Energy Efficient Rectangular Indexing for Mobile Peer-to-Peer Environment

Mr. Tusharsaheb G. Patil
Student: Dept. of Computer Engineering
MET's Institute of Engineering, Bhujbal Knowledge City
Nashik, India
tushgp@gmail.com

Dr. M. U. Kharat
Professor: Dept. of Computer Engineering
MET's Institute of Engineering, Bhujbal Knowledge City,
Nashik, India
mukharat@rediffmail.com

***Abstract*—** Now a days in wireless environment there are many challenges. One of them which is need to be addressed in mobile Peer-to-Peer environment is getting the information of interest quickly and efficiently. Wherein whenever the node tries to get the desired data it has to wait too long or have to contact to unnecessary nodes which are not having their data of interest. This causes the node to waste the limited power resources and incurs more cost in terms of energy wastage. Here we proposed an energy efficient rectangular indexing called PMBR (Peer-to-Peer Minimum Bounding Rectangle) which allows the user to get the information of interest in energy efficient manner. We proposed algorithms namely PMBR_DSS, PMBR_HB and PMBR_CP and processed Nearest Neighbor & Range type queries. The experimental results carried out shows that the proposed algorithm PMBR_CP provides the efficient, quick and assured access to information of interest by saving the scarce power resources.

Keywords- *PMBR, Peer-to-Peer, Nearest Neighbour, Range Query, Energy, Index, Wireless.*

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I. INTRODUCTION

A mobile Peer-to-Peer environment is a set of ambulant nodes that communicate through small range wireless technologies like IEEE 802.11, Bluetooth, or Wi-Fi. In fact there are two types of approaches to answer the location aware services [2-3]. Particularly mobile nodes can be equipped with peer-to-peer abilities which will enable them to be a part of self-organizing and managing and easily be deployed in communication [4-6]. Recent advances in wireless networks have led to enhancement of new type of services called as Location Aware Service. These services give the answers to the user's queries not only on the based upon the data values but also the location where the query was requested. Important classes of problems in Location Alert Services are: A) Range Query: Where client gets the desired data within particular range. B) Nearest Neighbor Query: Where clients get the desired data which is closer to query point. Basically there are main two approaches to get the information desired.

- Point-to-Point : Here client will separately send the request message to server and obtains the results via Point-point channel.
- Periodic Broadcast: Here client listens to the broadcast channel and obtains the query result through broadcast channel.

In wireless environment, broadcasting the most searched and accessed data items saves bandwidth as it removes down the separate but similar responses to requests. To save the scarce power in mobile we should have some technique that will save the access time and finally the energy of the device. The basic idea to deal with this scenario is to broadcast the data having index with it that will be effective for client in listening process. Advantages of using the index will be:

1) It diminishes communication cost since client only sends the request to the desired node having information of interest and access data items through air indexing.

2) It diminishes the amount of time spent listening on the broadcast channel.

Over past years many studies have been introduced for data broadcast periodically. However these techniques had taken into consideration only distribution of reports about resources without considering insufficient resources of clients which are mobile in environment Moreover, none of had considered location based data dispersal and indexing for mobile peer-to-peer spatial queries in periodic broadcast systems. Our main objectives are: A) Present a new direction of organizing geographical information and supporting geographical queries. B) Introduce a new index method for broadcast based mobile P2P environments. C) Develop a new index search algorithms. So we extend the previous works as: 1) we proposed a new indexing scheme called as PMBR for efficient and effective access of information of interest. 2) We develop a Range Query and Nearest Neighbor Query algorithms based PMBR to support peer-to-peer geographical queries. 3) We extend the DSS to PMBR CP which outperform DSS (Distributed Sequence Scheme) in terms of access time and energy requirements.

II. LITTERATURE SURVEY

This section provide brief idea about the work done before the current proposed work. So we have discussed it here but these techniques failed to provide the satisfactory results to for the problems stated above.

A. Spatio-Temporal Information dispersal using hotspot

This proposed an approach, where a node generates spatiotemporal information of the available resources and obtains new reports in return [O.wolfson et.al. proposed][10].

A mobile node steadily receives availability reports from visited peers. Since the number of reports saved and communicated by a peer may gradually increase, the authors apply a relevance function that prioritizes the availability reports in order to limit the volume of data interchange. However this technique didn't taken into account the direct interchange of resources.

B. Indexing using Recursive tree (R- tree)

Almost existing studies on geographical search are based on indexes that store the locations of the indexed objects. One of the example of it is R-tree index. A searching algorithms based on R-tree mainly expand the search space around the query point using branch and bound approach. It requires the backtracking till it found target leaf node. Information is broadcast using a predefined sequence and it is only available when it is broadcast. Backtracking tree search incurs a serious problem for sequential access media (e.g., broadcast channel for wireless data). B. Zeng et.al explained [11]. However this technique is designed only to support traditional spatial databases and can't deployed in wireless environment as they do not consider time characteristics of air index [11-14].

C. Indexing Technique using buckets(1.m)

In traditional broadcast environment of client server mechanism minimizing the access time and tuning time are the most important issues in terms of power conservation and accurate answers. (1, m) [T. Imielinski et.al proposed] [14] is the most popular indexing scheme. In this, the index is broadcast m times during a one single broadcast cycle. The broadcast index is broadcast every fraction (1/m) of the particular broadcast cycle. Selective tuning is achieved by multiplexing an index with the data items to be broadcast. In general, the faster access time in a broadcast cycle is obtained in absence of the index, as the size of the entire broadcast cycle is reduced but this increases the time of tuning. In such a case, the average latency time is [O/2 + t] where O denotes the number of data objects and t denotes the time of download for those data objects. On the other hand addition of number of index segments in a single broadcast cycle minimizes the average probe wait3 time but increases the access time due to the additional index information.

A major pitfall of this index is the probe wait time may increase the average access time. Also it didn't consider the linear streaming property of wireless data broadcast.

D. MAPPLE Project

It is sharing based closets neighbor model. Where each node is designed for distributing the results of queries that are cached locally by clients which are mobile in nature [W.S.Ku et al. proposed] [16].

E. ESS (Exponential Sequence Scheme) Indexing

It is novel broadcast-based spatial data distribution and selective tuning algorithm that equipped clients with the ability to perform selective tuning and expedite in minimizing the clients tuning time.[17-19]. The basic idea is the use of exponential pointers from every data item. Each data object contains pointers that which accommodate the Identifiers, localities and arrival times of the data items that will be broadcast correspondingly. Each client uses an exponential pointer from every data item to reduce the energy consumption. However it is suitable only for client-server traditional broadcast environments as the server broadcasts all data items of the universe.

F. Broadcasted Spatial Index Trees for Query Processing

This technique is used for scheduling a geographical index tree for broadcasting in a single and dual channel environment. The algorithms executed by the clients which aim at diminishing the latency and tuning time. However it still supports only for traditional client-server environment.

G. Data Management in mobile peer-to-peer environment

This describes the management of database of spatio temporal information of resource in mobile peer-to-peer networks, where moving objects imparting among themselves via short-range wireless transmission technique. Several intrinsic characteristics of this environment, including the dynamic and unforeseeable network topology, the scarce peer-to-peer communication throughput, and the need for impetus for peer-to-peer cooperation, impose challenges to data management. It examines the various characteristics of mobile peer-to-peer networks such as dynamic unpredictable network topology, inadequate peer-to-peer throughput, etc. It also explains the various data models to organize the data in mobile peer-to-peer network, economical model for query processing, query processing language, validity regions and reports collected about data while moving and data dissemination.

III. SYSTEM IMPLEMENTATION DETAILS

A. Energy Conumption Models for Peer-to-Peer

Here we discuss first the energy consumption models for point-to-point and periodic broadcast mechanism and compare them in terms of energy efficiency. Let $\mathcal{E}\_r$ and $\mathcal{E}\_a$ be the energy consumption for requesting the desired information and getting back acknowledgement. Let $\mathcal{E}\_d$ $\mathcal{E}\_ds$ and $\mathcal{E}_{\_i}$ be the energy required to access the desired data through broadcast cycle, receiving the data with selective contact of nodes and to access the index to get the information of interest. Let $\mathcal{E}\_ad$ and n be the energy consumption for the summation of downloading all required data item(s) and the number of nodes of contact till the final results obtained by the client, respectively. These approaches are as described below:

- Point-to-point: Client obtains the aspiring result by contacting each node. In this method, the client send request and receives acknowledge message from N nodes (e.g., from N1 to N5). Then, the client obtains the final result from the nth node (e.g., N5). Thus, Average Energy Consumption of Point-to-Point is

$$n * \mathcal{E}\_r + \mathcal{E}\_a + \mathcal{E}\_d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

value of n affects the energy consumption significantly since the client must repeatedly sends a query and receive an acknowledgment message in return.

- Periodic Data: Here the client tunes the broadcast data items from the N nodes. Then, the client receives the final result from the N^{th} node. The average energy utilization is given by

$$n * \mathcal{E}\_ad + \mathcal{E}\_d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

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here no of data items and size hampers the energy consumption since the client must stay in active mode until it receives the information of interest.

- Periodic Index: In this method client tunes indexes and from N nodes. Then client sends the request and obtains final result from N^{th} node. Therefore the AEC is given by

$$n * \varepsilon\_i + \varepsilon\_r + \varepsilon\_d \quad ....(3)$$

IV. PEER-TO-PEER MOBILE ENVIRONMENT DETAILS

We consider the peer-to-peer model as a geometric model and represent it using 2D coordinate system.. Where these coordinates will show the locations and each node will be having limited transmission range so that it can contact to nearest neighbors. Also we have used the decentralized environment instead of centralized server as this will provide a strong access to the data over the network. The formed network typically looks like as shown in below fig. We assume the same data size and only one client is able to contact to the single broadcast channel at a time. Also to facilitate the efficient access to desired information we have classified the clients in two types as.

- **SRD (Sufficient Resource Device):** These devices are mainly those which can be provided with external electrical power source to get power so client does not have to worry about power consumption. These clients will broadcast the data items with PMBR indexes in periodic fashion. Example includes: ATMs, Information Centers, Restaurants, Banks, Cinema Halls etc.
- **IRD (Insufficient Resource Device):** These are devices which are equipped with limited power resources. So power consumption should be minimized. Therefore in this case clients will only broadcast PMBR index in periodic fashion.

A. *PMBR Index Structure*

- PMBR Index structure can be graphically represented in 2D coordinate system as below:
- Here there are total 2 PMBRs i.e. PMBR1 which accommodates thee bounded object as O1, O2, O3, O4, O5,O6 Fig. 1. PMBR Index and PMBR2 which contains the bounded objects as O4, O5, O7, O8, O9, O10.

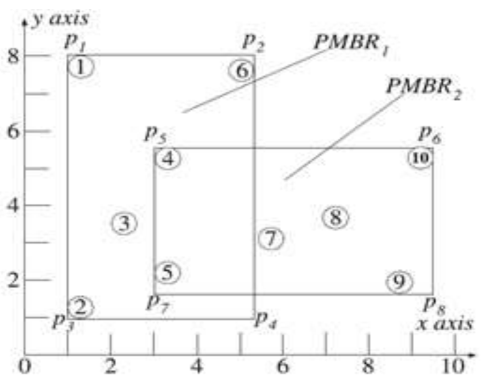
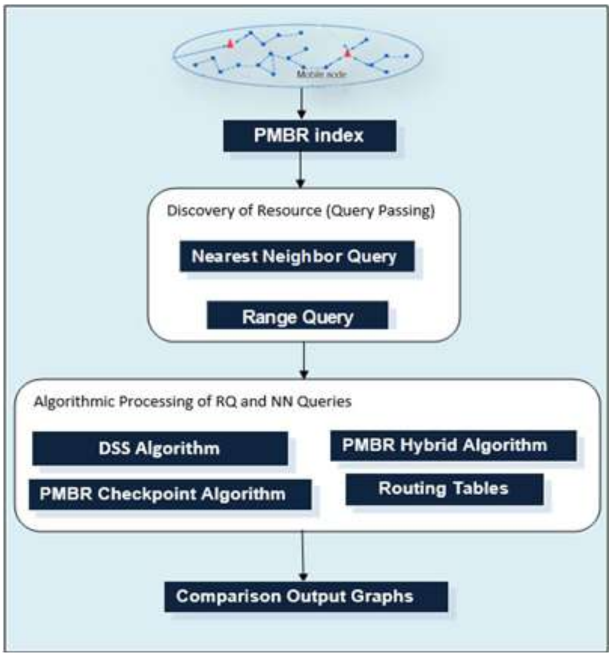


Fig. PMBR Index Structure.

- Let us consider the above fig.1 where SRD clients broadcast PMBRs as 1) PMBR1 : P1(x:1y:8), 2(x:5.3,y:8), P3(x:1,y:1), P4(x:5.3,y:1). And similarly PMBR2.

V. SYSTEM ARCHITETURE DETAILS

The system architecture as shown below contains following modules and discusses details of the same.



A. *PMBR Index Module Details*

This section explains the implementation details of the module containing the novel rectangular indexing structure i.e. PMBRs created by every node in Peer-TO-Peer environment. These PMBRs are tuned by every node whenever they need some information of their interest for their purpose or want to share the same with their neighboring nodes. PMBR facilitate this tuning using the rectangular indexing approach which contains similar object bounded within the rectangle.

B. *Range Query Processing Module Detail*

This part provides implementation details of the algorithm for range query processing. Using this algorithm user will be able to get the answers to the queries which will have constraints of range specified by him. E.g. No of ATMs available nearby in 10 KM range. Such queries are answered by using any of the three algorithms implemented here in this paper. This module incorporates the implementation of DSS, PMBR_HB and PMBR_CP (i.e. Distributed Sequence Scheme, PMBR Hybrid and PMBR Check Pointing algorithm) algorithms

C. *Nearest Neighbour Query Processing Module Detail*

This section discusses the implementation details of Nearest Neighbor Query Processing Algorithm. Whenever any user wants to share the information with its neighboring node then it can share it using this approach which facilitates the caching of information. In this case another user will get the information available easily without having repetitive contact with server. E.g. a User wants to share the information about the famous places visited in foreign countries with his friend. This incorporated the implementation of PMBR_HB and PMBR_CP (i.e. PMBR Hybrid and PMBR Check Pointing algorithm)

D. Selective Tuning Module Detail

This section explains the implementation details of Selective tuning algorithm i.e. DSS (Distributed Sequence Scheme) which will equip user with the ability to particularly tune to the selective broadcast channel to get the desired information of interest. Using this approach the user will save the time of unnecessarily contacting to nodes which are of no interest.

VI. ALGORITHMIC DETAILS OF THE SYSTEM

Here we discuss the algorithmic strategies used to implement the said system for Peer-To-Peer environment.

A. Data Distribution Algorithm

Using this algorithm we have defined and formed the boundaries of PMBR which will contain the bounded objects Also these boundaries will define the broadcast ordering about the information of the data objects. It will work as follows:

Parameters:
P = data objects located inside PMBR
D_l = data object located at leftmost extremity of the PMBR.
D_c = data object currently at leftmost extremity.
D_{c+1}: =data object a leftmost extremity but with Dc as

Exception.
X_c and X_{c+1} be the x coordinate of D_c and D_{c+1}
x-dt and y-dt be the counter values initially=0;
Input: IDs and location of D.
Output: broadcast sequence election result.
Algorithm:
1. Sort the object according to x-dimension.
2. While (P not empty)
3. For each object D in P
4. Find Dl in P, Dc = Dl exclude Dl from P // if two objects Have same x coordinate Then select upper object first.
5. For each object D in P
6. Find Dl in P, Dc+1 = Dl; exclude Dl from P.
7. If (| Xc - Xc+1|) > (| Yc -Yc+1 |) then
8. Increase x-dt
9. Else increase y-dt
10. End while
11. If x-dt > y-dt then
12. Select HB for broadcast the objects.
13. Else
14 Select VB for broadcast the objects.

B. Range Query Processing Algorithm

This algorithm provide the answers to the queries which imposes the range constraints on to the search to carry out. The details are as follows.

Parameters:
T = Set of PMBRs tuned currently, initially T=0;
C_l = leftmost cell that include or intersects the query region Qr
Cr = rightmost cell that includes or intersects the query region Qr.
S_l = sum of the objects situated at left side of Cl
S^t = St Object broadcast just before the object inside Cl
Input: PMBRs and objects contained in them.
Output: Resultant PMBRr
Algorithm:
1. Read PMBR
2. Divide it according to value of PCs
3. Find C_l and C_r
4. Check S_l and identify S^t object
5. While (PMBRr)
6. For each object O_k
7. If (x-coordinate of O_k) _ (x-coordinate of C_l) then
8. Change to doze mode until of arrives //Of is the first data
Object broadcast.
9. Else
10. While (S^t object comes)
11. Change to doze mode
12. End while
13. While (x-coordinate of O_k) _ (x-coordinate of C_r)
14. If Ok situated inside of Q_r then
15. PMBRr = $PMBR_r$ + O_k
16. End while
17. End while
18. Return PMBRr

C. Nearest Neighbour Query Processing Algorithm

This algorithm will provide answers to the queries requesting closest available data object through selective contacting. The algorithm works as follows.

Input: PMBR and data object inside PMBR.
Output: Closest Neighbor.
Algorithm:
1. Read the PMBR
2. Find CNp and draw the LBC (Least Bounding Circle)
3. While (identify CN)
4. For each $PMBR_k$
5. Read $PMBR_k$
6. If LBC contains the PMBR then
7. Selective tune to the data objects inside $PMBR_k$
8. Find CN_p and draw LBC.
9. If $PMBR_k$ contains LBC then CN_p = CN.
10. Else if T contains LBC then CN_p = CN
11. Else T + $PMBR_k$ and CN_p = CN
12. Else CN_p = CN_p skip to tune to other data objects inside
$PMBR_k$
13 End while
14. Return CN.

D. PMBR Check Pointing Algorithm

This algorithm provides the any type query (NN or RQ) result without fail. Here the client node will definitely get the answer in energy efficient manner with quick response as despite of ARD failure or other nodes not having information of interest.

Parameters:
x-dist: x distance of object inside PMBR.
y-dist: y distance of object inside PMBR.
O_{ARD}: ARD node inside PMBR.
Q: Query issued.
O_c: Closest object
Q_r: Query Result.
Input: PMBR, Query, Objects inside PMBR.
Output: Query Result.
Algorithm:
1. Read PMBR and objects inside PMBR.
2. Sort the object in ascending order of x-dist and y-dist
3. Compare x-dist and y-dist of each object with x-dist and y-dist of O_{ARD} according to PMBR boundaries.
4. Choose the closest object O_c from O_{ARD}
5. Assign checkpoint to Oc.
6. Cache the information broadcast by O_{ARD}.
7. O_{ARD} sends acknowledgement periodically to O_c.
8. Check if O_{ARD} is active and not loaded.
9. Continue caching the information
10. Else
11. O_c takes over the work of O_{ARD}
10. Send Q_r to client node.
11. Stop.

VII. EXPERIMENTAL IMPLEMENTATION DETAILS

This section provides the detailed idea of the implementation of proposed algorithm and system developed.

Experimental set up contains a local database server containing bounded objects' information with various categories used e.g. Malls, Restaurants, Hotel, Theaters and ATMs etc. This database provides necessary information to the nodes whenever accessing first time or subsequent time. The system implemented contains a network of nodes where we provide the no of nodes which communicates among themselves using broadcast approach. Then node gets the answer to its query through DSS, PMBR_HB and PMBR_CP Graphs of Energy Consumption, Success Packet Ratio and Average Access Time are drawn for all the three algorithm namely DSS (Distributed Sequence Scheme), PMBR_HB (PMBR Hybrid) and PMBR_CP (PMBR checkpoint). It shows that PMBR_HB outperforms the DSS as it does not use the R-tree approach and make effective use of caching to avoid the repeatedly contact to the server. Whereas proposed algorithm PMBR_CP outperforms the DSS and PMBR_HB as it definitely provide answers to the user's query despite of server failure. The Input & Output Processing of the system implemented is given as below.

Input: All the nodes in the network.
Processing:
- Creation of PMBRs of all the nodes network.
- Discovery of Resource (Issuing Query i.e. NN Query or RQ) through broadcast by any node.
- Selection of algorithm for getting answer to the query.
- Execution of algorithm selected.

Output: Graphs of Comparison.

I. RESULTS

We have calculated the performance of the proposed algorithm i.e. PMBR_HB (PMBR Hybrid) with PMBR DSS (PMBR with Distributed Sequence Scheme) [1]. Then we have compared these both the algorithms with our proposed algorithm i.e. PMBR_CP (PMBR Check Point). Here we have shown the results consisting of no of nodes vs access time, no of nodes vs success packet ratio and no of nodes vs average energy consumption for all the three algorithms. Also we have shown the results containing no. of request vs average access time, no. of request vs success packet ration and no. of request vs average energy consumption. Ultimately results shown below proved that PMBR_CP is most efficient in terms of time, success ratio and energy than DSS and PMBR_HB as it outperforms both the algorithms in terms of stated parameters.

First of all we give the tables of comparison where table no.1 shows the obtained values in terms of No. of nodes Vs Access Time, No .of nodes Vs Success Packet Ratio, No. of nodes Vs Average Energy Consumption.

The values obtained for average access time, success packet ratio and average energy consumption are in milliseconds, percentage and joule units.

TABLE I. EFFECT OF NO OF NODES OVER ACCESS TIME, PACKET SUCCESS RATIO AN ENERGY

Sr No.	No. of Nodes	Algorithm	Avg. Access Time	Success Packet Ratio	Avg. Energy Consumption
1	50	DSS	681.5	0.89	3822
2	50	PMBR_HB	615.5	1.09	3691
3	50	PMBR_CP	614.5	1.2	2941
4	70	DSS	811.43	0.8	7666
5	70	PMBR_HB	774.43	0.89	6552
6	70	PMBR_CP	705.43	1.2	5046
7	90	DSS	1045.16	0.6	7720
8	90	PMBR_HB	946.16	1	6842
9	90	PMBR_CP	902.16	1.2	5951
10	120	DSS	807.66	0.89	20209
11	120	PMBR_HB	822.66	1.09	11916
12	120	PMBR_CP	806.66	1.2	10368
13	130	DSS	939.66	0.89	17933
14	130	PMBR_HB	836.66	0.89	12975
15	130	PMBR_CP	813.66	1.2	10636

In table no 2 we have shown the obtained values in terms of No. of Requests Vs Average Access Time, No. of Requests Vs Success Packet Ratio and No. of Requests Vs

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Average Energy Consumption. The Tabular results are as given below.

TABLE II. EFFECT OF NO OF REQUEST OVER ACCESS TIME, PACKET SUCCESS RATIO AN ENERGY

Sr No.	No. of Requests	Algorithm	Avg. Access Time Delay	Success Packet Ratio	Avg. Energy Consumption
1	5	DSS	210.73	0.6	3572.2
2	5	PMBR_HB	202.36	0.89	2127.2
3	5	PMBR_CP	162.73	0.80	1708.6
4	10	DSS	550.46	0.89	5243.4
5	10	PMBR_HB	405.73	1.0	4254.4
6	10	PMBR_CP	325.46	1.20	3607.2
7	15	DSS	911.19	1.0	7037.59
8	15	PMBR_HB	575.99	1.05	6381.59
9	15	PMBR_CP	488.19	1.066	5295.79
10	20	DSS	883.93	1.05	14449.8
11	20	PMBR_HB	905.46	1.08	8508.8
12	20	PMBR_CP	650.93	1.099	4836.4
13	25	DSS	1425.66	1.08	11528.0
14	25	PMBR_HB	813.66	1.099	10636.0
15	25	PMBR_CP	536.83	1.11	9966.0

Secondly we have shown graphs of comparison which are calculated for the same parameters stated above in the table no.1 and table no.2. Graphical comparison is as given below.

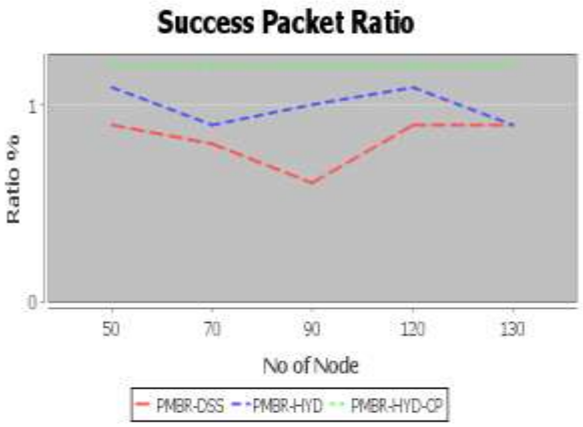


Fig. 3 (a) No of nodes Vs Success Packet Ratio

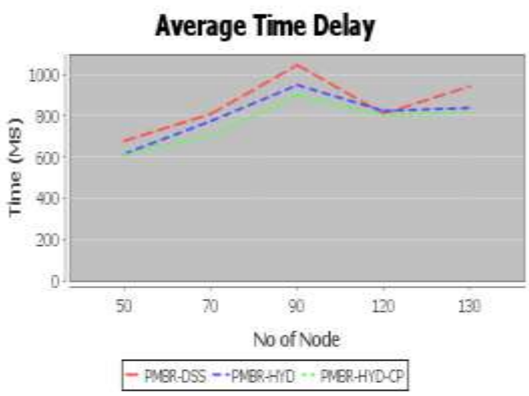


Fig. 3 (b) No of nodes Vs Average Access Time Delay

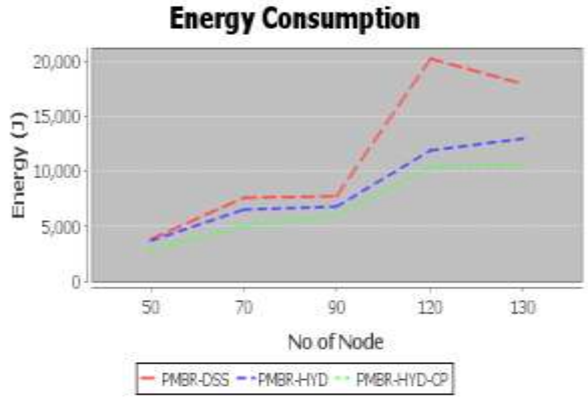


Fig. 3 (c) No of Nodes Vs Average Energy Consumption

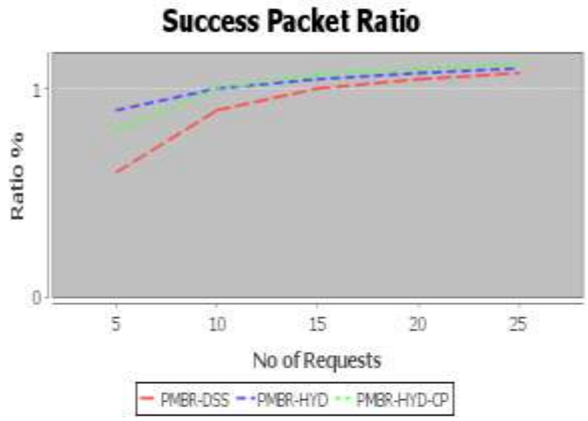


Fig. 4 (a) No of Requests Vs Packet Success Ratio

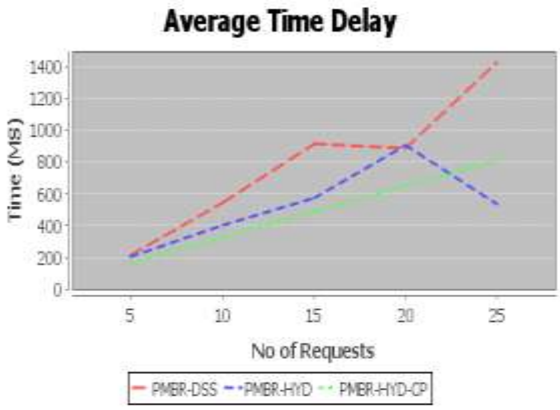
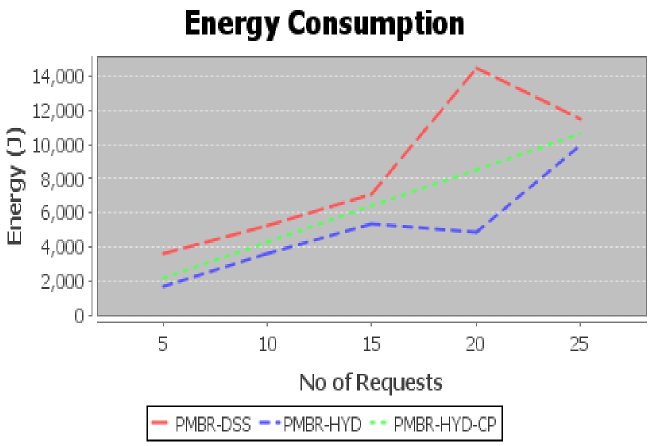


Fig. 4 (b) No. of Requests Vs Average Access Time Del



CONCLUSION

We developed a system which works for peer-to-peer environment to provide the desired information for the user without fail and with energy saving approach. This system provides the peer-to-peer environment the flexibility which provides the information of interest to intended client by avoiding the contact with unnecessary nodes. To contact to particular node using selective tuning approach this system uses a powerful rectangular PMBR indexing which itself shows the intelligence of the system to provide the desired information without hurdle and saving the scant resources. The PMBR_CP (PMBR checkpoint) algorithm which is more efficient in terms of energy, access time, tuning time and packet success ratio. Where client by any way will definitely get the answer for its query without fail as the information of interest will always be available at check point node despite of ARD failure, down or busy due to overload.

FUTURE SCOPE

This developed work can be extended in future to support the dynamic objects' searching. It means we will be able find out the answers to queries which will involve the constraints on objet which will be dynamic in nature. We will be able to find out the answers for queries like e.g. Find out the no of trains pass by me in next 10 mins. In future answers to such queries stated above will be more advantageous in terms of getting the information about the dynamic object in advance.

ACKNOWLEDGMENT

This developed work is based on "Energy Efficient Data Access in Mobile P2P Networks", Kwangjin Park and Patrick Valduriez, IEEE knowledge and data engineering, vol 23, no.11,pp. 1619-1634, 2011. An approach is developed to implement the methodology suggested by [1] as a dissertation of M.E. As a contribution a novel algorithm is implemented to make the system energy efficient.

REFERENCES

[1] Kwangjin Park and Patrick Valduriez, "Energy Efficient Data Access in Mobile P2P Networks," IEEE knowledge and data engineering, vol 23, no.11, pp. 1619-1634, 2011.

[2] B. Xu and O. Wolfson,Data Management in Mobile Peer-to-Peer Networks, Proc. Second Intl Workshop Databases, Information Systems and Peer-to-Peer Computing (DBISP2P), pp. 1-15, 2004.

[3] Z. Huang, C.S. Jensen, H. Lu, and B.C. Ooi, Skyline Queries against Mobile Lightweight Devices in MANETs, Proc. Intl Conf. Data Eng. (ICDE), p. 66, 2006

[4] K. Aberer, A. Datta, M. Hauswirth, and R. Schmidt, Indexing Data Oriented Overlay Networks, Proc. 31st Intl Conf. pp. 685-696, 2005

[5] J.X. Parreira, D. Donato, S. Michel, and G. Weikum, Efficient and Decentralized PageRank Approximation in a Peer-to-Peer Web Search Network, Proc. 32nd Intl Conf. pp. 415-426, 2006.

[6] K.C.K. Lee, W.-C. Lee, J. Winter, B. Zheng, and J. Xu, CS CacheEngine: Data Access Accelerator for Location-Based Service in Mobile Environments, Proc. ACM SIGMOD Intl Conf. Management of Data, pp. 787-789, 2006.

[7] D.L. Lee, W.-C. Lee, J. Xu, and B. Zheng, Data Management in Location-Dependent Information Services: Challenges and Issues, IEEE Pervasive Computing, vol. 1, no. 3, pp. 65-72, July 2002.

[8] J. Zhang, M. Zhu, D. Papadias, Y. Tao, and D.L. Lee, Location- Based Spatial Queries, Proc. ACM SIGMOD Intl Conf. Management of Data, pp. 443-454, 2003

[9] B. Zheng, J. Xu, W.-C. Lee, and D.L. Lee, Grid-Partition Index: AHybrid Method for Nearest-Neighbor Queries in Wireless Location Based Services, Intl J. Very Large Data Bases, vol. 15, no. 1, pp.21- 39,2006

[10] O. Wolfson, B. Xu, and H. Yin, Dissemination of Spatial-Temporal Information in Mobile Networks with Hotspots, Proc. Second Intl' Workshop Databases, Information Systems and Peer-to-Peer Computing (DBISP2P), pp. 185-199, 2004.

[11] O. Wolfson, B. Xu, and H. Yin, Dissemination of Spatial-Temporal Information in Mobile Networks with Hotspots, Proc. Second Intl' Workshop Databases, Information Systems and Peer-to-Peer Computing (DBISP2P), pp. 185-199, 2004.

[12] B. Zheng, W.-C. Lee, and D.L. Lee, Spatial Queries in Wireless Broadcast Systems, Wireless Network, vol. 10, no. 6, pp. 723-736, 2004.

[13] K. Park, M. Song, and C.-S. Hwang, Continuous Spatial Queries via Wireless DataBroadcast, Proc. Symp. Applied Computing (SAC), pp. 78-82, 2006

[14] K. Park, M. Song, K.-S. Kong, S.-W. Kang, C.-S. Hwang, K.-S. Chung, and S.Y. Jung, Effective Low-Latency K-Nearest Neighbor Search via Wireless Data Broadcast, Proc. Intl Conf. Database Systems for Advanced Applications (DASFAA 06), pp. 900-909, 2006

[15] T. Imielinski, S. Viswanathan, and B.R. Badrinath, Energy Efficient Indexing on Air, Proc. ACM SIGMOD Intl Conf. Management of Data, pp. 25-36, 1994.

[16] W.-S. Ku, R. Zimmermann, C.-N. Wan, and H. Wang, MAPLE: A Mobile Scalable P2P Nearest Neighbor Query System for Location Based Services, Proc. Intl Conf. Data Eng. (ICDE), p. 160, 2006.

[17] K. Park and C.-S. Hwang, Client-Side Caching for Nearest Neighbor Queries, J. Comm. and Networks, vol. 7, no. 4, pp. 417- 428, 2005.

[18] K. Park, M. Song, and C.-S. Hwang, Continuous Spatial Queries via Wireless Data Broadcast, Proc. Symp. Applied Computing (SAC), pp. 78-82, 2006.

[19] K. Park and H. Choo, Energy-Efficient Data Dissemination Schemes for Nearest Neighbor Query Processing, IEEE Trans. Computers, vol. 56, no. 6, pp. 754-768, June 2007.