An optimistic concurrency control approach for faster abortion of conflicting transactions

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Abstract: In this paper, the main focus was on designing a concurrency control mechanism which is suitable for mobile database systems. In the suggested plan, a new architecture is proposed for mobile environments, which causes acceleration when committing the transactions and reduces the communication overload of this environment. In addition, we enhance the conventional optimistic concurrency control with an early termination mechanism on conflicting transactions, called "intermediate validation phase". By using this phase, conflicting transactions can be identified timely and terminated before reaching the validation phase. This mechanism is highly desirable in the mobile environment, because allowing conflicting transactions to continue, not only wastes constrained computing power and low bandwidth, but also exacerbates conflicts. This observation leads to ignore some conflicts and reduce restarts.

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1. Introduction

The mobile database architecture consists of a Fixed sever, Mobile Hosts, Mobile Server, Mobile Support Station (MSS) and Control Server. The region under the network coverage is divided into various zones each of which is again divided into several cells. The Fixed Servers are computers that are connected to the fixed network and do not have the mobility feature. These computers have the duty to process the transactions, manage the information and respond to queries. Breaking down the transaction and sending it to another fixed station in the network which can execute that sub-transaction. Another part of this architecture is the Mobile Hosts. These hosts are computers that are moving through the wireless network and have the ability to connect to the network via the wireless interfaces [7]. In this part, data storage and transaction management do not take place. The mobile servers are similar to the fixed servers except for this difference that they are capable of mobility and making connection to the wireless network. The main difference between the fixed server and the mobile server is related to the transactions breakdown and processing. In the mobile database architecture, the connection of each cell with other cells is facilitated via a wireless interface specific to that cell which is called the Mobile Support Station and holds the address of all cells. In each network, there is only one Control Server that is responsible for maintaining the physical location of the Mobile Hosts in that network and also the global concurrency control, management and recovery of transactions [4]. As it's obvious, transaction processing and concurrency control are always biggest challenges in the database. Because of its inherent limitations in mobile databases, greater difficulties were faced with us in concurrency. Many methods were proposed to improve the concurrency in these environments and each of them has its weaknesses and strengths. Some of these methods are as following:

- S2PL method improvement in concurrency control [5]
- Hybrid concurrency control for mobile transactions [2]
- Flexible combination of pessimistic and optimistic concurrency control in mobile environments
- Concurrency control approach based on forecasting
- Distributed lock management for mobile transactions [1]
- Infinite block prevention of mobile transactions [6]

By studying the present approaches, it can be understood that the lock-based methods always face the concurrency level reduction, high rate of being blocked, and an increase in the system response time. Also the optimistic mechanisms scuffle with numerous abortions of transactions and often cascading abortions. Compared to the locking methods, the optimistic approaches seem to be attracting for mobile environments due to their nature of being free from deadlocks and less communication overload [8][9]. Therefore, in this paper, it has been decided to take measures to help cover the shortcomings of the optimistic concurrency control mechanisms and evict those transactions condemned to abortion from the colony of the system active transactions by early detecting them and prevent the proliferation of conflictions among other transactions and reduce the system concurrency.

2. The architecture of the suggested system

In the suggested plan, a set of mobile support stations (cells) form 'a zone'. In each zone, an MSS is considered to be the mobile transaction manager (MTM) (fig. 1). It should be mentioned that in the presented figure the dotted lines indicate the wireless communications and the connected lines indicate the wired communications. Upon arriving at each zone, the mobile host stores the number of the zone MTM in its memory. This information enters a two dimensional array in which one dimension includes the MSS numbers and the relevant MTM number is inserted in another dimension. Suppose that MSSs 1, 2 and 3 are under the supervision of MTM number 1 and the MSSs 4, 5 and 6 are under the supervision of the MTM number 2. Both The mobile host and the MSSs have this array. The MTM of each zone has a copy of all MSS data under its cover. When a transaction is issued from a mobile host, it gets divided into some sub-transactions which will be distributed to various MSSs. The sub-transactions that are executed in the MSSs of a zone will also be executed in the MTM of that zone identically with the same scheduling. In fact, MTM is an intensive pattern from the whole MSSs of a zone and performs the execution of sub-transactions under the same applied scheduling in MSSs. The advantage of this architecture is that it does not require a coordinator when committing the transactions so as to send the committing command to all MSSs involved in the execution of the transaction and only sends it to the mobile transaction managers of each zone (MTMs). Hence, the exchange of information in the network will be reduced and committing will occur faster. In each zone, the number of MSSs is constant and the number of mobile hosts is variable. Each MTM keeps its list of constant and variable members and updates them. If a mobile host goes from one cell to another cell which is under the zone MTM cover, no change will be made in the list. But if the mobile host exits a zone under an MTM cover and enters a new zone, (gives its previous MSS/Id to the new MSS as a part of hand-off. Then the new MSS checks the received Id with its two dimensional array. If any differences arise, which means the mobile host entered a new zone, the MSS sends the join ( ) message (through the wired network) to the zone manager which places the mobile host in its list, and simultaneously informs the previous MSS of removing the mobile host from the previous zone manager's list (He sends the Leave ( ) message to the previous MSS and it in turn sends the message to the MTM of its zone). It should be mentioned that the exchanged messages across the network will be transferred at the fixed network level which can be ignored due to the high speed of these networks compared to the mobile networks. The zone manager should have enough information about its zone data, MSSs under cover and the mobile hosts which enter or exit the zone and also the transactions that are issued from these hosts and work on the data to be able to manage the concurrency and data processing. Ergo, there is a quadruplet set called 'the access set' in the form of d_i:<$time_i$,O_i,MSS_i,MH_i> for each datum in the MTM which indicates that in $time_i$, the O_i operation (the subscript indicates the transaction and O is the read and write operations ($O_i \in (r_i, w_i)$) performed an operation on the datum d_i from a transaction which its origin is the MH_i and is in the MSS_i. r_i indicates the read operation and w_i indicates the write operation. Information was created under the name 'report' from the union of access sets belonging to various data in the MTM memory which is stored in the MTM memory of each zone. The report containing information is about an operation that the transaction performs temporarily in the read phase and is supposed to be evaluated in the validation phase. Therefore, after these transactions are aborted, this information will be continually updated and cannot be reflected in the database until the end of the final evaluation. Also, MTM keeps a variable called $R(t_i)$ for each transaction which indicates the number of commands that have been read by the t_i transaction. One unit is added to $R(t_i)$ each time a command is performed. This variable indicates the transactions working progress and serves a purpose when comparing their performance rate and making decisions to select a victim to get aborted in the 'intermediate validation phase'.

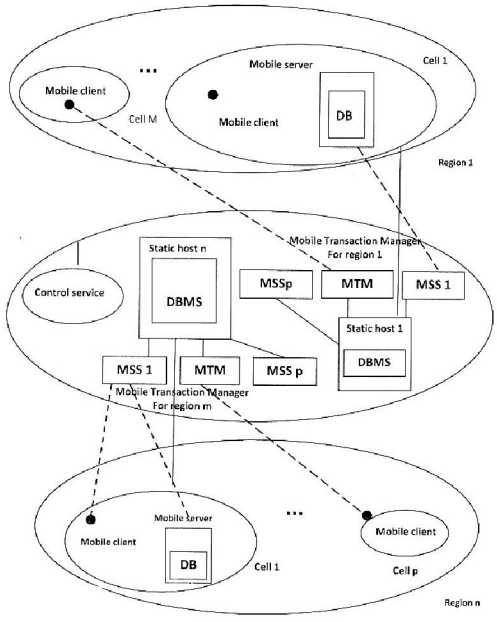

Figure 1: Mobile database architecture, taking into account regional manager of mobile transactions

3. Concurrency control under the suggested architecture

As it's obvious, in the optimistic concurrency control approach, transactions are allowed to continue their job until they arrive at the committing point without any obstacles. Then, they will be validated before being committed. In the traditional optimistic concurrency control, performing the transactions consists of three phases, namely read, write and validation. The transactions fate will be sealed in the last phase [10] [11]. Validation can take place in one of the two ways, namely 'backward validation' and 'forward validation'. Most of the existing OCC protocols use the forward validation due to its flexibility when selecting the transaction condemned to restarting in terms of criticality or priority from among then transactions being validated or the conflicting active transaction [4]. While in the backward validation, the candidates are only those transactions under validation. Also, the forward approach recognizes the conflictions quicker which leads to economization in time and the system sources. Hence, the forward validation will be used in the suggested plan. In the suggested concurrency control mechanism, performing the transaction has four phases, namely the read, intermediate validation, final validation and the write phase.

3.1 Reading Phase

At this stage, the transactions are conducted freely, but they all write operations in the working space which is accessible only for private transactions, so they are not visible to other transactions.

3.2 Intermediate validation

By using this phase, conflicting transactions can be detected early and before the final validation phase are completed. In our proposal, MTM performs validation on a periodic basis every L seconds. So the steps which are taken up to the moment of the transaction (intermediate validation moment), are compared to other concurrent transactions. To avoid repetition of tests a "check point" can be inserted into transaction reading set. However, despite using of intermediate validation phase, transaction failure in final validation phase is probable. For example, the intermediate validation could be done every 7 seconds and transaction execution time is 17 seconds. Last intermediate validation will be happen in the 14th second, while it may be failed in the 15th second. As noted above, in this phase the reading set of the transactions is compared to reading set of other concurrent transactions. Intermediate validation is performed on MTM. As it's clear, MTM keeps an access set di:<$time_i$,o_i,Mss_i,MH_i> for each of its data. This information is continually updated based on the transactions reading set which is temporary. If they have been studied, it could be inferred that confliction of those transactions which simultaneously get access to a datum. Whenever a transaction is aborted, its related information is removed from the access set of those data with which the transaction worked. During the intermediate validation, this information is exchanged among the MTMs that cooperated with one another during the performance of the transaction, because it is possible that the datum 'di' gets accessed by those transactions that are outside of a zone under MTM coverage. After getting information from other MTMs, the serializability graph of each zone will be created during the evaluation, the transaction is aborted sooner if a cycle is found. It should be mentioned that these reports are exchanged periodically and concurrent with applying the intermediate validation phase by the MTMs. Each MTM is responsible for sending the report definitely to other engaged MTMs. In the following, you can see the report-making and sending algorithm:

1- For each di<$time_i$,o_i,Mss_i,MH_i> which is in each MTM, Id of each Mss_i is scanned.

2- If Mssi belongs to the zone under MTM coverage, it means that the datum is accessed locally. Therefore, we will insert di:<$time_i$,o_i,Mss_i,MH_i> into the related report.

3- Otherwise (i.e. non-local access to the data), it would be inserted to access the set into the report and then send it to the MSS which is the supervisor of the non-local MTM.

4- It has been combined the local report with reports from other MTMs.

```
For each di:<time_i,o_i , Mss_i, Mh_i>  in MTM
{if (di is accessed  locally)
add access- set to the report ;
else { add access- set to report and send it for MTM which Mss_i belongs to it  } }
Combine Report with external reports from another MTM
```

Figure (2): The report-making and sending algorithm

In each intermediate validation, an evaluation is carried out in order to identify the conflicting transactions by receiving and combining reports. Figure (3) shows the algorithm for identifying the conflicting transactions.

For two transactions $t_i$and t_j on the MTM

```
{for each di:<time_i,o_i,MSS_i,MH_i> in the combined report of MTM_i
{for each dj:<time_j ,o_j, MSS_j, MH_j> in the combined report of MTM_j
{if (di=dj and t_i<t_j)
Terminate t_i ;/* if the read timestamp <update timestamp*/
}}}
```

Figure (3): The algorithm for identifying the conflicting transactions

3.3 The final validation phase

In this phase, the evaluation will be carried out in front of all of the transactions that are being performed concurrently. Identification of the conflictions takes place by comparing the write set of the transaction under evaluation with the read set of the active transaction. Most of the OCC protocols use the forward validation. The transaction that is aborted in this phase should be restarted immediately. In order to carry out the final validation, it is not necessary for all commands to be evaluated from the beginning and evaluating the commands after the last check point will suffice. This way, the transaction won't wait too much for the final validation and the speed of its being committed and as a result the concurrency of the system goes up.

3.4 The writing phase

In this phase, after the final validation, the result of the transaction operation in the read phase is transferred from the workspace to the database. This way, the transaction private records will be visible for other transactions.

4. Comparison of the suggested plan and the traditional optimistic approach

In order to evaluate the performance of the concurrency control mechanisms, there are various parameters such as the response time, the effective output and the probability of transactions conflict. In this part, two approaches were compared, namely the traditional optimistic concurrency control mechanism and the suggested plan based on the framework of these parameters.

4.1 The time complexity function of the transactions' responsiveness

The average of transactions' response time has a direct relationship with the size of transaction and the number of conflicts in the system [3].

$$R(M) = (k+1)\,s(\overline{M}_a) + kp_c w \qquad (1)$$

In equation (1), K is the transaction size; and p_c is the probability of conflict for each data requested by the transaction. $S(\overline{M}_a)$ is the average of the processing time for each transaction step in a system with M active transactions. The conflicting transactions restart after the specified delay (W). If this transaction is condemned to abort, according to the suggested plan and based on the period adjustment of the intermediate validation phase, a specific transaction might be identified after executing k/2 of its size (on average). Therefore, the average of the conflicting transactions' response time decreases as follows which is shown with index (our):

$$R(M)_{our} = (\frac{k}{2}+1)\,S(\overline{M}_a) + \frac{kp_c W}{2} \qquad (2)$$

4.2 The transactions' effective output

The transactions' effective output can be obtained from equation (3) and equals to dividing the number of the database transaction by the transactions' response time [3]:

$$T(M) = \frac{M}{R(M)} \quad \Rightarrow \quad T(M) = \frac{M}{(k+1)s(\overline{M}_a) + kp_c W} \qquad (3)$$

Since the amount of response time for the transactions decreases in the suggested plan according to equation (2), the transactions' effective output is as follows which is indicated by the index (our):

$$T(M)_{our} = \frac{M}{R(M)_{our}} \Rightarrow T(M) = \frac{M}{(\frac{k}{2}+1)S(\overline{M}_a) + \frac{kp_c W}{2}} \qquad (4)$$

It goes without saying that as the R(M) decreases, the amount of the conflicting transactions' effective output increases.

4.3 The relationship between the conflict probability and the transaction size

Regarding the fact that n_c is the average of the number of conflicts for each transaction, it equals $n_c=kp_c$. When a transaction requests data, the probability of data conflict (p_c) for the i^{th} data request equals [3]:

$$P_c = \frac{\overline{N} - i}{D - i} \simeq \frac{(M-1)\overline{L}}{D} \simeq \frac{(M-1)k}{2D} \qquad (5)$$

$\overline{L}$ Indicates the number of data that are accessed by the transaction; $\overline{N}$ is the average of the number of data which is utilized by other transactions (M-1); and D is the total number of the database data. Hence, the data conflict probability after performing the last step of a transaction equals:

$$p_w = 1 - (1 - p_c)^k \simeq kp_c \sim \frac{(M-1)k^2}{2D} \qquad (6)$$

This conflict probability is obtained after the last data required by the transaction was requested in the last step (k^{th}) of performing the transaction; while in the suggested plan, it's possible to decrease this percentage to the proposed value in equation (7) by evaluating the transaction in the intermediate validation phase and identifying the transaction condemned to abort by executing k/2 its size.

$$p_w = \frac{(M-1)k^2}{2D} \quad k = k/2 \Rightarrow p_w^{our} = (1 - p_c)^{k/2} \simeq k/2\, p_c \sim \frac{(M-1)k^2}{8D} \qquad (7)$$

4.4 The average of the transactions' validation time

In the optimistic techniques, transactions undergo evaluation after the reading phase is completed and before committing .Considering the probability of data conflict and the number of active transactions, the average of the evaluation time equals [3]:

$$E = \sum_{j=1}^{K} \frac{2j}{k(k+1)} \quad [(k-j)\ (S(\overline{M}_a) + p_c] \qquad (8)$$

j is the number of data that are accessed by the active transactions. In the proposed approach, committing of the transactions takes place after making some arrangements with a limited number of MTM_s and it occurs faster compared to other concurrency control approaches in which the coordinator exchanges information with a large number of MSS involved in the operation. On the other hand, the status of the active and delayed transactions can be determined faster using the intermediate validation in general and the data conflict decreases as a result. It is clear that the decrease in $S(\overline{M}_a), j, p_c$ affects the final validation time average of transactions. Besides, according to the intermediate validation phase effect and the fact that at least half of the transaction size is evaluated in the pre-mentioned phase, the rest of the steps will be evaluated after the check point in the final validation phase. Ergo, the average of the final validation time decreases as follows:

$$E = \sum_{j=1}^{K} \frac{2j}{k(k+1)} \quad [(k-j)\ (S(\overline{M}_a) + p_c]$$

$$k = k/2 \Rightarrow E_{our} = \sum_{j=1}^{K/2} \frac{2j}{\frac{k}{4}(k+\frac{1}{2})} \quad [(k/2 - j)\ (S(\overline{M}_a) + p_c] \qquad (9)$$

5- The evaluation environment

This system is evaluated via the MATLAB software in which the parameters are considered as depicted in table (1). It should be mentioned that the selected values in this table are common in many of the evaluations in the mobile environment. [3][4]. as it's obvious, the optimistic approaches are suitable for the environments in which the number of reading operations is more than the writing operations [10]. Also, since the transaction size in the mobile environment is not much, the maximum size is taken to be 20.

Table (1): The characteristics of the evaluation environment

Values	Parameters
λ_u	The input rate of write transaction is 5 per second.
λ_r	20 read-only transactions enter the system each second.
m	The probability of the mobile host's movement from one cell to another equals 0.1
M	The total number of transactions that enter the system is between 50 to 250
D	Database size were considered the to be 250. By size, we mean the number of data items in the bank.
K	The maximum size of transactions is considered to be k=20
W	Delay to restart a transaction is taken to be 10 time unit.
$P_c = \frac{(M-1)k}{D}$	The probability of one write command conflict with another read command equals 2

5.1 The evaluation results

Regarding the relationships which were proposed in the previous part, the suggested approach is compared to the traditional OCC approach and the results of evaluation are depicted as some charts.

According to the suggested plan, most of the conflicting transactions in the intermediate validation phase will abort except for those which commit failure after the last intermediate validation. Therefore, the system's response time for conflicting

transactions decreases as figure (4). It is clear that as the time decreases for the conflicting transactions, the total average of the response time decreases for all the transactions that are a combination of the conflicting transaction and those without conflicts. As can be seen in figure (4); the response time of both approaches increases as the size of transactions increases. In the traditional OCC approach, the time equals 450 time units considering the values depicted in table (1). Each transaction gets restarted all over again after getting aborted with a w(10) delay of the time unit. $S(\overline{M}_a)$ is the average of the processing time for each transaction step in a system with M active transactions which equaled 0.2 [3] and p_c which happened to be 2 after placing the values of table (1).

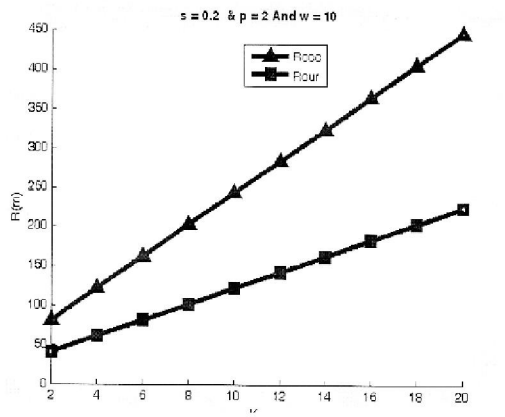

Figure (4): The comparison of the transactions' response time average between the traditional OCC and the suggested approach

The effective output of transaction is obtained by dividing the ratio the total number of transactions by the response time average. Needless to say, the effective output of each transaction increases when the transactions' response time decreases according to figure (4). Figure (5) indicates an improvement in the suggested plan. The increase in the transactions' size led to an increase in the conflict probability and the response time increases as well. In both approaches, the increase in transactions' response time led to a decrease in the transactions' effective output. But, the transactions' effective output shows lesser decrease in the suggested plan due the improvement in the response time. In such a way that to obtain $0.3<T_{our}<1.2$ and $0.2<T_{occ}<0.6$.

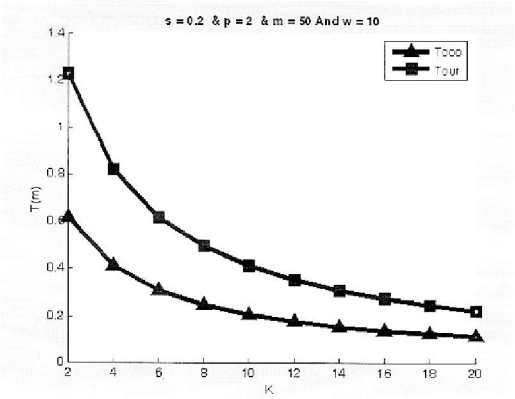

Figure (5): The comparison of the average of the transactions' effective output between the traditional OCC and the suggested approach

It is clear that the more the transaction size, the more the conflict probability in the system. If this transaction is a transaction condemned to abort, in traditional OCC techniques, the total transaction size will be evaluated in the final evaluation phase; but in the suggested technique, at least half of the transaction size will be evaluated in the intermediate phase; So if this is a transaction condemned to fail, it does not wait for the evaluation and prevents more conflicts by getting early aborted. As it is shown in figure (6), in both approaches, the increase in transaction size leads to an increase in the conflict probability. Regarding the evaluation environment parameters, in the traditional OCC approach, this conflict probability is between 0 to 20 and in the suggested plan, it is between 0 to 4.

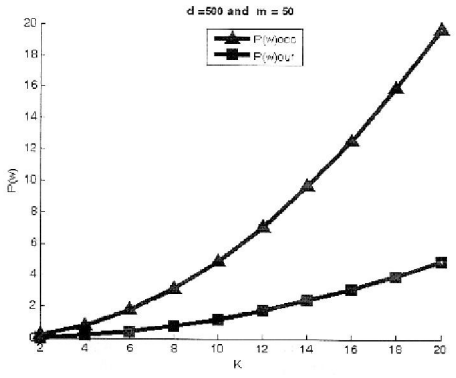

Figure (6): The relationship between the conflict probability and the transaction size and its comparison in the traditional OCC and the suggested plans.

Also, in the presented plan, due to the presence of the intermediate evaluation phase which of course does not create any delays in the transaction process, according to figure (7), the final evaluation time decreases. In both approaches, as the transactions size increases, the evaluation time increases as well. But in the suggested plan, commands will be evaluated after the check point in the final phase. In such a way that obtained $0.05<E_{our}<0.45$ and $0.1<E_{occ}<1$ when we consider the evaluation environment parameters of table (1).

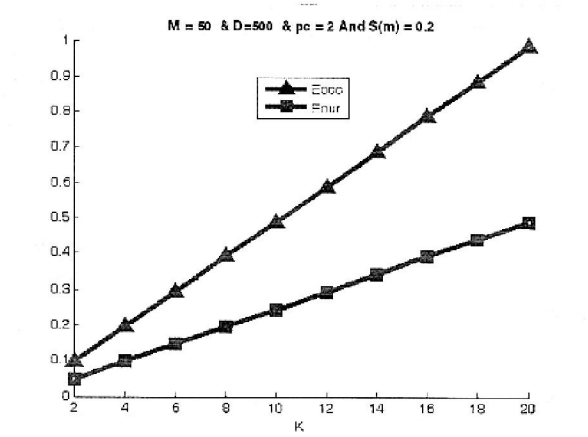

Figure (7): The relationship between the evaluation time and the transaction size and its comparison in the traditional OCC approach and the suggested plan

6. Conclusion

In the suggested plan, a set of MSSs form a zone and each zone is under the supervision of a station, namely the mobile transactions manager.

1. Under the proposed architecture, the time-consuming and costly operations such as the intermediate validation, the final validation and committing in the fixed and intensive part of the network, namely MTM will take place. Thus, the pre-mentioned operations will take place quicker and the fate of a transaction (commit or abort) will be determined sooner.

2.When sending the commit command from a mobile host, there is no need for a coordinator to send the commit command to all MTMs involved in performance of the transaction and simply should send it to the managers of each zone, MTMs, (MSS>>MTM). Therefore, the information exchange among the mobile support stations will decrease and so does the network traffic.

3.When committing the transactions, under the 2PC protocol, the coordinator which is responsible for committing should send the committing command to all mobile support station involved in performing the transaction. The coordinator waits until it gets 'yes' from all MSSs or set a specified deadline. If one of the MSSs stop working and does not send the message, the deadline will be missed and the coordinator attempts to abort the transaction [4]. In the suggested plan, in case of a failure in any MSS when receiving the answer 'yes', committing the transaction does not get delayed or often aborted.

4. Using the intermediate validation, the conflicting transactions can be identified and aborted sooner. In this way, we can economize significantly in consuming the system sources which is very vital in the mobile systems.

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