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Mobile Transaction Processing in Mobile Environment

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Abstract

The evolution of mobile computing device and wireless network has created a new mobile computing environment. Users equipped with portable devices can access, retrieve and process information while in mobility. Mobile devices like laptops; mobile phones become more powerful data processing elements. Traditional transaction model has moved forwarding to mobile transaction. This essay describes the mobile computing environment. The mobile transaction characteristics are discussed in detail as well as mobile transaction models. The research issues related to mobile transaction are outline.

1. Introduction

At present, many type of mobile computing devices such as laptops, personal digital assistants (PDA) are available. The capacities of these mobile devices become more powerful. They have more processing speed and longer operating time. Mobile computing devices are becoming the major work processing equipments in every daily activity. Combining with the expanding of the high-speed network like the Internet, mobile computing applications are growing rapidly.

The environment for processing and accessing information is changing rapidly from human-requested interaction to fully automatic processing at anywhere anytime. For example, the banking system has been shifting from traditional banking to Internet banking. Ten years ago, people could go to the bank to withdraw money in personally, then with the help of Automatic Teller Machine (ATM) the withdraw activities can perform anywhere anytime. By the advantages of the Internet, banking system has been moving to Internet banking system. According to [11], banks with transaction website increase from 21 per cent in September 1999 to 44 per cent at the end of year 2000. Customers can access to the bank through their computers at home and perform transactions online. The use of online transaction with debit card has increased more than 400 per cent from the period 1992 to 1996 [7]. With in seven years from 1991 to 1997, business-to-business electronic payment has increased from less than 10 million to 45 million financial electronics data interchange (EDI) payments [7]. With the help of portable devices, Internet banking transaction can be operated from laptop computers or other mobile devices like mobile phones. Moreover, many online applications like personal services to product and business services [11] [13] have been offered to customers.

The above example shows that the information processing environment is changing forward to mobile environment. In this essay, I will review and discussion topics

related to mobile transaction processing in mobile computing environment. Section 2 of the essay will describe the currently agreed mobile computing environment. In section 3, the challenges and characteristics of mobile computing is review and discussing. Mobile transaction is discussed in section 4. Section 5 outline some of the current research issues in mobile transaction and section 6 gives the conclusion of the essay.

2. Mobile Computing Environment

It is important to identify and define the mobile computing environment. Based on that defined mobile environment, requirements as well as characteristics will be identified. Mobile computing environment includes: a wired network with fixed work-stations or fixed hosts (FH), mobile hosts (MH) and mobile support stations (MSS) [3] [4] [8] [9] as in figure 1.

Connection between MH and MSS is wireless network, this network is characteristic by it low bandwidth, error-prone and frequently disconnection. These characteristics will be discussed in detail in section 3. MSS and FH communicate with each other via reliable high-speed connection networks, which can be wired network or wireless network (within limited range, such as inside a building). The MSS is motionless. Mobile hosts can include broad types of mobile devices, typically laptop computers with high-speed modems. Works can be sharing between MH and FH. The role of MSS is not processing element but it is acting as an interface to help MH getting contact with relevant FH.

Each MSS responds for an area (called a cell) in which it will support all MH operate in this area. One MH can only connect to one MSS at any given time. A mobile host is moving from one area to another area when computation work is in processing, and sometimes MH requests to connect to a database or computing resource resided from a FH on fixed network. This work will be done with the help of MSS. Mobile support station will receive requests from MH, forward the requests to the responsible FH and return the answer from the FH to the MH. When a MH is leaving a cell controlled by a MSS, this MSS will perform a hand-off operation to transmit or forward all information related to this MH to next MSS. The next MSS in new cell will be ready to support the MH.

Databases and other computing resources are stored on the fixed host on wired network, this environment allow mobile environment inherits from the current existing distributed computing environment. Normally, power supply and storage device limits mobile host computing capacity. However, with the current technology, the power of mobile computers can last for several hours and the storage devices can store a large amount of data [5]. Then mobile hosts can become major hosts for data processing.

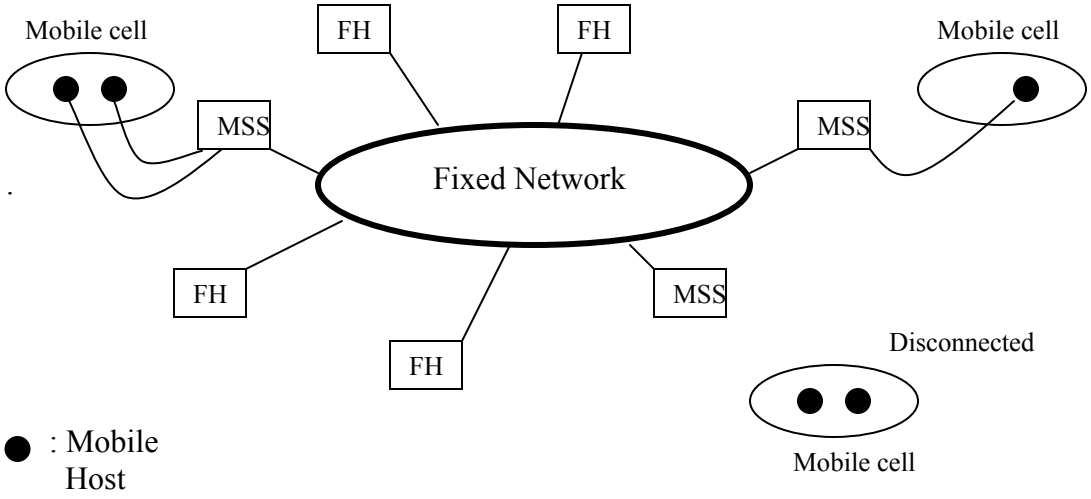

Figure 1. Mobile Computing Environment

3. Characteristics of Mobile Computing and Research Problems

The main characteristics of mobile computing environment are communication, mobility, portability [6] and heterogeneity [3]. There are many research issues that are rising from these characteristics.

3.1. Communication

Mobile hosts connect with mobile support stations through wireless network. It is obvious that this wireless network does not have capacity as fixed wired network. First, the wireless bandwidth is very low, for example cellular network has bandwidth in the order of 10Kbps or wireless local area network has bandwidth of 10Mbps [5], Second, wireless network are higher error rate and frequent disconnection [3] [5], the same network data package may require re-transmit many times.

When MH is moving from one cell to another cell, the current connection with MSS will need to be changed to new connection. This process requires two steps: disconnect from the current connection, and establish new connection.

The above disadvantages result in taking more time to transfer a same amount of data from the MH to FH and via versa. Re-transmit data causes unnecessary processing power, which is already very limited on the mobile host. The situation is more complicated if two mobile hosts need to exchange data during cooperative work. Messages cannot be delivery directly between two MH but via one or more MSS. Because of larger overhead in communication time, the longer time requires for mobile host to perform computation. Caching mechanism is currently the major method to eases the problem.

3.2. Mobility

Mobility is the most frequency activity of a mobile host. When MH is moving from one cell to another cell in wireless network, the connection will need to be changed because one MSS can only support mobile hosts within its limited area. This cause frequently need of re-configuration network topology and protocols. The more mobility the more time spends on re-establish communication between MH and MSS.

Because the activities of MH need supporting from its MSS, therefore location management is another problem caused by the mobility of MH. Mobile hosts need to track MSS in order to obtain data from the FH or other MH. In the other hand, MSS also needs to keep track on MH in order to transmit the result from the FH or to update the state of current mobile host profile.

Mobility of MH raises the question on location dependent data [10]. The same query will have different results depending on the location of MH. For example, bus timetable will depend on the location of the bus stop.

3.3. Portability

The availability of mobile devices depends on their power supply. A mobile phone can live up to five days but the laptop can only be for several hours. The more complicated application requires more processing power. Refining computation process into smaller partition (fined grain) or shifting heavy process from MH to FH for processing can save energy.

Communication in mobile hosts requires a lot of power. Compressing data or data distilling before transmission can reduce communication time. Caching is also help mobile computer works in disconnected period.

Portability of mobile devices requires more sophisticated software applications. MH has smaller user interface like display screen, keyboard [6]. Many PDA support handwriting, therefore handwriting recognition software is required.

3.4. Heterogeneity

One MSS needs to support broad types of mobile devices which operating in its cell. Identifying what kind of hardware of the MH is important. Different MH requires different applications and data representations. When MH requests communication with other MH, the heterogeneous problem needs to be taken into account. How do MSS solve this problem? A Composite Capabilities/Preference Profiles (CC/PP) profile can be used to provide a description of mobile device [14].

Different MSS are in different heterogeneous network and these MSS need to cooperate and communicate with each other for exchanging data. A standard interface

is needed between MSS. Java technologies or a middleware like CORBA can be used to solve the heterogeneous problems.

4. Mobile Transaction Processing

This section will review the transaction processing concept and discuss on mobile transaction.

4.1 Introduction on transaction processing

In [1] transaction is defined as following:

```
A transaction is a collection of operations on the physical and
abstract application state.
```

Transaction processing systems provides a means to record all states and effects of execution of program in computing resources. Transaction not only relates to operation on database system but also involves on many daily applications upon many computing resources like telephone call, email system, flight reservation.

A computation processing is considered as a transaction or conventional transaction if it satisfies ACID [1] [2] (Atomicity, Consistency, Isolation, Durability) properties:

- Atomicity: an executable program, assumed that this program will finally terminate, has one initial state and one final state. If it appears to the outside world that this program is only at one of these two states then this program satisfy the atomicity property. If there are intermediate result or message needs to be display, then they are not displayed or they are displayed in final state of the program. If the program achieves its final state it is said to be committed, otherwise if it is at the initial state after some execution steps then it is aborted or rollback.

- Consistency: if a program produces consistent result only then it is satisfy the consistency property and it will be at the final state or committed. If the result is not consistent then a transaction program should be at the initial state, in other word the transaction is aborted.

- Isolation: if a program is executing as if it is an only single program on the system then it satisfy the isolation property. If there are several other processes on the system, then none of the intermediate state of this program is viewable until it reaches its final state.

- Durability: if a program reaches its final state and the result is made available to the outside world then this result is made permanent. Even a system failure cannot change this result. In other words, when a transaction commits its state is durable.

The programming model of a transaction can be described as following:

```
Begin_transaction()
        Execution of transaction program
If (reach_final_state) then Commit_Work(final_state)
Else    Rollback_Work(initial_state)
```

The simplest form of transaction is flat transaction. A flat transaction can be considering as a sequential correctness computer program. Every execution step is after one another. Flat transaction has many disadvantages. For example, it cannot support long transaction efficiently. If failure happens during its execution then it has to rollback to its initial state and wastes all of useful computation.

Nested transaction is a more flexible transaction model. This model is a tree of transactions. A big transaction is refined into many smaller (flat) transactions called sub-transactions. These sub-transactions can execute concurrently in different processes in different processing hosts. The ACID properties are more relaxed in this nested transaction model.

4.2 Mobile Transaction

Mobile transaction is defined [3]:

```
A transaction submitted from a mobile host is called mobile
transaction.
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The mobile host, which issues transaction, and the mobile host, which received the result, can be different. For example, a user queries for a bus timetable from her laptop computer and requests the answer will send to mobile phone via SMS message. Because of the characteristics of mobile environment, mobile transaction has several additional requirements:

- Because MH has less processing capacity as FH, mobile transaction should be able to split into a set of smaller transactions. These shorter sub-transactions can execute on FH or other mobile hosts. If possible, most of the computation on the MH should be shifted to FH for processing. When computing tasks are moving to FH, the FH have more computing power and shorter processing time. In addition, the computing resources are closer in FH. If the tasks require extra computing resources, wired network bandwidth is faster for resource allocating than wireless network. MH can save energy by disconnecting their connection while waiting for the results from the FH.
- Mobile transaction has longer processing time or long-lived. Because of the communication overhead and frequent disconnection, the time required for exchanging needed data between MH and MSS is longer. A part from this, MH has slower processing speed therefore a same transaction on MH will require longer time for completing than on the FH.

- Mobile transaction should be executable when MH is in mobility and disconnected from the computing resources. It is not possible for MH staying connected all the time with the data resources. After the needed data has been caching into mobile storage device then MH can operate in autonomous mode. Data inconsistency in short time should be allowed. When the connection is established the new data item will be updated to the main database.
- Mobile transactions require being able to operate in distributed heterogeneous environment. Different types of MH cooperate in mobile environment and different database systems are accessed during execution state of mobile transaction. Mobile application should take into account the representation of data format in different system.

Mobile transaction is more complicated than conventional transaction in both of design and execution states. When a MH moves from one cell to another cell, many computing activities like establish new communication channel, forward the state of transaction to new MSS are involving. The execution of mobile transactions not only is normally unpredictable in time but also depends on their location.

Some of the techniques developed in conventional transaction such as two phases commit (2PC) protocol, caching mechanism need to be extended or modified to be able to apply in mobile transaction. Another issue is made the intermediate states of mobile transactions available to others. This will release locks on data item earlier and avoid blocking other transactions.

4.3 Mobile transaction models

Location and time of MH are the two major factors that effect on mobile transaction processing. This section outlines three mobile transaction models, which focus on mobility of MH. These three models are: Moflex [8], Pre-wite [4] and Kangaroo [9].

Moflex transaction model allows to model mobile transaction with extra information such as location, time and the precondition of mobile transactions. The sub-transaction T of mobile transaction M can be executable only when its external precondition predicated is satisfied. Moflex takes into account which sub-transactions are location-dependent.

Pre-write transaction model allows a transaction on a mobile host to submit a pre-commit state and the rest of the transaction can be carried out at the fixed or other mobile hosts at later time. The main point is making all the updated data items visible to other transactions. This model can be use to support mobile hosts which have little power for processing data. Pre-commit transaction model eases the locking on data record and avoid longer time blocking other transactions. However it is not carefully taking into account the risk of frequent disconnecting and higher error rates of wireless data transmission.

Kangaroo transaction model is developed beside the existing multi-database environment. Kangaroo mobile transaction does not start and end at the same host. In this model, mobile transaction hops through stationary hosts in wired network. The whole transaction and related information are pushing forward to the final committed host. Kangaroo model is supported by the autonomy of local DBMS. Kangaroo is one model that captures the movement nature of mobile unit.

5. Issues in Mobile Transaction Processing

Mobile transactions are long-lived, bound to many different types of mobile devices, involved in heterogeneous database and network, and execution time is varying. In this section, research challenges in mobile transaction are outline. The main focus topics are mobile database, service hand-off and scheduling.

5.1. Mobile Database

Currently, the mobile transaction is developed on top of currently existing database system. Most of mobile transaction models are based on the defined mobile environment. In this environment, the database resides, replicated and distributed on the fixed hosts in wired network. However, the capacity of mobile computing device is expanding and a mobile host can become a host for data processing or a place to store the native data. In this case, the physical location of database system is changing. Identify the location of the mobile hosts which stores the required data is one of the major issues in mobile database [5].

To obtain optimization on query processing, databases are replicated or fragmented in MH. Because of the disconnection and mobility of MH, maintaining data consistency between MH is more complicated. Location dependent data also needs to be considered.

5.2. Service Hand-off

When a MH moves into a new cell, a new MSS is assigned to this MH. Information about current transaction state is saved and transferred from old MSS to next MSS. This operation sometimes is unnecessary because not all the time MH requires assistant. The figure 2 illustrates the situation.

Mobile host *M* is moving from cell A to cell C through cell B. However, in cell B the MH does not need any assistant from MSS in cell B. The information about transaction state should directly forward to MSS in cell C. This information package also includes the hardware profile of MH, context of application and environment. If this information is stored at mobile host then the MH can become an active element, which can initiate a connection when needed. The question is how a MH finds out what MSS it should connect to.

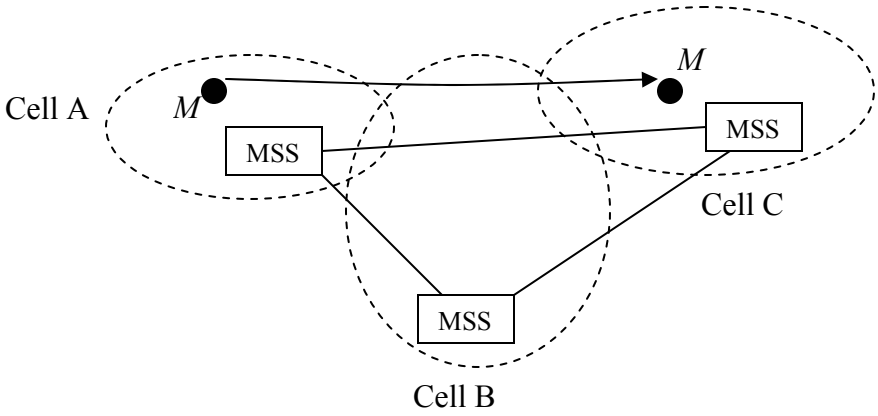

Figure 2. Service Hand-off Between MSS

Currently, when a MH wants to exchange information with another MH then they have to rely on the supporting from at least one MSS. How can one MH directly obtain communication channel with other MH?

5.3. Scheduling

As mention in section 4, execution time of mobile transaction is varying. Mobile transaction can easy miss its required deadline due to its mobility and portability. It is not applicable in mobile transaction if a missing deadline transaction is always aborted. Missing deadline causes inconsistency in global state of transaction and blocks other transactions' execution. Enforcing technique like earliest-deadline-first [3] can be applied.

Mobile transaction requires flexible scheduling mechanism. Scheduling a transaction in a fixed host is different from mobile host. Schedule in mobile transaction should takes into account the mobility of MH in both location and time. Mobile hosts should be able to reschedule its execution plan according to its physical state (power, communication bandwidth).

6. Conclusion

The essay has reviewed the mobile computing environment and its characteristics. The mobile computing environment can support mobile hosts to perform mobile transaction. Users can easily manipulate information despite of their location and what mobile devices they have. However, the disadvantage of this environment is that it cannot provide flexible way to exchange data between MH. One MSS respond for supporting all MH in its cell, this can cause a bottleneck when there are many MH in the same cell and single failure mode if this MSS fails.

Current mobile transaction models are based on existing database systems. The models along with the characteristics of mobile environment help to analyze the requirement of mobile applications. The challenge is that when every host in mobile environment is mobile host.

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