Caching in broadcast data dissemination environment have been studied in [3]. A policy with optimal updations on memory along with minimizing latency over the cache objects is given in [4] for a specified schedule of broadcast. All these studies are based on the assumption that the data objects existed with the same size without considering their updates and the possible disconnections. *SAIU*-CRP [5] was proposed for on-demand broadcast in mobile environment that was based on factors like data size, retrieval delay access probability, update frequency that are responsible for affecting cache performance but at the same time it did not consider the requirement of cache consistency. In this paper, we propose a cache replacement policy called HCRP in location-dependent mobile environment that ensures cache consistency during the communication among the mobile nodes in a multicast environment as crucial applications like financial transactions should effectively handle cache validation delays due to CRP. Another policy Min-SAUD uses a gain function based on retrieval delay, update frequency, access probability and data size to perform the page replacement. It is shown that Min-SAUD is optimal with reference to independent reference model [6]. The performance of the *Min-SAUD* policy is evaluated in on-demand broadcast scenario. The user access demands for data are best provided by usage of periodic broadcasts in wireless environment that are not meant for a specific user and are based on the information of public interest. A system that supports both broadcasting and on-demand services is termed as the wireless on-demand broadcast system [7, 10]. It uses a low-bandwidth uplink channel that is used by clients to give uplink request to the server. The server is then responsible to disseminate the requested data to the users through the same channel. To improve the system performance wireless data caching [2, 8] is required. This paper is prepared to investigate the issue of data caching in wireless multicast data dissemination environment. The objects that are delay sensitive are addressed in [12, 13]. Many Cache replacement policies have been studied in [2, 14, 15] that are based on assumptions like no updates, no disconnections and fixed data sizes which made the implementation impractical.

The traditional CRPs assumed same size for the blocks of replacement. Due to this Cache miss penalties are the same and the cache hit ratio is dependent on the access latency. The shorter the access latency, the higher is the hit ratio. So Cache hit ratio is used as a measure for evaluating CRPs. But it cannot be used as the metric of evaluation when the size of blocks is variable. In some works byte hit ratio is used as evaluation performance metric which refers to the ratio of total number of bytes found to the total number of bytes. In the on-demand broadcast environment [1] access latency and stretch [3] is used as metric. Access Latency refers to the time elapsed when a request is submitted to the time taken to service the request. Similarly stretch is the ratio of the access latency of a request to its service time and service refers to the ratio of the requested item's size to the broadcast bandwidth.

A caching strategy is used to minimize access latencies and increase data availability. Broadcast schedules are also affected by usage of caching method. Since they minimize the user requests to the server and change the access patterns of users. Also broadcast scheduling algorithms play important role in selection of caching strategies because they result in different retrieval delays for the request of similar data types. Therefore selection of the broadcast scheduling algorithm is vital to increase system performance. Many Algorithms like Longest Wait First (LWF), Longest Total Stretch first (LTSF) have been studied in [7, 9, 16].

Periodical propagation of Invalidation Report (IR) is an efficient strategy to maintain cache consistency [17, 18]. Server history of updates of w-broadcast intervals is specified in IR. An IR notifies every mobile user about the latest updates of data items. Each client listens the broadcast channel to invalidate cache data using these IRs. A mobile user should have updated data in its local cache to answer a query effectively. This is possible if the system uses IR-based Cache invalidation approaches [19].

In this paper we propose that multicasting of data is a secure and reliable strategy instead of on-demand broadcasts.

III. PROPOSED SYSTEM

A. *The Proposed Cache Replacement Algorithm*

An efficient cache replacement policy is the required key that controls the operation of cache management in location-dependent wireless environment. The existing Cache Replacement policies such as LRU is not suitable for use in location-dependent environments since it is based on caching objects that are of same size thus giving rise to same penalty of miss rates. Thus LRU do not perform well in wireless location-dependent data dissemination. In this section we give an introduction of a novel heuristic-based cache replacement policy, Heuristic CRP and the performance of proposed policy when BDD and MDD are used in location dependent wireless data dissemination.

The cache replacement is required to determine a victim set V_j in the client cache which can be evicted for accommodating the incoming data item in the jth access. A cache replacement policy makes the decision of eviction based on the factors such as little retrieval delay, high update rate, lower access probability, size of data item and the cost of cache validation.

The algorithm uses the following parameters when replacing jth data item in the user cache:

$Size_{cache}$ represents the size of user cache

B_{cache} represents the block size of user cache

$Mean_j$ represents the mean arrival rate for accessing a data item

$Update_j$ represents the mean arrival rate for updating the data item

$N_j = Update_j / Access_j$

$Frequency_j$ represents the frequency of accessing data item

S_j represents the size of data item

$Latency_j$ represents the cache validation latency of an invalidation report.

$V_{j\ represents}$ the victim page (page selected for eviction)

The cache miss penalty in the multicast environment can be computed as follows:

$$L_j = W_{coeff} + X_{delay\_DTA} + Y_{mult\_update} + Z_{network\ distance}$$

where

W_{coeff} = coefficient of the stability of a DTA

X_{delay_DTA} = delay associated for designating DTA

Y_{mult_update} = time taken by DTA to multicast the latest update to the nodes i.e access rate among the peers and

$Z_{network\ distance}$ = network distance that considers distance in networks not in plane, in place of broadcast interval where b_i represents the delay from server (cache miss rate of data object $D_{k.}$

Since it is a location-dependent environment the updates are frequent in this scenario and thus multicasting is a better solution when compared to broadcasting. The DTA constantly updates the cache in the multicast group until it is likely to leave the specific network or its energy level falls low. Therefore we confirm that if Heuristic CRP is used in multicasting data during wireless data dissemination, it performs better in comparison to On-demand broadcast as it is not only as scalable as the latter one but also even more reliable.

B. *Maintaining Cache Consistency in Multicast Environment*

The basic requirement of applications is a reliable and secure multicast that provides end-to-end reliability without any packet loss encompassing error recovery and cache consistency. Consistency check can either be from source or cache nodes. In the source initiated approach, the update status of data items is communicated through the invalidation reports to the cache nodes using broadcast strategy. The other approach works by the cache node polling the owner and identify whether its cached data item is stale. The burden of consistency maintenance is on the source node. In the source-initiated approach push operation the node pushes the update information to other cache nodes. In operation the individual cache nodes retrieve the updated data objects from the source in cache-initiated method. A stable network uses push-based strategies and guarantees consistency for users (online and reachable) but have low query latency and cannot help in providing solution for disconnection problem. Moreover if the nodes are disconnected then no information can be passed on to them and may use the stale data whenever reconnection occurs. The dynamic networks support pull based strategies but high communication overhead is incurred on message flooding. On-demand polling of the cache node takes more battery power.

We propose a hybrid and generic strategy that uses multicasting and name it as dynamic-transmitting agent-based cache consistency that encompasses the benefits of both pull and push approaches by bypassing their weaknesses. This strategy maintains strong cache consistency in location-dependent wireless environments, by making the selection of stable, highly accessible and powerful mobile hosts to transmit invalidation massages to the peer mobile nodes on the network. Each mobile node present in the network, to which the proposed strategy is applied, employs H-CRP algorithm as their cache replacement discipline.

The protocol periodically elects dynamic-transmitting agent based on the selection criteria using four parameters among the peers: 1) coefficient of access rate 2) coefficient of the stability of a node 3) coefficient of the energy level of a node 4) Network distance (considers distance in networks not in plane). A cache node becomes a DTA candidate if its coefficients satisfy a criterion and can become a DTA if it can listen to the invalidation information messages sent from the source node of its cache. And successfully obtains the approval message from the source node. In this arrangement the source mobile node pushes data and invalidation information to its peers periodically while communication between other mobile nodes and DTA is pull-based to deal with unreliable network connections. Thus, if a mobile cache node has been disconnected from the network, upon reconnection it need only poll the nearest DTA rather than polling the source mobile node to check the status of its cache.

IV. System Architecture

A. Client-Server Architecture for Wireless Infrastructure-based networks

The general client-server architecture for a mobile environment with several mobile nodes is given below:

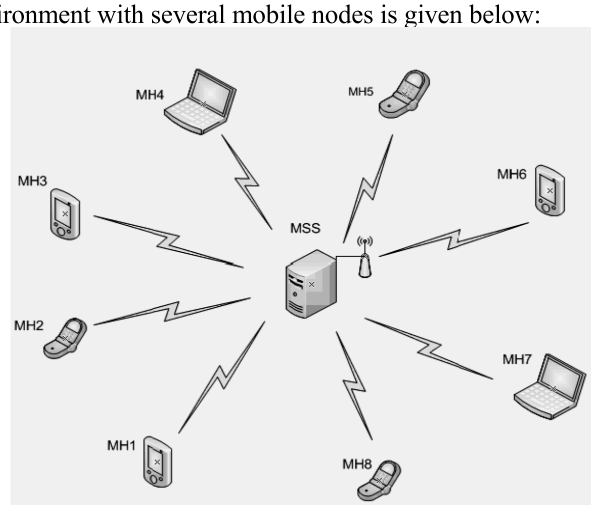

Fig. 1. Client-Server Architecture for Wireless Infrastructure based networks

B. A DTA-based Architecture to maintain Cache Consistency in Mobile Environment

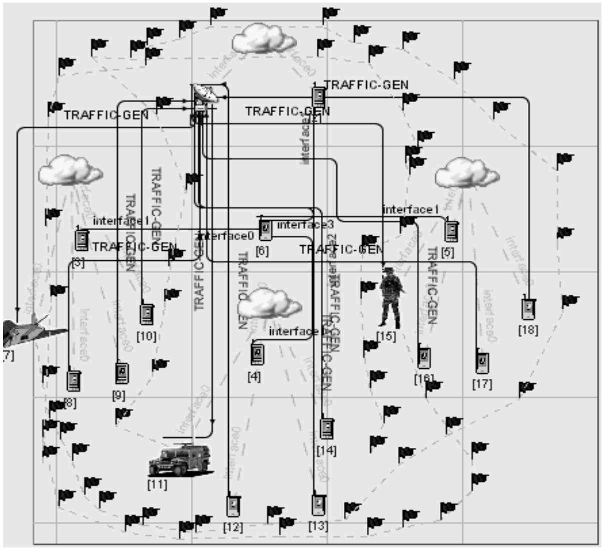

Figure 2. A DTA-based Architecture for Maintaining Cache Consistency in Mobile Environment

C. On-Demand Broadcast-based Data Dissemination to Maintain Cache Consistency in Mobile Environment

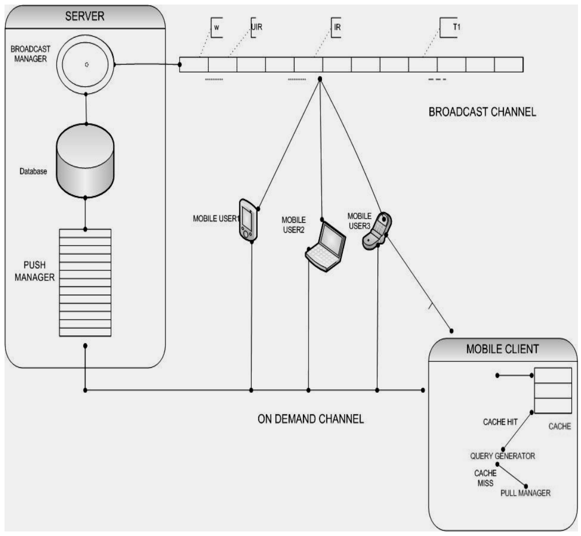

Fig 3. System Architecture for On-Demand Broadcast

In this section, we give a brief description of the existing system architecture for data dissemination in mobile environment. Figure 3 depicts the generic architecture of the wireless data dissemination systems studied so far in which the assumption is that the system employs on-demand broadcast for data dissemination. This architecture depicts On-Demand broadcast data dissemination strategy in which the clients send pull requests to the server. Through the uplink channel. In response, the server disseminates the requested data items to the clients through the broadcast channel based on a scheduling algorithm [2]. The clients retrieve the items of their interest off the air by monitoring the broadcast channel. Push-based broadcast is a common alternative to on demand broadcast for wireless data dissemination [1]. In push-based broadcast, a fixed set of data is periodically broadcast based on precompiled data access patterns. In fact, push-based broadcast can be seen as a special case of on-demand broadcast, where uplink cost is zero and data scheduling is based on the aggregate access patterns. Consequently, the result presented in this paper can also be applied to push-based broadcast. As illustrated, there is a cache management mechanism in a client. Whenever an application issues a query, the local cache manager first checks whether the desired data item is in the cache. If it is a cache hit, the cache manager still needs to validate the consistency of the cache-hit item with the master copy at the server. Thus, it retrieves the next invalidation report (see below for details) from the broadcast channel to validate the item. If the item is verified as being up-to-date, it is returned to the application immediately. If it is a cache hit but the value is obsolete or it is a cache miss, the cache manager sends a pull request to the server in order to schedule broadcast of the desired data. When the requested data item arrives in the wireless channel, the cache manager keeps it in the cache and answers the query. The issue of cache replacement arises when the free cache space is insufficient to accommodate a data item to be cached. Techniques based on Invalidation Report (IR) have been proposed to address the cache consistency issues [3, 6]. Interleaved with the broadcast data, IR's are periodically disseminated on the broadcast channel. An IR consists of the server's updating history up to w broadcast intervals (w can be a constant or a variable). Every mobile client maintains the timestamp T1 of the last cache validation. Thus, upon reception of an IR, a client checks to see whether it's Tl is within the coverage of the IR received. If yes, the client starts the invalidation process in accordance with the IR type. Otherwise, it drops the cache contents entirely (w is a constant) [3] or ignores the IR and sends its Tl to the server in order to enlarge w of the next IR (w is a variable) [6]. As in a previous study [13], in this paper we use stretch to evaluate the performance of cache replacement policies: Stretch [2]: the ratio of the access latency of a request to its service time, where service time is defined as the ratio of the requested item's size to the broadcast bandwidth. Compared with access latency, which does not count the difference in data size/service time, it is believed that stretch is a more reasonable metric for items with variable sizes.

D. Multicast-based data dissemination to maintain Cache Consistency in location dependent mobile environment

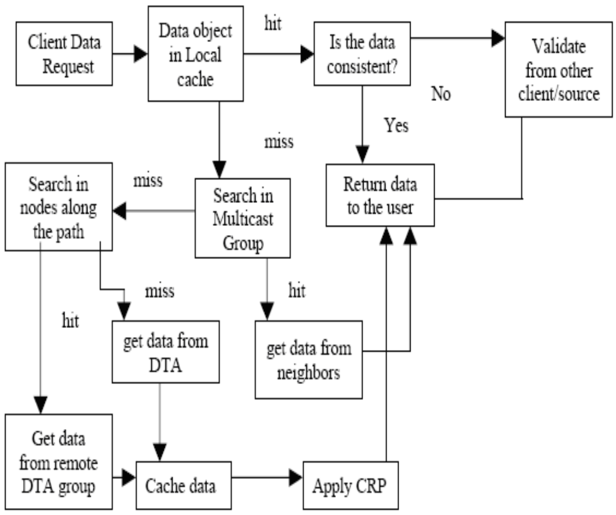

Fig 4. Flowchart of Service of a request of client using DTA-strategy

V. SIMULATION MODEL

The simulation model used for experimental evaluation is given in figure 5 and the details are outlined in section III. It is implemented using QualNet Simulator. A three cell environment is considered. The model consists of a single server and number of clients. Multicast is employed for wireless data dissemination. The default system parameter settings are specified in Table 1-4 corresponding to the parameter settings made for different components on the network for MDD. The settings corresponding to broadcast scenario are not given due to space constraints.

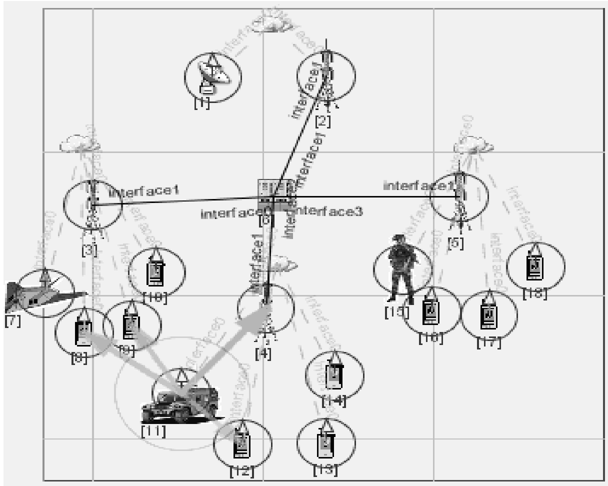

Fig 5. A Scenario depicting Multicast-based data dissemination in Location-dependent Wireless Environment

TABLE I. PARAMETER SETTINGS FOR BASE STATION & GROUND STATION (SERVER)

Parameter	Settings
IP Queue Scheduler	Strict Priority
Maximum Segment Size	512
Send Buffer Size	16384
Receive Buffer Size	16384
Enable Multicast?	NO
Mobility	FALSE
Channel Frequency	2.4GHz
Data Rate	2Mbps

TABLE II. PARAMETER SETTINGS FOR MOBILE DTA

Parameter	Settings
IP Queue Scheduler	Strict Priority
Max Segment Size	512
Send Buffer Size	16384
Receive Buffer Size	16384
Enable Multicast?	YES
Multicast Protocol	PIM
GMP	IGMP
Router List	MN1-{7,8,9,10} MN2-{11,12,13,14} MN3-{15,16,17,18}
Mobility	TRUE
Data Rate	2.4GHz
Channel Frequency	2Mbps

TABLE III. PARAMETER SETTINGS FOR SWITCH CENTER

Parameter	Settings
IPQueueScheduler Maximum	Strict Priority
Segment Size	512
Send Buffer Size	16384
Receive Buffer Size	16384
Routing Policy	Dynamic
Enable Multicast?	NO
Mobility	FALSE
Channel Frequency	2.4GHz
Data Rate	2Mbps

TABLE IV. PARAMETER SETTING FOR STATIONARY DTA (CLIENT)

Parameter	Settings
IP Queue Scheduler	Strict Priority
Maximum Segment Size	512
Send Buffer Size	16384
Receive Buffer Size	16384
Enable Multicast?	YES
Multicast Protocol	PIM
Group Management Protocol	IGMP
Router List	Node in n/w1-{7,8,9,10} Node in n/w2-{11,12,13,14} Node in n/w3-{15,16,17,18}
Mobility	FALSE
Channel Frequency	2.4GHz
Data Rate	2Mbps

A. Client Model

Each client is simulated by a mobile node and implements Heuristic Cache Replacement Algorithm given in section III. It generates a set of queries and data by Traffic Generating Protocol for data transfer on mobile networks. After the data exchange occurs, the mobile client waits for a specific period of time. During this time if it moves outside the area of base station it makes a hand off of the data to the server. Instead of this we use a multicast scenario wherein one node is designated as DTA that is responsible for making the multicast when it leaves a particular range. There is a probability for the client to enter the disconnected state and when it happens then it is updated by the other nodes about the new DTA and it can then resume into the thinking state (the state when a node is idle not transmitting data but can receive data). The time that a client the disconnected state of the client reflects an exponential distribution with a mean time. Each client has a cache of defined by S_{cache} specified in section III. An assumption that the different caching strategies, includes space needed for storing data object along with its attributes and that the client access pattern follows a Zipf distribution[5]. The data objects are sorted such that the object 0 is the most frequently used and the last object is assumed to be least frequently used. The access probability of any data object within a specified region is uniform (assuming the Zipf distribution to these regions). The default client (stationary DTA) parameter settings are given in Table 2. A summary of client activities is provided in fig 4.

B. Server Model

Table 1 gives the server (base station) parameter settings. The requests from the clients are buffered at the server using an IP Queue Scheduler that employs First come first serve scheduling algorithm (FCFS) and the buffer size is assumed to be unlimited. In FCFS the server selects the request from one end of the buffer then broadcasts it then the next one and so on. The overhead due to scheduling and request processing are assumed to be negligible at the server when compared to the data transmission delay and are not considered in the multicast-based data dissemination strategy. Data updates follow an exponentially distributed inter-arrival time for the updates at the server side. The broadcasts are done periodically from server and also all the nodes in the network form a multicast group with DTA as the group head following the parameter criteria specified in section III and then re-nominated as the different clients move from one location to another. The server activities are summarized in the flowchart given below:

C. Experiments and Results

The following section gives the comparative performance details of broadcast and multicast data dissemination when every client implements the Heuristic CRP at the different levels of OSI layers such as Physical Layer, Data Link Layer, Network Layer, Transport layer, and Application layer.

The scenario in figure 5 depicts a network consisting of 18 nodes that illustrates the MDD strategy. Among these nodes n2, n3, n5 are represented as base stations for three cells, n1 is represented as the server, Mobile DTAs are designated as a human(n15), jet plane(n7) and vehicle(n11). The rest of the nodes are stationary DTAs. The graph in figure 7(a) shows node no: on X-axis and No: of Hello packets sent on Y-Axis.(node 7,8,11, 12, 15, 16).(b) No: of hello packets received by (7,8,11, 12, 15, 16)(c) Current no: of neighbors (7,8,11,15,16). The graph in figure 8 gives the UDP packets exchanged between application layer and transport layer. The graph in figure 9(a-f) and figure 12(a-f) gives the comparative details of the data received at the client with respect to session start and end time, throughput, number of bytes and data units received, data fragmented using MDD and BDD strategies. The graphs in figure 10(a-d) and figure 11(a-d) gives the details of BDD and MDD w.r.t Physical Layer.

The scenario in figure 6 depicts a network consisting of eight nodes and illustrates the BDD strategy. Among these nodes - four function as base stations with each of them using the wireless subnet associated with them to communicate with other nodes within the network. Subnets are employed here to partition networks into logical segments as it results in a greater ease of administration. When subnets are properly implemented, both the performance and security of networks can be improved. This is the extra overhead in broadcasting. As the number of nodes is increased the complexity of the network increases and the security implementation becomes an issue. Each of the base stations is connected to the switch center which is responsible for forwarding the updates and information about the mobile nodes which are currently displaced from their home area network to all the connected stations. A switch center automatically or semi-automatically relays the network traffic. A node within one of the base stations work as a server and the clients are located in base stations other than that of the server's base station. The mobility of two of the nodes (rendered as a vehicle and a human in figure 6) is enabled so that we can track as to how the communication between the mobile nodes and the server proceed when the clients are displaced from the home area network. Here we study the effect of mobile on the communication between the server and the client. As we are trying to capture the performance of broadcast based communication downlinks are established between the server and each of its clients. The server implements the traffic-gen protocol on its application layer which is a random distribution based traffic generator. It supports a variety of data size and interval distributions and QoS parameters. Initially when the nodes are within their home area the broadcasted packets are transmitted to them through their home agent but when they are displaced the home agent encapsulates the packets into a message with address of the foreign agent inserted into destination address field. The server is also made aware of the mobile node's new care-of address by the home agent so that packets are directly destined to the foreign agent instead of home agent diverting the data to it. The figure 10(a-d) gives the signals transmitted, received, locked and received with errors by the three nodes that received the broadcast information. The number of nodes selected for broadcast being less show that the signals received with errors figure10(d) is more. But with multicast figure12(d) it is minimized since the multicast (PIM) takes care of reliable data transfer.

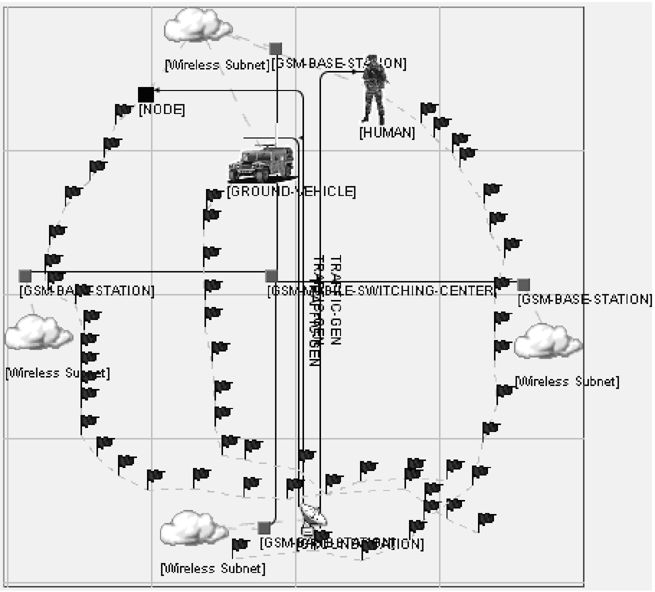

Fig 6. A Scenario depicting Broadcast Data Dissemination

VI. Conclusion

In this paper we have investigated the comparative performance of broadcast and multicast-based data dissemination in location-dependent mobile environment different from the existing work. It is shown with the help of simulation experiments that the cache replacement policy namely HCRP performs better in MDD when compared to on-demand BDD under different workloads and is appropriate for clients that need access to a definite set of data objects of any size. As an enhancement to the proposed work we are interested in giving the design of an optimal cache policy with a strong data consistency requirement in multicast scenario. Prediction techniques can be employed to obtain a better performance in location-dependent scenario. Since data caching and broadcast scheduling affect each other, we shall investigate scheduling algorithms which cooperate with client cache management schemes to achieve better performance.

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Performance Evaluation for MDD in Location-dependent Mobile Environment

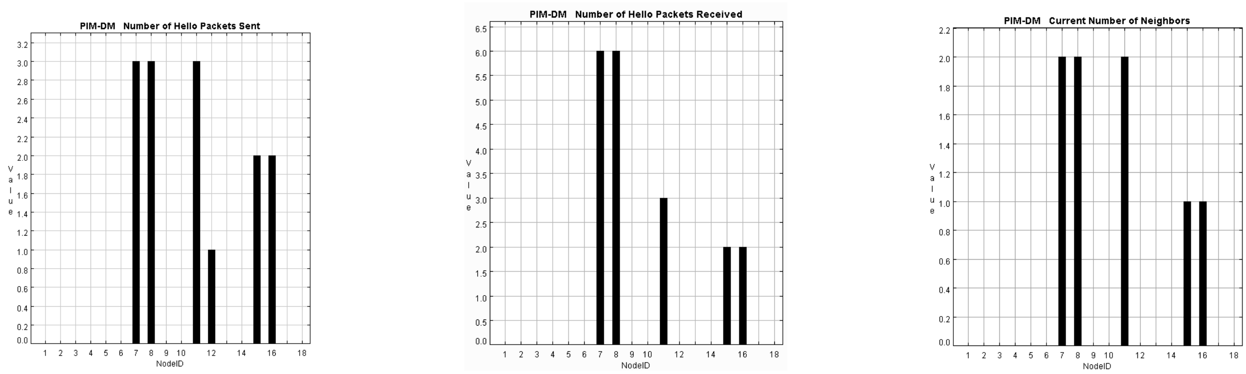


Fig. 7 Packets exchanges in MDD using PIM-DM: (a) No: of Hello packets sent(b) No: of Hello packets received (c) Current no: of neighbors

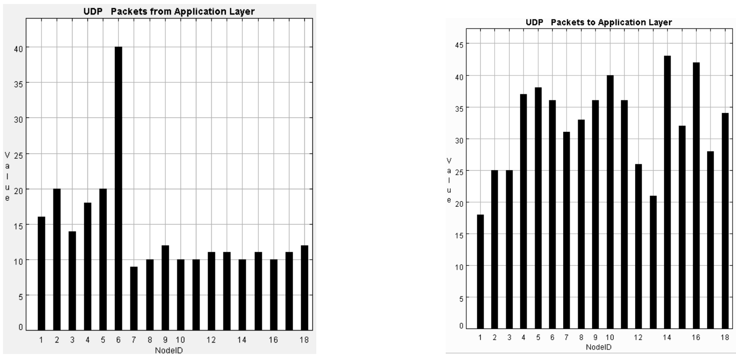


Figure 8. TRANSPORT LAYER(a) UDP packets from application layer(b)UDP packets to application layer

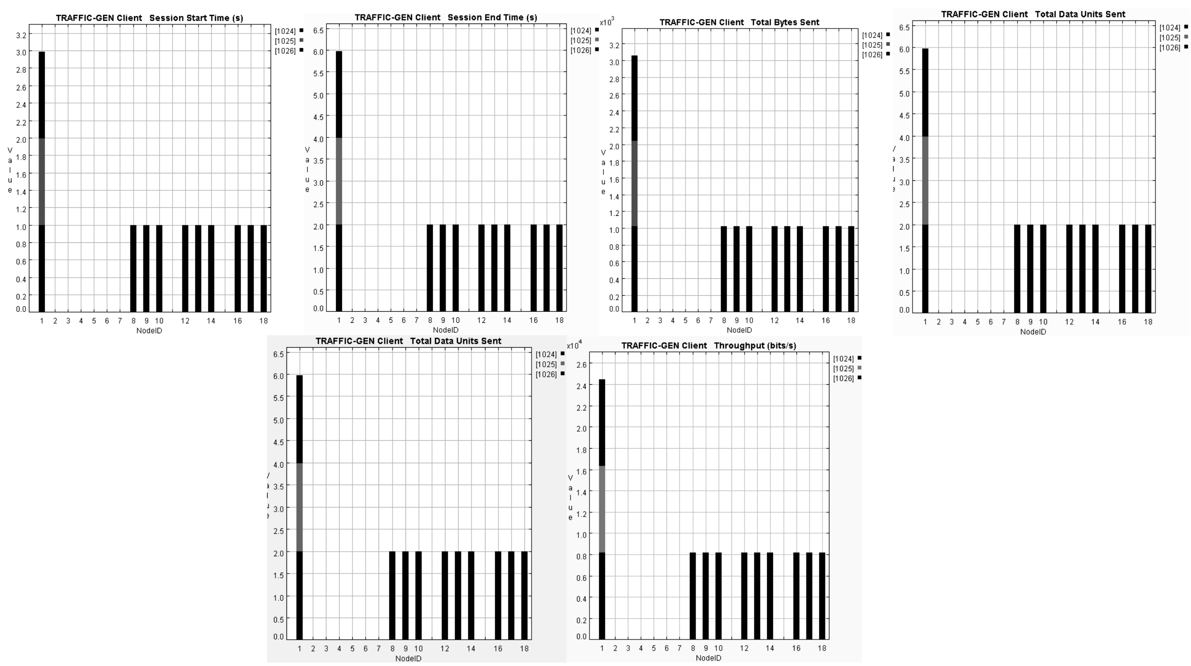


Fig. 9. APPLICATION LAYER (a) Session start time for data Exchange (in seconds)(b) Session start time for data Exchange (c)Total number of Bytes Sent (d) Client Throughput(bits/s) (e) Data Sent in terms of Data Units (f) Total Fragmented number

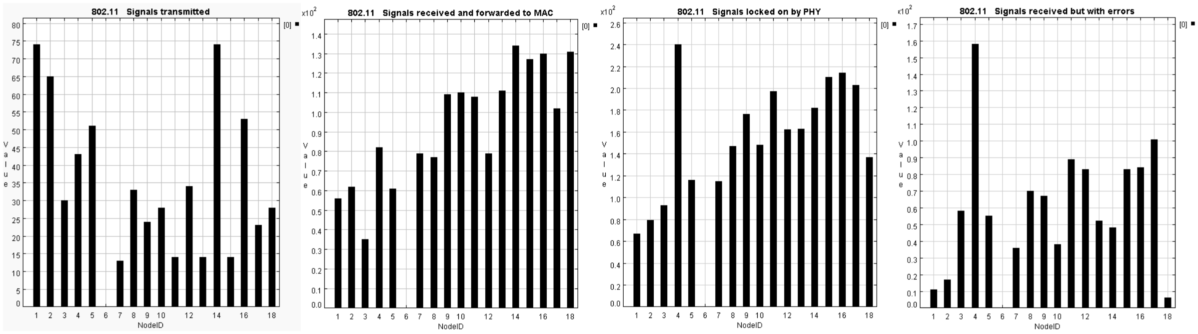


Fig. 10. PHYSICAL LAYER (a) Signals Transmitted (b) Signals locked by Physical Layer (c) Signals received and forwarded to MAC (d) Signals received but with errors

Performance Evaluation of BDD in Location-dependent Mobile Environment

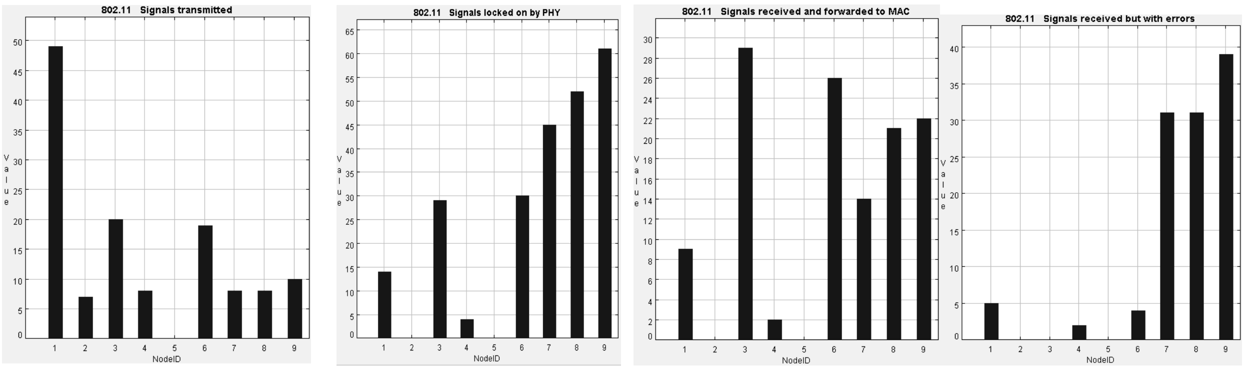
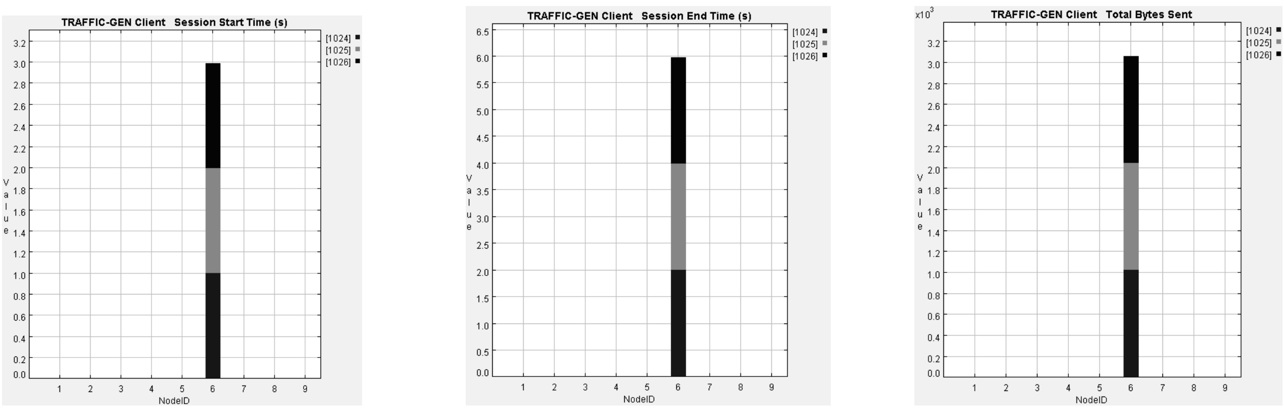


Fig. 11. PHYSICAL LAYER (a) Signals Transmitted (b) Signals locked by Physical Layer (c) Signals received and forwarded to MAC (d) Signals received but with errors



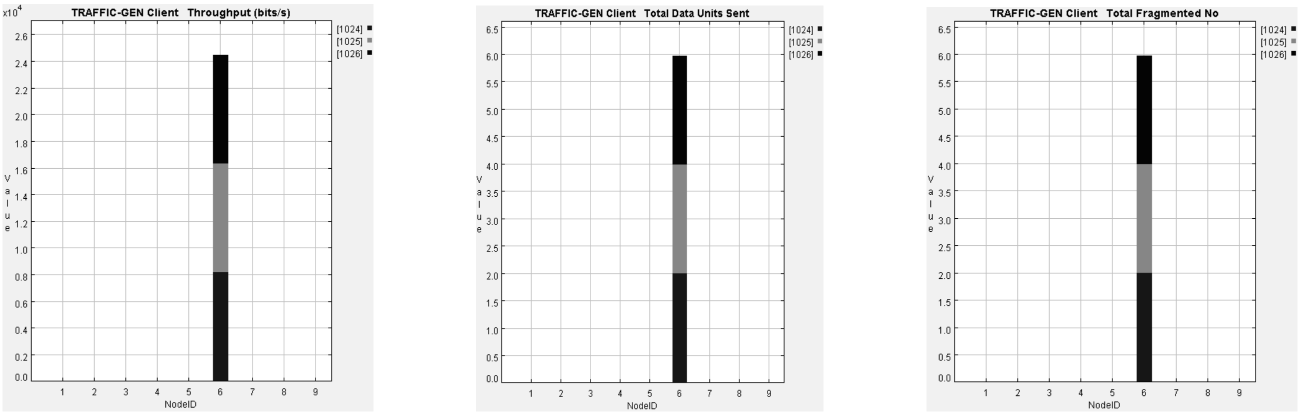


Fig. 12. APPLICATION LAYER (a) Session start time for data Exchange (in seconds)(b) Session start time for data Exchange (c)Total number of Bytes Sent (d) Client Throughput(bits/s) (e) Data Sent in terms of Data Units (f) Total Fragmented number