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Relocation Strategy for an Efficient Management of Replicated Data on Mobile Computing

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ABSTRACT

Rapid advances in mobile computing and the availability of wireless communications will soon provide mobile users with the ability to access data regardless of the location of the user or of the data. SRA(Static Replica Allocation) that is traditional scheme has been used for the replication method on the server. This replicates the data on the replica server after a moving host has been transferred to the cell. This strategy is simple and can easily relocate data. However, if a mobile user does not exist in the cell, the replicated data can be deleted in order to maintain data consistency. In addition to, if the mobile host leaves from replicated cell, it is difficult to access data in terms of replication route. Therefore, this paper proposes a new method of relocation based on data consistency strategy called USRAC(User Selection Replica Allocation based on Consistency) and also analyzes access cost according to the moving rate of mobile users, according to the access rate of mobile hosts, and according to the number of cells of mobile users and mobile hosts.

모바일 컴퓨팅상에서 중복데이터의 효율적 관리를 위한 재배치 전략

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요 약

모바일 컴퓨팅의 급속한 발전과 무선 통신의 유용성은 모바일 사용자들에게 사용자나 데이터의 위치에 상관없이 데이터 접근을 용이하게 제공해 주고있다. 기존 기법인 정적중복배치(SRA)는 서버상에서 중복 데이터 사용을 위해 현재 사용되고 있으며 이동 호스트가 셀에 이동하고 나서 복제서버에 데이터를 복제하는 방법이다. 이 기법은 복제 작업이 간단하고 쉽게 재배치 할 수 있다. 그러나 이동한 셀에 이동사용자가 존재하지 않을 경우에는 데이터 일관성 문제로 인하여 데이터가 삭제된다. 그리고 이동호스트가 복제된 셀로부터 이동하게 되면 경로를 통한 데이터의 접근도 어렵게 된다. 따라서 이 논문에서는 데이터 공유와 효율적 중복데이터 관리를 위해 데이터 일관성 유지 메커니즘을 기반으로 한 새로운 재배치 전략인 일관성 기반 사용자 선택 중복배치(USRAC)를 제안하며 이동사용자의 이동율, 이동 호스트의 접근율 그리고 이동사용자와 이동 호스트의 셀 수에 따른 접근 비용에 대해 기존방법과 비교 분석한다.

Key words: mobile computing(모바일 컴퓨팅), replicated strategy(복제전략), data consistency(데이터 일관성)

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1. Introduction

Mobile computers and wireless communication networks have made it possible to open up a new field in mobile computing. Mobile computing provides mobile users with the ability to access information regardless of the location of the user or the information. In traditional distributed database systems, various strategies have been suggested in order to process transaction and maintain consistency. But most solutions are restricted to mobile computing because of mobility, network failure and lower bandwidth. The replication of data allows mobile computers to quickly access data. But consistency among duplicated data should be maintained. The distributed database in the mobile computer environment for replicating data has used SRA(Static Replica Allocation). SRA is a scheme that when a mobile host moves to a cell, replicates data to the replica server within the cell. Mobile host is a data server that processes transaction commands. In case the network is stable and a number of mobile users smaller than cells, this scheme does not cause any problem with using data. However, after the mobile host moved to a cell, if no mobile user existed in the replicated cell, replicated data become useless. And this scheme is not suitable for the mobile computing environment because of frequent disconnection, lower bandwidth, etc.[4,10,17]

In this paper, we present our replica allocation called USRAC (User Selection Replica Allocation based on Consistency scheme) which makes up for defects of SRA scheme and is appropriate to the mobile computer environment. This scheme replicates data and then allocates it to the cell in which mobile users are numerous.We have conducted a detailed performance evaluation of SRA, USRA and USRAC scheme proposed in terms of access cost and communication cost based on access ratio of mobile user, access ratio of mobile host and variation of number of cells.

2. SRA(Static Replica Allocation)

Replication is the process that automatically updates data involved in a replica server maintains the same object and data. Whenever mobile users need to replicate data, they can do it. The replication is used to increase the speed of the query and information retrieval. SRA(Static Replica Allocation) is a strategy that has been currently researched. SRA is a method that replicates data to the replica server of moved cell if a mobile user requires data. The advantage of this method is that data replication is simple and easily relocates data. However, because mobile host replicates data to moved cell, in case mobile user does not exist in the moved cell, the replicated data can be deleted for consistency maintenance. And if mobile host leaves replicated cell, the access of data through route becomes difficult because of the frequent disconnection of mobile computing environment

The advantage of SRA strategy is to easily replicate transacted data and replication is simple. Therefore, this scheme is suitable when the network is stable and mobile users in the cell are smaller than mobile support stations. However, the first disadvantage of this scheme is that searching the route of the cell in which data transacted is replicated is difficult. Second, although location replicated is known, it is not easy to access a data through route since a frequent disconnections is occurred. Third, in case mobile user does not exist in the replicated cell, data transacted cannot be used. Fourth, if a mobile host moves, the data of replica server is deleted since the data of replica server cannot maintain consistency. Replica server is a system that replicates a replicated data within mobile support station.[9,21]

2.1 Cost Computation Equation

In the cost computation of SRA strategy, the read and write of mobile user and write of mobile host are together presented. The read and write of mobile user and write of mobile host are each,

R_{muser}, W_{muser} and W_{muser}.

The average access cost of SRA, AVG is as shown in equation (1).

$$AVG_{SRA} = R_{muser} + W_{muser} + W_{mhost} \quad (1)$$

The probability that mobile user of k person exists in the cell which replicated server exists, *is as shown in equation (2).

$$P(k) = \binom{n-1}{k}\left(1-\frac{1}{N}\right)^{n-1}(N-1)^{-k} \quad (2)$$

Therefore, each the access cost of mobile user and mobile host is equation (3), (4), (5).

$$R_{\mu ser} = \sum_{k=0}^{n-1} P(k)\frac{n-1-k}{n-1}(1-\alpha)\lambda \quad (3)$$

$$W_{\mu ser} = \sum_{k=0}^{n-1} P(k)\gamma_{\mu ser}(1-\alpha)\lambda$$

$$\left\{\frac{k-N-1}{n-1-N} + \frac{n-1-k}{n-1}\left\{\frac{2}{N} + \frac{3(N-1)}{N}\right\}\right\} \quad (4)$$

$$W_{mhost} = \frac{N-1}{N}\gamma_{mhost}\alpha\lambda \quad (5)$$

Table 1. input parameter

Input parameter	mean
λ	The move ratio of mobile user
α	The access ratio of mobile host
γ	Update ratio
k	The number of mobile user that exists in the replica cell

3. USRAC(User Selection Replica Allocation based on Consistency scheme)

3.1 USRA(User Selection Replica Allocation)

Because SRA strategy is difficult to trace the location of a replicated data and use a data and maintain consistency, USRA(user selection replica allocation) was proposed. USRA strategy is a scheme that a replica server is assigned to a cell which mobile users are numerous and then relocates a data to the replica server. However, when access cost is computed to this scheme, cost to relocate replication is also added since this strategy additionally should relocate to the cell which mobile users are more numerous.

USRA separately stores the location of cell and mobile host which attempts to replicate to the table of location server. Mapping table linking separate tables maintains replication sequence in order to mobile user partly knows replication process and it can use the location of not only mobile host but also replication.

USRA is strategy that determines the location relocated of replication at location server and assigns replica server. Replica server takes data information and location information and then provides a data which mobile user requires. This scheme resolves disadvantage that a data is not used or the location route of a data has to be searched since selects cell which the user of a data is more numerous and replicates the data. If the relocation of replication is not determined, the loading of data replicated may increase.

3.1.1 Cost Computation Equation

To evaluate the performance of USRAC, we mean to present an equation that computes cost to access a data. Hence, we need an equation that computes access cost **W***mhost* which mobile hosts access to replica server, read cost R_{muser} which mobile users reads to replica server, write cost W_{muser} which mobile users writes to replica server, read cost and relocation cost $M_{replica}$ which mobile users relocates to replica server.

If D is represented as the data in the replica server and d is represented as the number of data which mobile host accesses, we represent $\left(\frac{d}{D}\right)$ as α and the range is $0 \le \alpha \le 1$.

Update ratio is the number of data that mobile host and mobile user update to data that exists in the replica server. The update ratio of mobile host is γ_{mhost} and its range is $0 \leq \alpha \leq 1$. The update ratio of mobile user is γ_{mhost} and its range is $0 \leq \alpha \leq 1$.

k is the number of mobile user that exists in the replica server and it become 1 when an access is required among cells otherwise it will become 0. The cost of relocation is 1 if data is replicated among cells otherwise 0. Because USRA has to add relocation work, the average access cost of a data to a mobile user can be represented as equation (6).

$$AVG_{USRA} = R_{\mu ser} + W_{\mu ser} + W_{mhost} + M_{replica} \quad (6)$$

, where $M_{replica}$ mean the average cost of replication relocation.

We represent the probability that there exists the mobile users of k persons in the cell which replicated server exists as $P(k)$. The access to replicated data does not exist in the cell smaller than $\left(\frac{n}{N}\right)$ and $P(k)$ is represented as equation (7).

$$P(k) = \begin{bmatrix} \text{if } k \langle \left(\frac{n}{N},\right) & 0 \\ otherwise, & q(k) \end{bmatrix}$$

$$q(k) = \sum_{k_2=0}^{\min(k,\, n-k)} \sum_{k_3=0}^{\min(k,\, n-k_2)} \cdots \sum_{k_N=0}^{\min(k,\, n-1-k-\sum_{i=0}^{N-1} k_i)} P_{all}(k, k_2, \cdots, k_N) \quad (7)$$

$\beta(k)$ is the probability that there exist the mobile users of k persons in the cell which mobile host replicates and relocates. $\beta(k)$ is represented as equation(8since the cell which mobile users are more numerous should be selected. Because replication is not relocated to the cell that smaller than $\left(\frac{n}{N}\right)$, in that case it is excepted.

$$\beta(k) = \begin{bmatrix} p(\bar{k},1), & for \quad \alpha < \frac{1-\alpha}{n-1} \\ \sum_{j=1}^{\frac{n}{k}} \frac{p(\bar{k},j)}{N}, & for \quad \alpha = \frac{1-\alpha}{n-1} \\ \sum_{j=1}^{\frac{n}{k}} \frac{jp(\bar{k},j)}{N}, & for \quad \alpha > \frac{1-\alpha}{n-1} \end{bmatrix} \quad (8)$$

, where $p(\bar{k},j)$ represents the probability that there exist the mobile users of k persons that there exists in the j cell and also it means one of existing in the cell replicated.

$$p(\bar{k},j) = \begin{bmatrix} \text{if } k \langle \left(\frac{n}{N}\right), & 0 \\ otherwise & \binom{N}{j} \\ P(k_1 = k, \cdots, & k_j = k \end{bmatrix}$$

$$p(k_1 = k, \cdots, k_j = k) = \sum_{k_{j+1}=0}^{\min(k-1,\, n-jk)}, \sum_{k_{j+2}=0}^{\min(k-1,\, n-jk_{j+1})}, \cdots, \sum_{k_N=0}^{\min(k-1,\, n-jk-\sum_{n_{j+1}=0}^{n+1} k_n)} P_{all}(k, k_{j+1}, \cdots, k_N) \quad (9)$$

, where $P_{all}(k, k_{j+1}, \cdots, k_N)$ is the probability that there exist in the N cells which mobile users of n persons are connected. Hence, R_{muser}, W_{muser}, W_{mhost} can be represented as equation (10), (11) and (12).

$$R_{\mu ser} = \sum_{k=0}^{n} p(k)(1-\alpha)\lambda \left\{\beta(k)\frac{n-k}{n-1} + (1-\beta(k))\frac{n-1-k}{n-1}\right\} \quad (10)$$

$$W_{\mu ser} = \sum_{k=0}^{n} p(k)\gamma_{\mu ser}(1-\alpha)\lambda\left\{2\beta(k)\frac{n-k}{n-1} + (1-\beta(k))\left\{\frac{k}{n-1} + \frac{3(n-1-k)}{n-1}\right\}\right\} \quad (11)$$

$$W_{mhost} = \sum_{k=0}^{n} p(k)(1-\beta(k))\,\gamma_{mhost}\,\alpha\lambda \quad (12)$$

Because replication is relocated to the selected cell, relocation cost $M_{replica}$ should know move ratio of mobile user represented as $M(k, \alpha)$. If the move ratio of mobile users is bigger than the number of mobile users, then replication cannot be relocated. Namely, only when the number of mobile users is bigger than the move ratio of mobile users, replication can be relocated. Therefore, $M(k, \alpha)$ is represented as equation (13), (14) and (15).

$$If\ k < \alpha,\ then\ \mathrm{M}(k, \alpha) \quad (13)$$

If $k < \alpha$, *then*

$$M(k,\alpha) = k\mu \Big[\sum_{j=0}^{\frac{n}{k}} p(\overline{k,j}) + \sum_{l=0}^{\frac{n-k}{k-1}} p(\overline{k},1,\overline{k-1},l) + \Big\{ \frac{1}{N-1} + \delta(\alpha) \frac{l(N-1-l)(1-\beta(k))}{N-1^2} \Big\} + \sum_{l=0}^{\frac{n-k}{k-1}} \sum_{m=0}^{\frac{n-k-l(k-j)}{k-1}} p(\overline{k},1,\overline{k-1},l,\overline{k-2},m) + \delta(\alpha) \Big] \quad (14)$$

If $k < \alpha$, *then*

$$M(k,\alpha) = k\mu [p(\overline{k},1,\overline{k-1},1) \Big\{ \frac{1}{N-1} + \delta(\alpha) \frac{(1-\beta(k))(N-2)}{(N-1)} \Big\} + p(\overline{k},1,\overline{k-2},1)\delta(\alpha) \Big\{ \frac{\beta(k)}{k(N-1)} + \frac{1-\beta(k)}{2(N-1)} \Big\}] \quad (15)$$

$$\delta(\alpha) = \begin{bmatrix} \text{if } \alpha > \frac{1-\alpha}{n-1}, & 0 \\ \textit{otherwise}, & 0 \end{bmatrix} \quad (16)$$

$\delta(\alpha)$ given in (16) imply that if the access ratio of mobile host is bigger than the number of mobile users return to 1, otherwise return to 0. Hence, the value of $M_{replica}$ based on all equations can be represented as equation (17).

$$M_{replica} = \sum_{k=0}^{n} M(k,\alpha) \quad (17)$$

3.2 USRAC Consistency Scheme

Data consistency among replicated data in the mobile computing environment should be maintained. Thus, we will propose a data consistency scheme for an efficient management of replicated data in the USRAC strategy.

3.2.1 Consistency Model

Fig. 1 shows a consistency model for representing consistency scheme. A transaction T1 develops two programs, M2 and M4, at workspace A. Workspace is work area of users. The other transaction T2 edits M3 and M4 at workspace B. Here we assume that M2 is **decomposed** into M4 and M5, where M4 is also used by M3. If M3 uses M4, we also say that M3 is a client of M4, since M3 requires the interfaces that M4 provides. The solid arrow denotes the relationship **'decomposed'**. The dashed arrow denotes the relationship **'uses'**.

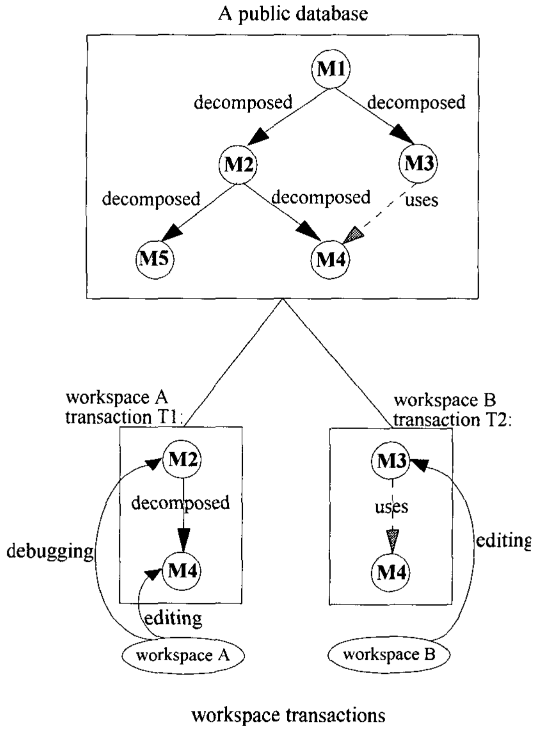


Fig. 1. A Consistency Model

3.2.2 Consistency Table

To represent the consistency scheme, we use the structure of linked lists, because the dynamic dependency grows and shrinks according to check-in/check-out operations performed. Dynamic dependency defines the inter transaction dependency relationships among all the objects checked out from the public database. The consistency table shown in Fig. 2, consists of three lists: a list of static relationships, a list of checkout relationships, and a list of dynamic relationships. In Fig. 2, the static relationships represent those relationships among all objects in the public database. For instance, the relationship 'decomposed(M1,M2)' means that M1 is decomposed into M2. The list

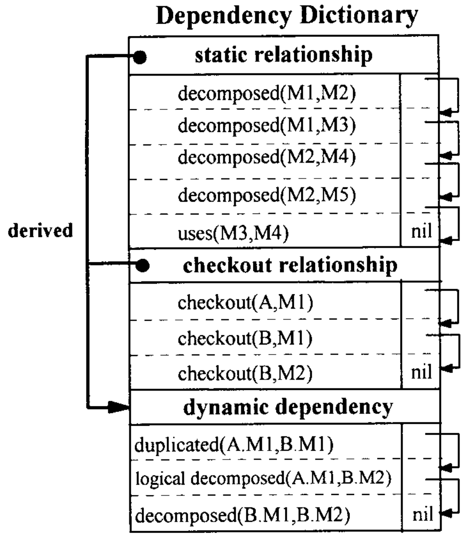
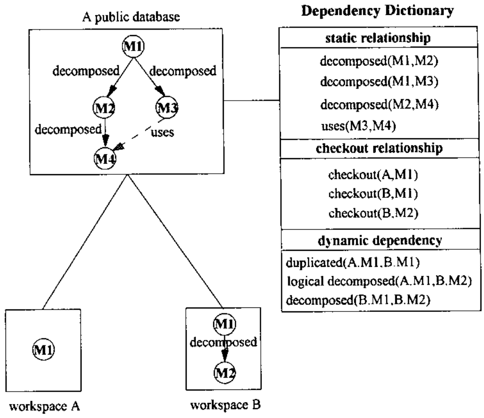


Fig. 2. Consistency Table

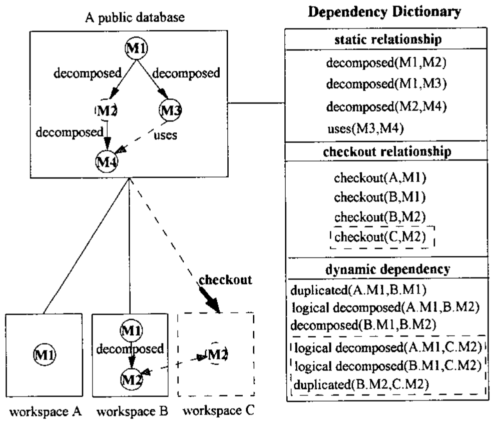
of static relationships is not influenced by any checkout operation. However, a new static relationship may be added to the list of static relationships by means of checkin operations.

3.2.3 Consistency Process

Fig. 3 is a process for consistency scheme. Fig. 3(a) represents the state before M2 is checked out to workspace C. Fig. 3(b) represents the state where M2 has been newly checked out to workspace C. The dashed rectangle within the consistency table in Fig. 3 (b) shows the new relationships generated after M2 is checked out into workspace C.



(a) before M2 is checked out



(b) after M2 is checked out

Fig. 3. Consistency process

4. Performance Analysis

We analyze performance among SRA, USRA and USRAC strategy in the mobile computing in terms of computing access cost and communication cost.

4.1 The Access Cost for Move Ratio of Mobile User

Fig. 4 illustrates the access cost of SRA, USRA

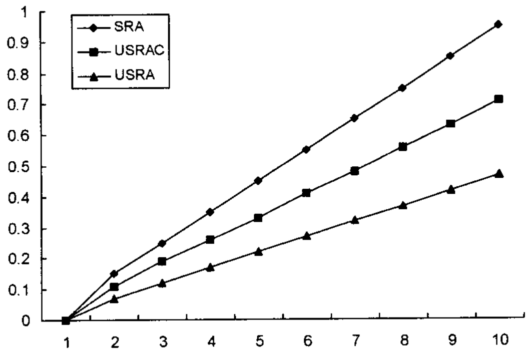


Fig. 4. Access cost of mobile user for $\alpha = 0.8$

and USRAC for the variation of access ratio(α) of mobile host. The move ratio of mobile user is generated from 0 to 1 λ. We found out that if α

is over 0.8, access cost maintains as Fig. 4 regardless of variation of α value.

4.2 The Access Cost for Access Ratio of Mobile Host

Fig. 5 illustrates the access cost of mobile host as the access ratio(λ) of mobile user and the access ratio of mobile host varies from 0 to 1. When the access ratio(λ) of mobile user is over 0.8, the result is as Fig. 5.

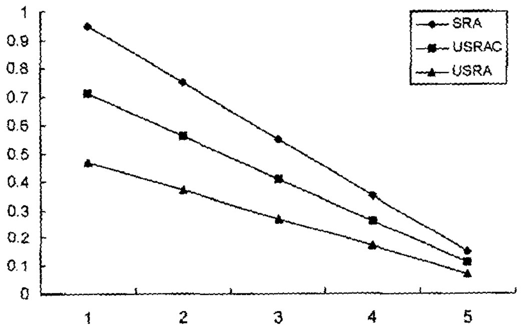


Fig. 5. Access cost of mobile user for λ=0.8

4.3 The Access Cost for The Number of Cells

Fig. 6 illustrates the access cost of SRA, USRA and USRAC for variation of the number of cells. We found out that the access cost of USRA and USRAC is more sensitive than SRA to the variation of the number of cells. Because the replicated cell also increases when the number of cells increases.

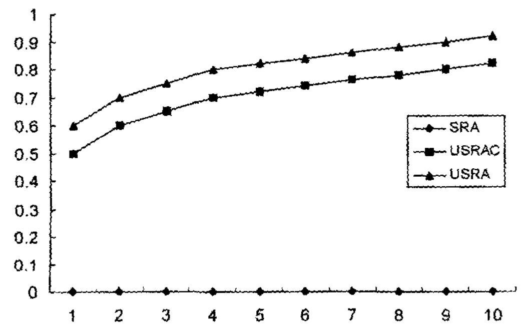


Fig. 6. The access cost for the number of cell to α=0.8, λ=0.8

5. Conclusions

In this paper we have considered USRAC scheme that relocates a replication on mobile computing. SRA(Static Replica Allocation) is a method that replicates a data to the replica server of moved cell if a mobile user requires a data. SRA takes the advantage that data replication is simple and can easily relocate data. However, if mobile user or mobile host is not existed in the moved cell then the replication data becomes useless and it makes move ratio is high. Because USRA selects and replicates the cell that the number of mobile user is most numerous, the move ratio of mobile user can be reduced.However, USRA scheme was not considered serious problem of data consistency in the mobile computing environments.In this paper we have investigated three schemes - SRA, USRA and USRAC and have analyzed performance in terms of cost based on schemes. Conclusively, though the USRAC scheme that we have proposed is medium cost, it provides maintenance of data consistency in the mobile computing.

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