EENMDRA: Efficient Energy and Node Mobility based Data Replication Algorithm for MANET

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Abstract: **A mobile ad-hoc network (MANET) is a self-organizing, rapidly deployable network which consists of wireless nodes without infrastructure. All nodes in a MANET are capable of moving actively and can be connected dynamically. It is used in various applications like video conferencing, rescue operations, military applications, Disaster Management etc. So the data sharing in network play a vital role. In order to ensure the effective data sharing, the data replication is needed. The main aim of the work is to develop the efficient energy and node mobility based data replication algorithm to balance the Query delay, energy consumption and data availability in MANET. Due to the presence of the network partition, mobile nodes in one partition are not able to access the data hosted by nodes in the other partition. So the performance of data access is degraded. Existing methods aims at balancing trade-off between query delay and data availability. In proposed method we focus on balancing between the node's energy consumption, data availability and delay. By simulation results show that the proposed scheme achieves better performance than the existing methods.**
Keywords - MANET, Data replication, Query delay, Network partition data availability and energy consumption.

I. INTRODUCTION

A. *Mobile Ad Hoc Networks (MANET)*

A mobile ad hoc network (MANET) is a collection of autonomous wireless nodes that may move unpredictably, forming a temporary network without any fixed backbone infrastructure [1,2]. Since the nodes are mobile, the network topology may change rapidly and unpredictably over time. The network is decentralized, where all network activity including discovering the topology and delivering messages must be executed by the nodes it selves, i.e., routing functionality will be incorporated into mobile nodes. But data availability in MANET is reduced due to dynamic topology.

B. Data Replication

Data Replication is technique which enhances data availability by making copies of data items. Furthermore there are various issues arise in MANET which leads to problem in data replication. Replication allows better data sharing. It is a key approach for achieving high availability. It is suitable to improve the response time of the access requests, to distribute the load of processing of these requests on several servers and to avoid the overload of the routes of communication to a unique server.

C. Issues concerning data replication for MANET databases

In addition to addressing issues such as data consistency and availability that exist in traditional databases, a data replication technique for MANET databases must also deal with the following additional issues arising from constraints imposed by their specific environments and applications As discussed in [3], these are the following issues concerning data replication;

• *Server power consumption*: Servers in MANET run on battery power. Power consumption of servers that provide database management system (DBMS) services to potentially many clients should be minimized. Servers with higher power availability are expected to perform more work than those that have lower power. If a server has low power remaining and if it is replicated with many frequently accessed data items (hot data), then frequent data access requests for these hot data might drain its power soon. Servers with no power remaining would not be able to provide any more services. The replication algorithm should thus replicate data items in such a way that the power consumption of servers is reduced, and is balanced among all servers in the system.

• *Server mobility*: Servers in MANET are mobile and the speed at which the network topology changes is higher than that in conventional mobile databases. Due to their mobility, servers might sometimes move to a place where they cannot be reached by other servers or clients. The replication technique should avoid replicating hot data items in such isolated servers.

• *Client mobility*: Clients that query the servers can be mobile. Clients sometimes send their transactions to the nearest servers to get a quicker response. The decision to replicate a data item in a particular server may be based on the access frequency of that data item on that server. Clients, after issuing their requests for data access to a server, might move to new positions after a certain interval of time, and they might send their query and update requests to the nearest servers from their new locations. Hence, the access frequencies must be dynamic in nature and the decision to replicate data items in appropriate servers must also be dynamic.

• *Client power*: Client machines also run using their battery power. Some clients like PDAs are more power restricted than servers. They are limited by the amount of energy they can use before their batteries need to be recharged. A client might lose its power rapidly if it waits for its transactions results for a long time. The replication technique should be able to replicate data items in appropriate servers in such a way that client power consumption is reduced.

• *Real-time applications*: MANET applications like rescue and military operations are time-critical and may contain both firm and soft real-time transactions. Therefore, the replication technique should be able to deliver correct information before the expiry of transaction deadlines, taking into consideration both real-time firm and soft transaction types in order to reduce the number of transactions missing their deadlines.

• *Frequent disconnection of mobile hosts*: Mobile hosts often get disconnected from the network due to various factors like power failure or their mobility. In addition, some mobile users switch their units on and off regularly to save power, causing more network disconnections. Servers which hold the data cannot provide services if they are disconnected from other mobile hosts. Thus, ideally, the replication algorithm should be able to determine when a particular mobile host would be disconnected and, accordingly, replicate its data items in a different server to improve data accessibility.

• *Network partitioning*: Due to frequent disconnection of mobile hosts, network partitioning occurs more often in MANET databases than in traditional databases. Network partitioning is a severe problem in MANET when the server that contains the required data is isolated in a separate partition, thus reducing data accessibility to a large extent. Therefore, the replication technique should be able to determine the time at which network partitioning might occur and replicate data items beforehand.

II. PREVIOUS WORK

Hara [4] has developed three techniques, namely, static access frequency, dynamic access frequency and neighbor hood and dynamic connectivity based grouping, to improve data accessibility in a MANET. These techniques make the following assumptions: (i) each data item and each mobile host is assigned a unique identifier; (ii) every mobile host has finite memory space to store replicas; (iii) there are no update transactions; and (iv) the access frequency of each data item, which is the number of times a particular mobile host accesses that data item in a unit time interval, is known and does not change. The decision of which data items are to be replicated on which mobile hosts is based on the data items' access frequencies and such a decision is taken during a certain period of time, called the relocation period.

Luo et al. [5] has introduced a set of protocols (PAN—probabilistic quorum system for ad hoc networks) that use a gossip-based multicast protocol to probabilistically disseminate updates in a quorum system to achieve high reliability even when there are large concurrent update and query transactions.

Hauspie et al. [6] developed a new metric for evaluating link robustness that is used to detect network partitions without using the services of a GPS. According to this technique, the decision to replicate data items is taken not only at the time of detecting a network partition, but also during the time when the condition of the wireless connections worsen in terms of reliability, bandwidth and delay. This is because in high density networks, the connection is reliable only as long as the server is near the client as they would be separated by fewer hops. In such a case, replicating a data service on a host that is closer to the client enhances the chances of the client being able to access the data on the server.

Chen and Nahrstedt [7] proposed a distributed data lookup algorithm to address the issue of identification of data availability in MANET and a predictive data replication algorithm. This technique uses the group-based data accessibility scheme. In such a scheme, a set of mobile nodes forms a separate group and the nodes within this group collectively host a set of data items that are available for data access to all the other nodes of the group, while reducing data redundancy within that group.

D.Ratner et.al [8] proposed a Roam scheme which is a replication technique that attempts to provide data availability to mobile hosts irrespective of the mobility of the hosts. It models the mobility of hosts by grouping them into wards and determines periods of motion of the mobile hosts. Ward masters are elected to provide communication across wards, but hosts belonging to the same ward may directly communicate with each other. Roam maintains consistency of replicas across the network, irrespective of the locations of movements' different hosts. None of the above replication techniques addresses the issues related to real-time database transactions and mobile hosts' power limitation. It should also be noted that network partitioning might occur not only due to mobile hosts' mobility, but also due to battery power drainage of some mobile hosts.

Moon et al. [9] introduced an energy efficient eager replication scheme, named E-DRM (eager replication extended database state machine), that have energy restrictions and achieve data consistency across the network reducing the number of broadcast messages.

Thanedar et al. [10] have developed a replication scheme, called Expanding Ring Replication (ERR) that combines the pull-based and push-based data delivery approaches. In pull-based data delivery approach, when a node require data item, it broadcast an advertisement message that contains description of the data items required. In the push-based approach, the data server measures the frequency of requests for each data item. If frequency exceeds a threshold value set by the server for data item, the server decides to replicate the data on one or more capable nodes in the network.

Zheng et al. [11] developed that the network is clustered into several clusters and network partitions often present between clusters, especially clusters without overlap. The basic idea of CDRA (Clustering-based Data Replication Algorithm) is that the requested data object in the clusters is replicated to prevent deterioration of data accessibility at the point of network partitioning. In CDRA every cluster head maintains states of all other cluster heads in the networks. If there is no replica of the requested data in network the request is propagated from the cluster head to all other cluster heads present in the network.

Yin et.al [12] proposed caching methods that alleviate access delay and reduce traffic for data transmission. Replica relocation in these methods is different from that in this paper because these methods do not consider the mobile hosts' remaining battery power, leaving unsolved the problem that mobile hosts frequently transmitting data items exhaust their batteries in a short time.

C.K.Toh et.al [13] proposed routing protocols that select a path to the destination by considering path length and the remaining battery power of the mobile hosts on the path when a mobile host transmits data items to another host (destination). These protocols are different from our data access method proposed by Shinohara et.al [14] because these protocols discover a path to only one mobile host in the network whereas our method considers paths to multiple mobile hosts that hold the requested data items.

Hara [15] proposed a data replication technique that replicates data items based on their access frequencies and the current network topology. Hot data are replicated before cold data items. If the access characteristics of data items are similar, there could be replica duplications at many mobile nodes. Hence, two other techniques are proposed to reduce replica duplication between mobile nodes. They also detect network partitioning and replicate hot data items before such a partitioning occurs to improve data accessibility. However in those techniques, when there is a replica duplication between any two connected mobile nodes, one of the duplicate replicas is replaced by another hot data item, irrespective of how high the access frequency of the replaced data item is or how low the access frequency of the new data item is.

The paper is organized as follows. The Section 1 describes introduction about MANET, overview of DSR protocol and stale route problems in DSR. Section 2 deals with the previous work which is related to the energy consumption. Section 3 is devoted for the implementation of source initiated energy efficient algorithm. Section 4 describes the performance analysis and the last section concludes the work.

III. IMPLEMENTATION OF EFFICIENT ENERGY AND NODE MOBILITY BASED DATA REPLICATION ALGORITM (EENMDRA)

In proposed Efficient Energy and Node Mobility based Data Replication Algorithm (EENMDRA), the data sharing is affected by four issues like determination of node mobility, determination of data access, Energy consumption prediction, and design of data replication. Our proposed algorithm consists of following issues. Before entering in to issues, we have made following assumptions.

- *Primary Assistants (P)*

  These primary assistants are the original owners of data or a file. It decides with when and where to create replica including number of replicas is to be created.

- *Secondary Assistants (S)*

  These are the mobile nodes that contain replicas and also maintain data availability. It serves the customer. It can also act as a primary assistant if it is disconnected from the network.

- *Customers (C)*

  These are the mobile nodes that request or access the data. It acts as a forwarder or router when communication happens between the two assistants.

A .Determination of Node mobility

Mobility prediction may positively affect the service-oriented aspects (network level) of ad hoc networking as well as the application-oriented aspects (application level). At the network level, accurate mobility prediction may be critical to tasks such as call admission control, congestion control, reservation of network resources, pre configuration of services and QoS provisioning. At the application level, user mobility prediction in combination with user's profile may provide the user with enhanced location-based wireless services, such as route guidance, local traffic information, tourism services, on-line advertising, etc. Given that 4G and beyond wireless ad hoc and hybrid networks will support real-time multimedia applications, the need for mobility prediction is of great significance.

Node mobility partitions the network. If a mobile node moves out of range, it cannot able to provide services thereafter. If the node mobility is calculated in advance, its data can be replicated in an appropriate node to improve data availability. Before entering in to determination of node mobility some assumptions have been made in the network. Here the nodes are connected symmetrically. Thus the network is not partitioned. So the each node can measure its received signal strength. Each mobile node frequently sends some hello messages from the neighbour and also the distance is estimated. If a node is a primary assistant of a data, it collects and records the node movement of secondary assistants where secondary assistants need not be the neighbor nodes of a primary assistant. While discussed in [16], the Friss transmission equation is used to calculate the received power of a signal .It is given as,

$$P_R = \frac{P_T * G_T * G_R * \lambda^2}{(4 * \pi * d)^2} \qquad (1)$$

Here P_R= received power, P_T = transmitted power,
G_R= antenna gain of the receiver, G_T = antenna gain of the transmitter, d is the distance and λ is the wavelength [6]. Measured signal strength of successive hello message is used to estimate the mobility between two nodes.

Estimated distance between two nodes A and B is given as

$$d = k/\sqrt{P_R} \qquad (2)$$

where d is the distance and k is a constant. Now A calculates the difference of estimated distance of a neighboring node B at two successive time moments t_1 and t_2.

$$D = d_2 - d_1 \qquad (3)$$

Where D is the difference between d_2 and d_1 are estimated distance at t_2 and t_1 [17].

Threshold defines the value which is greater than the minimum transmission range and less than the maximum transmission range between two nodes P and Q. If D is equal to zero, Q is not moving away from A. If D is reaching or equal to the threshold value, Q is drifting away from P and after a particular period of time it will be out of range from P. Therefore if a node is a primary assistant and if it find any changes in D of its secondary assistant or in its neighbor nodes it has to discard those nodes and find a suitable node to hold its replica. The main next issue is the response time. It is defined as the time taken for the client to access the data from the assistants. If assistant is far away from the network, response time will be more to service the customer. This can be improved in such a way that no two neighboring nodes should have the same replica. Thus determination of mobility always replicate data one in the least neighboring node and one in farthest neighboring node so that customer can access the data from nearby assistants.

B. Data Access (DA) Method

Mobile nodes consume more power when they access data items held by other nodes than when they access their own data items because the source, destination, and relaying mobile nodes need to send and receive data items. In the proposed Data Access (DA) method, mobile nodes with little remaining battery power may replicate data items that are frequently accessed by their nearby nodes and exhaust their batteries in a short time. To solve this problem, in the Data Access method each mobile node dynamically changes the accesses from its nearby nodes because of its remaining energy. The following is the behaviour of the Data Access method when *Mi* accesses D_{fresh}, which is not held by it.

Step 1:

M_i immediately replicates D_{fresh} and finishes the procedure if it has free memory space to create the replica. Otherwise, M_i floods mobile hosts within h(≥1) hops with a data information query packet. This query packet includes M_i's host identifier and the list of data identifiers of data items held by M_i and D_{fresh}.

Step 2:

If a mobile host, M_k, receives the query packet, it transmits a data information reply packet to M_i. This reply packet includes the host identifiers of M_i and M_k, access frequencies from M_k to data items included in the query packet, and flags that represent whether M_k holds these data items.

Step 3:

If mobile node M_i receives reply packets, it calculates the following criterion for each data item,

$$\Delta_{k,l \to fresh} = \sigma(\alpha_{k,fresh} - \alpha_{k,l}) + \frac{E_k}{E_{initial}}.\lambda(\frac{A'_{k,fresh}}{U_{k,fresh}+1} - \frac{A'_{k,l}}{U_{k,l}}) \qquad (4)$$

E_k and $E_{initial}$ indicates remaining and initial amount of energy respectively. $\alpha_{k,l}$ denotes the access frequency from M_k to D_l , $A'_{k,l}$ denotes the sum of the access frequencies to D_l from mobile nodes within h hops. σ, λ are the predefined weights.

Step3:

M_i selects D_l among its own data items so that has the positive maximum value and replaces $\Delta_{k,l \to fresh}$ D_l with D_{fresh}.

At an initial state, in the data access method mobile nodes have much remaining battery energy. When the remaining battery energy decreases as time passes, the second term in the right side of equation (4) becomes smaller, and each mobile node preferentially replicates data items that are frequently accessed by itself. This can prevent mobile nodes with little remaining battery power from being frequently accessed by their nearby hosts and exhausting their batteries in a short time.

C. Energy consumption prediction

Every mobile node is battery power-driven. If power drains off, the node gets disconnected from the network. To predict the energy assume that the transmit power is fixed. As in [18], the energy required for each operation like receive, transmit, broadcast, discard on a packet is given by,

$$E(packet) = m * (packet\_size) + n \quad (5)$$

Where m and n are coefficients for each operation. Coefficient m denotes the packet size dependent energy consumption whereas n is a fixed cost that accounts for acquiring the channel and for MAC layer control negotiation. Each node has to maintain a table to record the remaining energy of its neighboring node received during the last two communication and the related communication times as in [19, 20].This data is used by the node to predict the remaining energy of the neighboring node. Assume the remaining energy, of an neighbor node at time t_A and t_B are $remenr_A$ and $remenr_B$. The determination of remaining energy of this node at time t is given by,

$$remenr = remenr_B + [(remenr_B - remenr_A) / (t_B - t_A)] * (t - t_B) \quad (6)$$

Every node has to determine the remenr by itself and send it to its neighbor and to its primary assistant. If a node is frequently accessed for a particular data its power drains off quickly and the assistant has to find an alternate node to replicate data. This lead to poor utilization of other nodes containing replicas and frequent replication creates communication overhead. To avoid this, a parameter called Access Frequency A is recorded in all the nodes which determine how many times a data is accessed. If access frequency of a node reaches a particular value say approximately 5 then it forwards the customer's request to some other node that contains the data thus saving energy. Another parameter which determines the network disconnection due to node mobility and power off is the Energy Reliability Ratio (ERR). It is given as

Energy Reliability ratio (ERR) = percentage of node remaining energy * disconnection period (7)

Where disconnection period is based on the value D that is calculated in mobility prediction. For example if the value of ERR=0.5 then link stability between two nodes is 50%.

D. Design of Data Replication

Let P_1 be the primary assistant, S_1, S_2 ,S_3 are the secondary assistants and N_1,N_2 are neighbor nodes.P_1 maintains a cache table for secondary assistants and for neighbor nodes that act as a customer or router. Periodically, the primary assistant has to check the value of R of secondary assistant. If the reliability ratio of any secondary assistant is less say 40% then primary assistant assumes that the particular assistant is going to be disconnected and search for neighbor nodes to replace the replica. If neighbor node reliability ratio is high, and if it is not a secondary assistant before, it accepts the replica. Otherwise primary assistant broadcast the request message to all the neighboring nodes to replicate data. They in turn forward the request to their neighbor nodes until a suitable node is found. After finding a suitable node primary assistant replicate data in that node and label it as one of the secondary assistants and remove the old secondary assistant from its table. If the customer wants to access the data it route a request to neighbor nodes. If any of the neighbor nodes are the assistants of that data and if the access frequency F is less than 10, the data is granted to the customer. If not the assistant, forward the request to nearby assistants to give the data. If primary assistant itself is about to move or its remaining energy is low it chooses one of the secondary assistant as primary assistant based on the Energy Reliability Ratio. From then on that assistant decides when and where to place the replicas.

IV. PERFORMANCE ANALYSIS

We use NS2 to simulate our proposed algorithm. In our simulation, 100 mobile nodes move in a 1100 meter x 1100 meter square region for 60 seconds simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR). Our simulation settings and parameters are summarized in table 1

No. of Nodes	100
Area Size	1100 X 1100
Mac	802.11
Radio Range	250m
Simulation Time	60 sec
Traffic Source	CBR
Packet Size	80 bytes
Mobility Model	Random Way Point

A. Performance Metrics

We evaluate mainly the performance according to the following metrics.

Control overhead: The control overhead is defined as the total number of routing control packets normalized by the total number of received data packets.

End-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Data Availability Ratio: It is defined as the making the copies of data items which shared by several users in a particular point of time.

The simulation results are presented in the next part. We compare our proposed algorithm with Greedy Data Replication Algorithm (GDRA) [21] in presence of node mobility and energy consumption environment.

Figure 3 shows the results of average end-to-end delay for varying the nodes from 20 to 100. From the results, we can see that EENMDRA scheme has slightly lower delay than the GREEDY DRA.

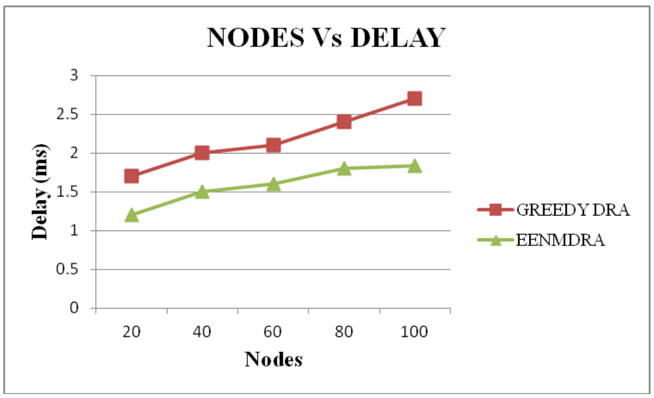

Fig. 3. Nodes Vs End to end Delay

Fig. 4, presents the energy consumption. The Comparison of energy consumption for EENMDRA, GREEDY DRA. It is clearly seen that energy consumed by EENMDRA is less compared to GREEDY DRA.

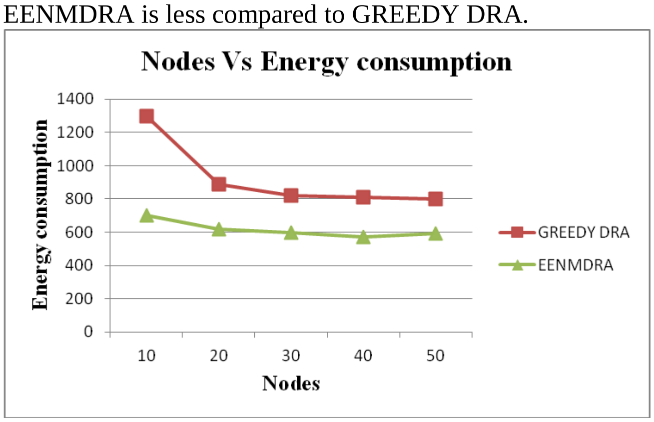

Fig. 4. No.of Nodes Vs Energy Consumption

Fig. 5, presents the comparison of overhead. It is clearly shown that the overhead of EENMDRA has low overhead than the GREEDY DRA.

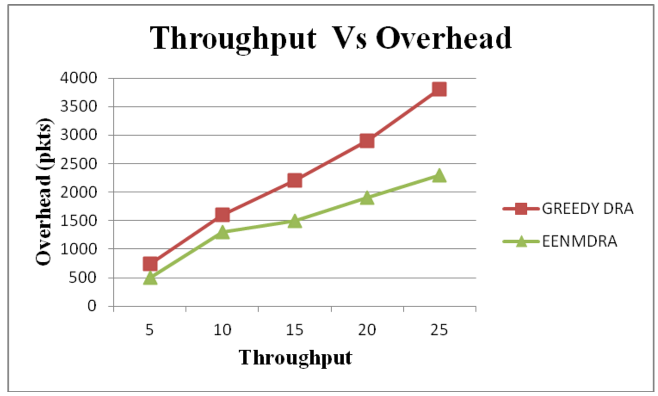

Fig. 5. Throughput Vs Overhead

Figure 6 shows the results of Mobility Vs Delay. From the results, we can see that EENMDRA scheme has slightly lower delay than the GREEDY DRA.

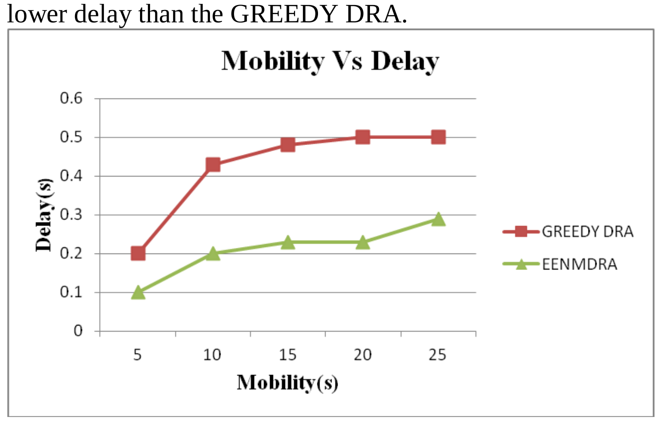

Fig. 6. Mobility Vs Delay

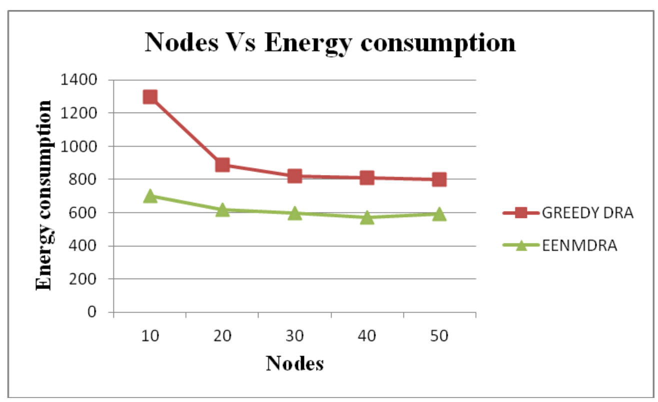

Fig.7 .Mobility Vs Energy consumption

Fig. 7, presents the comparison of total energy consumption while varying the mobility from 10 to 50. It is clearly shown that the energy consumption of EENMDRA has low overhead than the GREEDY DRA.

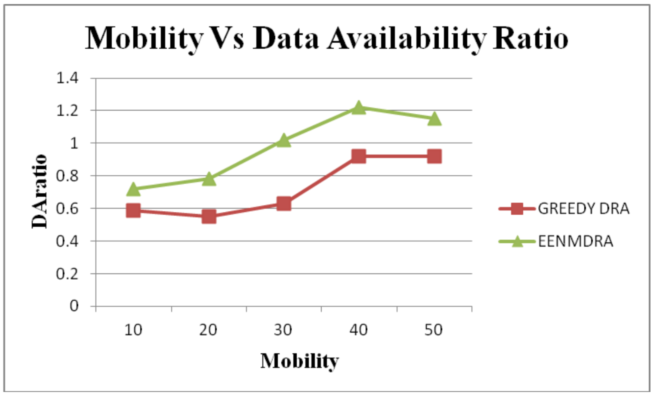

Fig.8. Mobility Vs Data Availability Ratio

Figure 8 show the results of data availability ratio for the mobility 10, 20…50 for the 100 nodes scenario. Clearly our EENMDRA scheme achieves data availability ratio than the GREEDY DRA.

V. CONCLUSION

In MANET, mobile nodes are moving randomly without any centralized administration. The replication technique makes data replication effective as it replicate data items on the basis of access frequency of data items, current network topology and stability of wireless links. It improves response time and maintained consistency. In this paper, we have developed an efficient energy and node mobility based data replication algorithm with energy consumption model which attains minimum energy consumption and provide data availability to the multiple mobile nodes whenever required. Our scheme comprises the determination of node mobility, determination of energy consumption and data replication which have been made balance between the query delay, energy and data availability. By simulation results we have shown that the EENMDRA achieves data availability ratio while attaining low delay, overhead, minimum energy consumption than the existing schemes GREEDY DRA varying the number of nodes, node mobility.

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