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Communication Cost of Content-Aware Mobile Database with Different Caching Approaches for M-Commerce Applications

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Abstract

In recent years, mobile computing technology has advanced so that users can carry the portable computers to access information from the network even when they are moving. In such a mobile environment, a personal communication service (PCS) network must keep track of the location of each mobile user in order to correctly deliver calls. Thus, the cache patterns for the M-Commerce applications are with the characteristics of Location-Awareness and Content-Awareness. A basic scheme used in the standard protocols is to update the location of a mobile user whenever the mobile user moves to a new location. Thus, the communication cost of location update operations increases rapidly as the mobility of the devices arises. In recent years, some caching approaches and management strategies for location updates have been proposed. However, the communication cost of the proposed approaches is an important issue needed to be investigated. Though data replication could reduce the communication cost for accessing information, the communication cost for maintenance/operation would increase. Thus, in this paper, three caching approaches, i.e., index caching, judicious caching, and pre-fetch caching, are studied and the communication cost for a content-aware mobile database with the caching approaches is evaluated by using analytical method and simulation study. The results of this study show that the communication cost of the pre-fetch caching is less than those of judicious caching and index caching with the penalty of some communication cost of database maintenance and update operations.

Keywords: communication cost, content-aware, database, mobile commerce.

1. INTRODUCTION

The goals of wireless communication technology are to eliminate the limitation of time and space, so that users can roam and access information from networks. However, several issues such as bandwidth, instability and accidental disconnection of communication should be resolved. On the other hand, information delivery services in wireless environment cannot meet the requirements of end users due to mobility. Moreover, when clients use mobile devices or Personal Digital Assistants (PDA) for a long time or access large quantity of data, power consumption is an another problem. So, to support efficient data access and to reduce communication cost by employing an effective data management framework is a critical issue. So, an effective mobile database framework that can reduce communication cost is explored in [1].

The objective of wireless technology is to eliminate the restrictions of time and space. In a wireless network mobile devices may frequently access to a comprehensive range of information [2]. Thus, a lot of E-commerce applications have been developed in recent years. With this concept applied to wireless technology and devices, M-Commerce has rapidly become an integral part of E-commerce. Some studies show that M-Commerce that is represented by commercial products and services derived from portable and wireless devices will dominate the commercial field and daily life [3-5]. M-Commerce is preferred to users due to the following reasons. Firstly, it adopts a mobile (or Location-Aware) database [6]. Secondly, the database is Content-Aware. In this paper, the communication cost of a Content-Aware mobile database with different caching approaches for M-Commerce applications are investigated. The three approaches are index caching, judicious caching, and pre-fetch caching. For the index caching the communication cost of database maintenance is low but access delay is obviously large. On the other hand, the pre-fetch caching can support quick access to data but it requires memory to store the pre-fetched data. However, the update of the pre-fetched data will introduce some communication cost for this approach. To trade-off the quick access and communication cost, the characteristics of these caching approaches should be investigated, so that a better scheme for caching data in a mobile content-aware database may be developed. The aim of this paper is to explore and compare the characteristics of these caching approaches. Moreover, a simulation study is conducted to validate the analytical results.

The rest of the paper is organized as follows. Section 2 presents the related work. In Section 3, the three caching approaches are discussed. Section 4 addresses the simulation study. Section 5 summarizes this paper.

2. RELATED WORK

In the Section, the related work for mobile commerce applications, mobile databases and content-aware services is presented as follows.

2.1 Mobile Commerce Applications

Three major reasons for promoting m-commerce are discussed in [7, 8]. These reasons are wireless base stations, wireless protocol standards, and bandwidth. Wireless communication base stations and users' equipment such as mobile phones, PDAs, etc. have been adopted widely in recent years. Due to the establishment of a number of wireless communication protocols and the broadband technology and networks, many versatile m-commerce applications are developed. Furthermore, three major applications of m-commerce are identified. The three types are transaction management, content delivery and telemetry services, which are further divided into active and passive services. The active services mean users can actively seek the services. On the other hand, passive services are those passively received by users.

In [9] an m-commerce application framework was proposed and a number of possible m-commerce applications are discussed. The applications include mobile advertising and shopping (MAS), mobile inventory management (MIM), product location and shopping (PLS), proactive service management (PSM), and wire1ess business re-engineering (WBR), etc. After analyzing the related work of m-commerce, the most m-commerce applications have the following two features: use of mobile location-aware databases and access to content-aware information. Therefore, this study explores content-aware mobile database. In [10], six elements for the m-commerce system are discussed. They are mobile commerce applications, mobile stations, mobile middleware, wireless networks, wired networks, and host computers.

2.2 Mobile Databases

In [11] four characteristics of accessing mobile database via wireless network are pointed out: asymmetry in communication, frequent disconnections, power limitation, and screen size. Due to the three characteristics, asymmetry in communication, frequent disconnections and power limitation, communication cost of accessing mobile database is becoming a critical issue. If a large number of connection and disconnection as well as asymmetrical communication, these require high communication costs and power consumption. If a better scheme for accessing mobile database can be found to reduce communication costs, it would improve the efficiency of accessing mobile databases [12]. Moreover, three research topics for mobile databases are data dissemination, data consistency and location dependent querying. In general, the environment of a mobile database includes the mobile unit (MU), mobile subscriber station (MSS), wireless network and wired network, etc.

Architecture for mobile databases was proposed in [13]. For data replication and conflict detection/resolution, a client-oriented replication approach is proposed as shown in Fig. 1. The client/server operation model has been widely adopted both on wired and wireless networks, and is proved to be working well and very successful. Its concept of operation is to link the central server database to fixed networks with large bandwidth, while replication of part of the data may occur in two statuses: online or offline. And there are three processes for the action of maintaining management data: definition of replication, synchronization and transaction processing [13].

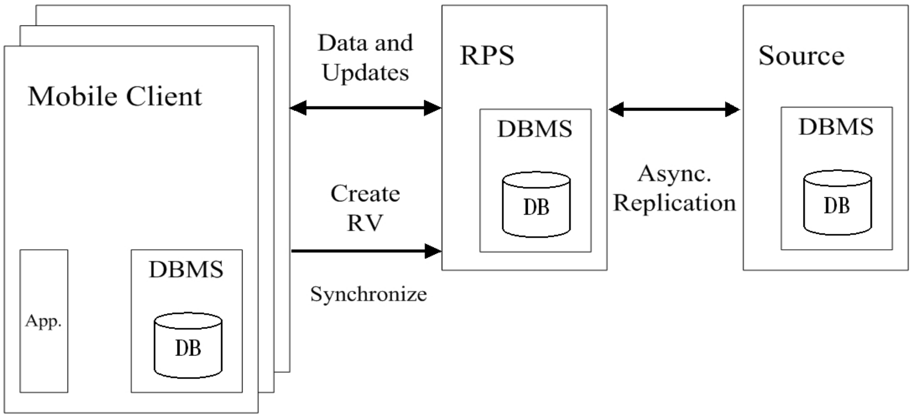

Fig. 1 Three-tier architecture

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2.3 Content-Aware Services

Several papers presented the studies on content-aware services, or so-called Location Based Services (LBS) [17, 18, 19]. Dunham *et. al.* proposed LDD which is a kind of data that the content value is determined by its location. LDD has the following characteristics: (i) the semantics of a set of data and their values are coupled with particular location, (ii) the answer to a query depends on the geographical location, and (iii) a query may be valid only at a particular location. In other words, the content values of the data, results of data query, and accuracy of query are all related to the physical location.

In addition, the replication of data is classified into two types: spatial replicas and temporal replicas. And the data consistency problems, which are caused by replication of data, are distinguished into temporal consistency and spatial consistency. Finally, problems and approaches of query processing and transaction management are discussed as well. In [20], the LBS is presented for each generation of mobile communication systems. The study covers two cases: traffic report and navigation service, and the relevant details of technology are also investigated.

The relationship between LBS and m-commerce was discussed in [21]. First of all, five categories of LBS are identified: information/directory services, tracking services, emergency services, navigation, and location-based advertising and promotions. Moreover, a lot of examples of specific applications are given. Besides, technologies for realizing LBS are discussed, such as network-based technology, handset-based technology, hybrid technology, and short-range technology (e.g., WLAN, Bluetooth). Three business models of m-commerce are also discussed, and they are network operator dependent business, network operator assisted business, and network operator independent business.

3. Caching Approaches

In this Section three caching approaches are presented. The three approaches are index caching, judicious caching, and pre-fetch caching.

3.1 Index Caching

An efficient index caching was proposed in [14]. The proposed approach could save an index to the mobile host so that data query performance is improved. Moreover, two cache replacement policies, lower level index first replacement policy and cut-plane-first replacement policy, are compared and clarified through performance evaluation.

In order to reduce power consumption of mobile clients, the index caching mechanism enables rapid and efficient query for disperse data. Moreover, index caching mechanism can shorten query and response time effectively. As shown in Fig. 2, if the required index data is not available in the cache memory of the mobile client, a query will be made at the Local Server (LS) #1 via wireless transmission. If no such index data is found in LS #1, a query will be made at the LS #2 via wireless transmission for a copy of the index data. Moreover, if such index data cannot be found in the other Local Servers, the Central Server must be queried through a wired transmission. On the other hand, for index data update the Central Server will copy all updated data to all Local Servers. Thus, extra communication cost is required for data query/access.

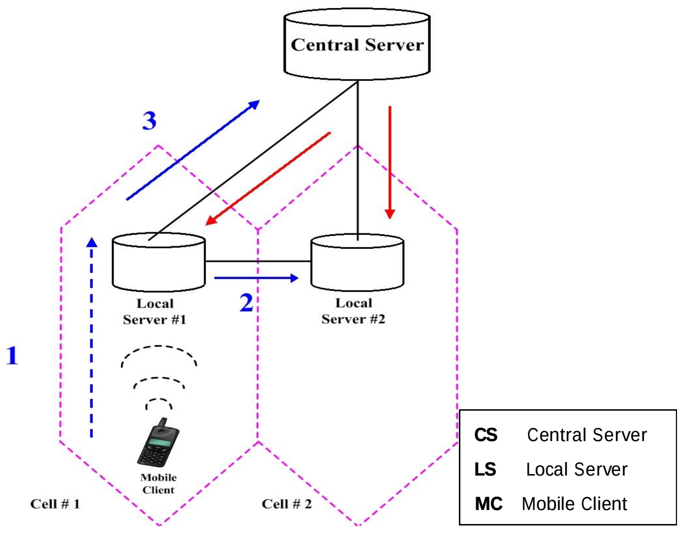

Fig. 2 Index caching approach

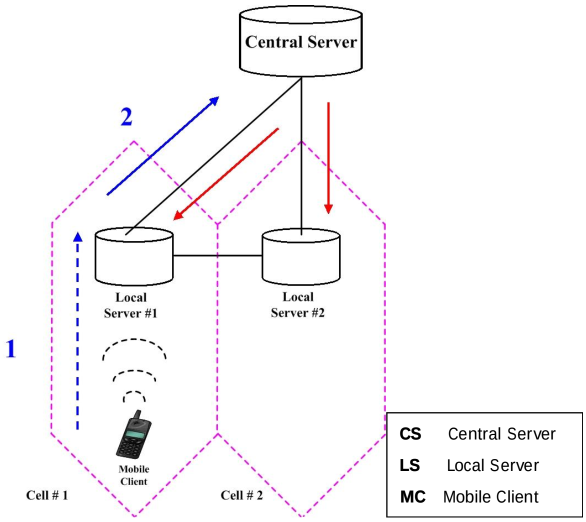

Fig. 3 Judicious caching approach

3.2 Judicious Caching

The judicious caching approach was proposed in [1]. The study conducted a detailed analysis of the characteristics of dynamic data management in LBS. And a scheme for classifying LBS by factors was proposed. The factors are source of data (central/local), period of validity (static/dynamic), target of audience (public/personal), and location dependency (independence/dependence). Moreover, the study also proposed several dynamic data management strategies, which are judicious caching, proactive pushing and neighborhood replication. A cost model was also proposed, so that the different strategies can be analyzed and compared. Based on the results of this study the wireless communication cost is considered in our cost model. In this paper, communication cost may not be dependent on distance only. It depends on bandwidth, delay, reliability, etc. For the database operations, more details of cost are developed. For example, both the time spent on replication and the cost of disk space is also considered in this paper.

As shown in Fig. 3, within an accessible range of the mobile client, judicious caching is used to generate a copy of cache on the Local Servers. Then, central server is responsible to update data in Local Servers and maintain its value at any time by employing judicious caching approach. So, the Local Server can access the latest copy of data without any delay within an accessible range of the Mobile Client. Once data update occurs in the Central Server, Local Server must duplicate the latest copy of data at additional maintenance cost. In Fig. 3, if the required data is not available in the cache memory of the mobile client, a query will be made at the Local Server (LS) #1 via wireless transmission. If no such data is found in LS #1, a query will be made at the Central Server through a wired transmission. As for the data update, the Central Server will copy all updated data to all Local Servers, so that additional communication cost is incurred for data query/access.

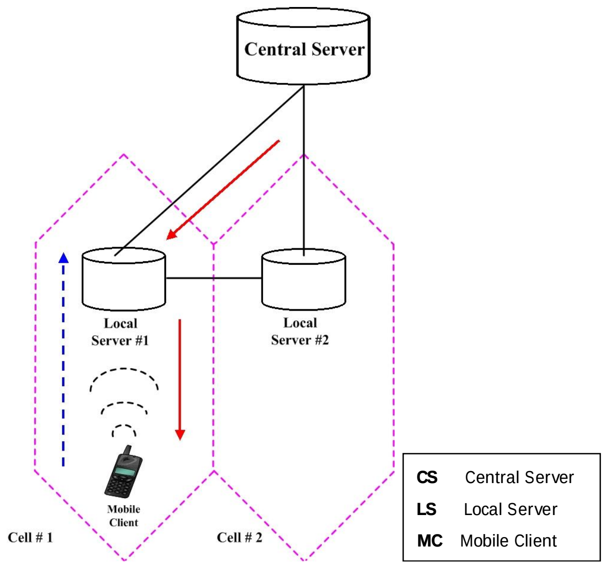

Fig. 4 Pre-fetch caching approach

3.3 Pre-fetch Caching

In a dynamic data framework, if data that would be accessed by the mobile client can be predicted and pre-fetched in the Cache, it is likely to increase hit ratio and improve the cache efficiency [15, 16]. Though the cache stores only past data, mobile clients may not find the new data in the cache. Thus, pre-fetch caching approach is proposed to address such an issue. However, the fetched data cannot be oversized. Otherwise the significance and function of pre-fetch caching approach will be compromised. The predicted results should be precise, small in size and with no compromise of accuracy and hit ratio. In this way, communication cost can be improved efficiently.

As in Fig. 4, if the mobile client sends out a request to the system only when the data is actually required, it may not receive the necessary data in time due to insufficient bandwidth or disconnection. To avoid the occurrence of such problem, the mobile client may pre-fetch the necessary content-aware data, and keep them in the Local Server prior to actual utilization, so that the mobile client may obtain it immediately from the nearby Local Server when the data is actually used or queried. This shortens delay of data access.

3.4 Communication Cost

Table 1 summarizes the definitions of factors for the communication cost, which is employed to evaluate the three caching approaches in this paper.

Eq. 1 denotes the total cost, which consists of communication cost and maintenance/operation cost. Note that c, n and b are common variables of the total costs. Eq. 2 expresses the maintenance/operation cost, which sums up the cost of cache invalidation mechanism and operation cost of cache replacement mechanism. Note that M_{ci} indicates the cache size used by mobile clients and D_u indicates the cost of updating data per byte by the mobile client. Moreover, D_c indicates the effective byte of cache received by the mobile client and D_a indicates the size in byte of content accessed by the mobile client at the local server. Eq. 3 depicts the communication cost, in which C_n indicates the cost for sending out request by the mobile client, C_d indicates the cost of making connection between the mobile client and the Local Server, B indicates all the transaction costs after connection is established. The final total cost is expressed as Eq. 4.

$$C = C_m + C_c = C\ (c, n, b) \quad (1)$$

$$C_c = C_c\left(C_n, C_d, B\right) \quad (2)$$

$$C_c = Q_u H_r + W_s(1 - H_r) + L_l + L_c \quad (3)$$

$$C = C_m + C_c = C_m + Q_u H_r + W_s(1 - H_r) + L_l + L_c \quad (4)$$

Consider the following equation:

$$C_c = Q_u H_r + W_s(1 - H_r) + L_l + L_c \quad (5)$$

Tab.1. Definition of factors

Notations	Definition
C	Total cost
C_m	Maintenance/Operation cost
C_c	Communication cost
Q_u	The total quality query cost from mobile client
W_s	Communication cost between the local server and mobile client.
L_l	Communication cost between the local server and other local server.
L_s	Communication cost between the local server and other central server.
c	Communication unit cost
n	The total number of communication
b	Size of the data item for communication
A_c	The average hit ratio of the mobile client cache
M_v	Access Probability
H_r	Mobility Probability
C_v	Wireless unit communication variation cost

Four variables A_c, M_v, H_r and C_v would cause value change on Q_u, W_s, L_l and L_s for the three caching approaches. In this paper a simulation study is conducted to explore the impact of access probability, mobility probability, and cache hit ratio and wireless unit communication cost on total costs.

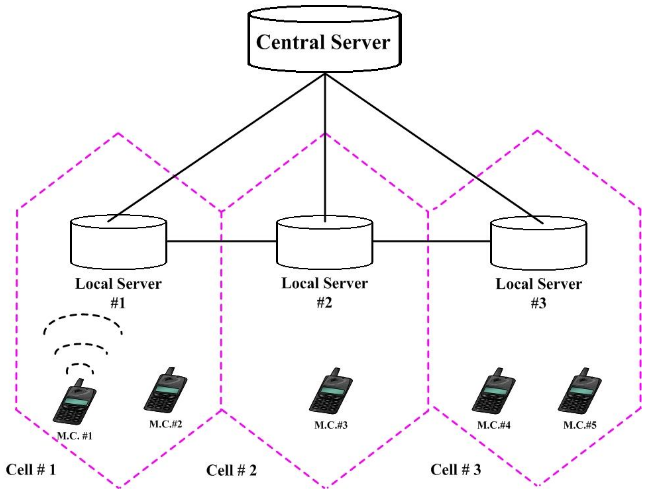

Fig. 5 Simulation model

4. SIMULATION STUDY

4.1 Simulation Model

In order to analyze the total cost, a model for a three-tier content-aware wireless communication environment is employed in this study. The model comprises a central server, three local servers and five mobile clients. A wired network connection connects the central server and the three local servers. And a wireless network is used to connect the local servers and mobile clients. The mobile client can access the data on its local server or access the copy of data on the other local servers via wireless connection. This simulation study investigates the total cost versus the simulation factors described in previous Section.

4.2 Simulation Results

4.2.1 Communication Cost vs. Access Probability

The probability of a mobile client accessing data is set from 0.05 to 0.3 as shown in Fig. 6. Besides, the mobility of mobile clients and the hit ratio of mobile client accessing data on local servers are fixed (mobility = 0.1 and hit ratio = 0.2). The simulation results show that the communication cost of index caching approach is the highest among these three approaches. And the judicious caching approach requires more communication cost than pre-fetch caching approach. Obviously, index caching approach requires much communication cost for transmitting data from local server and mobile client. On the other hand, the pre-fetch caching approach stores predicted data on mobile clients or local server, so that it requires less communication cost but much memory space is required on mobile clients and local servers. For the three approaches, the communication cost increases as the probability of mobile clients accessing data on the local server increases.

4.2.2 Hit Ratio and Access Probability vs. Communication cost

The Scenario II for this simulation study is with the fixed mobility for mobile clients and the fixed wireless communication unit cost. As shown in Fig. 7, both the hit ratio and the access probability affect the communication cost. For index caching approach, when the hit ratio decreases the communication cost will increase quickly. The possible reason is that the low hit ratio means much data transmission from local server and mobile client. Similarly, the communication cost increases as the hit ratio decreases and access probability increases for the other two approaches. Moreover, the hit ratio effect of judicious caching and pre-fetch caching is less than that of index caching. However, the two approaches require much memory space on mobile client and local servers. In general, the pre-fetch caching approach requires less communication cost when hit ratio decreases and access probability increases. Thus, it is a trade-off between communication cost and device cost when the three approaches are considered respect to hit ratio and access probability.

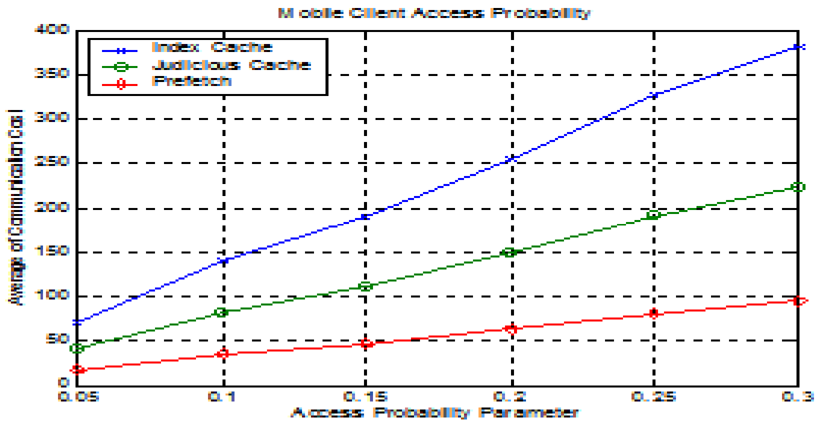

Fig. 6 Access probability vs. communication cost

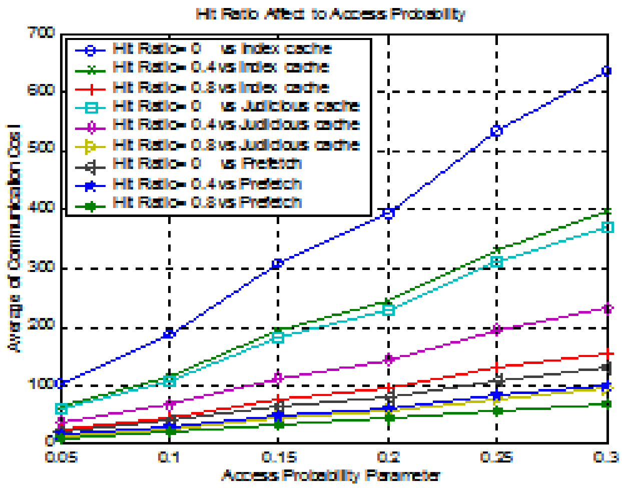

Fig. 7 Hit ratio and access probability vs. communication cost

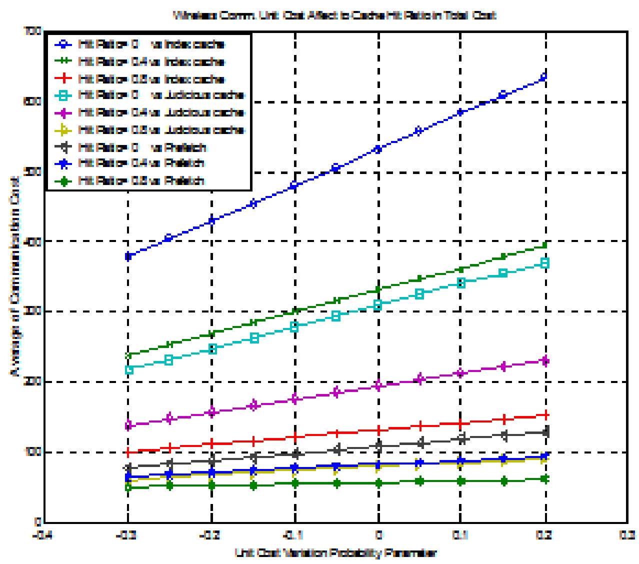

Fig. 8 Unit cost of wireless communication vs average communication cost

4.2.3 Wireless Communication Unit Cost vs. Average of Communication Cost

The Scenario III for this simulation study is with the fixed access probability and the fixed device mobility. As shown in Fig. 8 the communication cost increases as the unit cost of the wireless communication increases and the hit ratio decreases. The communication cost of the index caching approach increases abruptly as the hot ratio decreases and unit cost of wireless communication increases. It is obvious that index caching approach requires more communication between local server and mobile client and between local server and central server. Thus, its communication cost will increase as the unit cost of wireless communication increases. Similarly, when the hit ratio decreases the data transmission from local server and mobile client and local server and central server increases so that the communication cost arises. Fortunately, the communication cost for the pre-fetch caching approach increases smoothly as the access probability increases and hit ratio decreases. This means that the pre-fetch caching approach is more stable regarding to the wireless communication environment and user behavior. However, the pre-fetch caching approach needs much memory space at mobile clients and local servers.

5. CONCLUSIONS

Recently, the advancement of the mobile computing technology motivates the development of many versatile m-commerce applications, which employ content-aware databases. For these databases, the communication cost of location update operations may increase rapidly as the mobility of the devices and data access probability increase. In this paper, three caching approaches, i.e., index caching, judicious caching, and pre-fetch caching, is discussed. And the communication cost for a content-aware mobile data that may be used in m-commerce applications is analyzed. To investigate the communication cost for the three approaches, a simulation study is conducted. The simulation results show that the communication cost of index caching approach is the highest among these three approaches. And the pre-fetch caching approach requires less communication cost when hit ratio decreases and access probability increases. Moreover, the communication cost for the pre-fetch caching approach increases smoothly as the access probability increases and hit ratio decreases. Though the pre-fetch caching approach outperforms than the other two approaches from our simulation results, the extra cost for the pre-fetch caching approach is that it requires much memory space on mobile clients and local servers. Generally speaking, our study shows that it is a trade-off between communication cost and device cost when the three approaches are considered in a wireless environment.

References

[1] Shiow-yang Wu and Kun-Ta Wu, “Dynamic Data Management for Location Based Services in Mobile Environments,” in Proceedings of the Seventh International Database Engineering and Applications Symposium (IDEAS’2003)
[2] M.-H. Jin, J.-T. Horng, H.-K. Wu and B.-J. Liu, 2000, “Reducing the Location Query Cost Based on Behavior-Based Strategy,” Proc. of the 11th Intl. Conf. on Database and Expert Systems Applications, pp. 397 - 406.
[3] Ayse Yasemin Seydim , Margaret H. Dunham , Vijay Kumar, 2001, ”An Architecture for Location Dependent Query Processing,” in Proc, of the 12th International Workshop on Database and Expert Systems Applications, pp.549-555.
[4] Jianliang Xu, Baihua Zheng, Manli Zhu, and Dik Lun Lee, March, 2002, “Research Challenges in Information Access and Dissemination in a Mobile Environment,” Proc. Pan-Yellow-Sea International Workshop on Information Technologies for Network Era (PYIWIT'02), Japan.
[5] Upkar Varshney, 2001, “Addressing Location Issues in Mobile Commerce,” in Proc. of the 26th Annual IEEE Conference on Local Computer Networks, pp. 184-192.
[6] Wang-chien Lee, Jianliang Xu, Baihua Zheng, March 30 - April 2, 2004 , “Data Management in Location-Dependent Information Services,” The 20th IEEE International Conference on Data Engineering (ICDE '04), Boston, MA.
[7] Baihua Zheng, Jianliang Xu, and Dik Lun Lee, 2002, “Cache Invalidation and Replacement Srtategies for Location-Dependent Data in Mobile Environments,” in IEEE Transactions on Computers, pp. 1141-1153.
[8] J. Senn, 2000, “The Emergence of M-Commerce,” Computer, vol. 33, iss. 12, pp. 148-150.
[9] U.Varshney and R.VetteL2001, “A Framework for the Emerging Mobile Commerce Applications,” in Proc. Int'l Conf. on System Sciences, pp.3516-3525.
[10] C.-W.Lee,W.-C. Hu, and J.-H.Yeh, 2003, “A System Model for Mobile Commerce, ”in Proc. Int'l Conf Distributed Computing Systems workshops, pp.634.639.
[11] Daniel Barbara, 1999, “Mobile computing and databases - a survey,” IEEE Transaction on Knowledge and Data Engineering, 11(1) , pp.108–117.
[12] K. Porkaew, I. Lazaridis, and S. Mehrotra, 2001,“Querying Mobile Objects in Spatio-Temporal Databases,” in Proceedings of the 7th International Symposium on Advances in Spatial and Temporal Databases, pp. 55–78.
[13] C. GOllmick, 2003,“Replication in Mobile Database Environments: A Client-Oriented Approach,” in Proc. Int’l Workshop on Database and Expert Systems Applications, pp980-981.

[14] Jen-Jou Hung and Yungho Leu, "Efficient Index Caching Schemes for Data Broadcasting in Mobile computing Environments," in Proceedings of the 14th Int'l Workshop on Database and Expert Systems Applications (DEXA '03), pp. 139-143.
[15] Huaping Shen, Mohan Kumar, Sajal Das and Zhijun Wang, 2004, "Energy-Efficient Data Caching and Prefetching of Mobile Devices Based on Utility," ACM/Kluwer Journal of Mobile Networks and Applications (MONET), Special Issue on Mobile Services.
[16] Athanasios E. Papathanasiou and Michael L. Scott, "Energy Efficient Prefetching and Caching," In Proceeding of the USENIX 2004 Annual Technical Conference, pp. 255–268.
[17] M. Dunham, V. Kumar, 1998, "Location Dependent Data and its Management in Mobile Database," in Proc. Int'l Workshop on Database and Export System Application, pp.414-419.
[18] C. Patterson, R. Muntz, and C. Pancake, 2003, "Challenges in Location-aware Computing," IEEE Pervasive Computing, vol. 2, iss. 2,pp.80-89.
[19] J. Myllymaki and S. Edlund, 2002, "Location Aggregation from Multiple Sources," in Proc. Int'l Conf. on Mobile Data Management, pp. 131-138.
[20] W.-J. Choi and S. Tekinay, 2003, "Location Based Services for Next Generation wireless Mobile Networks," in Proc. IEEE Semiannual Vehicular Technology Conf. (VTC 2003), pp.1988-1992.
[21] Ramaprasad Unni, Robort Harmon, "Location-Based Services: Models for Strategy Development in M-Commerce," in Int'l Conf. on Management of Engineering and Technology, July 2003, pp. 416-424.

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