ISSN:0975-9646
Mohammad Shameer M C et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 13 (5) , 2022, 103-109

A Study on the Requirements of a Transaction Model in Mobile Environment

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Abstract – **The tremendous growth of wireless mobile devices, networks and their applications has revolutionized the way people communicate and interact with each other. It facilitates the users to access data without considering the physical location of the user or the data repository. The data access includes query and update of data. To deal with the data communication and other control information transfer in a disconnected wireless environment, a transaction model is inevitable. A transaction model in a mobile environment is a necessity to maintain consistency and maximize concurrency of applications. The requirements for managing the transactions in a mobile environment are quite different from conventional database oriented models as these schemes should consider the factors such as bandwidth constraints, distributed and disconnected environment and mobility in addition to the heterogeneous nature of data. The scope of transactions and data exchanges extends beyond database oriented activities to encompass the heterogeneous types of transactions and message exchanges in mobile wireless environments.**

This paper discusses the transaction models currently prevailing in the wireless mobile environment and makes a study of the features and limitations of each of these models. Most of the transaction models available in the mobile environment are replications of database oriented models. Such models cannot properly address the synchronization and consistency in the mobile environment, which is inherently heterogeneous, disconnected and distributed in nature. Since the number of users and amount of data transmission is tremendously increasing, active research is carried out in the mobile communication field to improve the efficiency of network functionalities considering the limitations of the mobile environment. The study reveals that in spite of the various technological advances being reported in the literature, there is a scope for an efficient model for transmission of data intensive transactions based on the legacy XML/html standard, inheriting the relevant features of existing transaction models like splitting, low resource intensive nature, suited for wireless environment.

Keywords - Transaction, Mobile transaction models, Resource constrained network, data formatting schemes

1 INTRODUCTION

The advent of wireless portable devices and communication infrastructure opened a new computing arena namely wireless mobile computing. A mobile computing environment comprises multiple agents that may require access to information generated in different geographically dispersed sites. These data generated in different locations are processed by a set of computational engines [3]. This movement of data is achieved through transactions. A transaction is described by the atomicity, consistency, isolation and durability (ACID) properties. The very fact that a transaction is recognized strictly by the ACID properties, indicates that a relaxation of the atomicity, concurrency and isolations properties will have to be allowed in the design of new transaction models that are developed as extensions for the traditional transaction models [20], [22].

The inherent characteristics of mobile wireless devices and networks such as low bandwidth, mobility, and constrained resources and the distributed nature poses several challenges for the research fraternity, in the development of mobile transaction models[12]. The main factors that constitute a mobile transaction model include data consistency and concurrency control, infrastructure development, performance constraints, communications costs, relocation mechanisms, user profiles and scalability [2], [3]. The mobile transactions follow a disconnected behaviour as the device can move from one base station to another during a transaction [1]. Due to the inability to retain such connectivity for longer time duration, a transaction is viewed as a collection of sub transactions [31]. The existence of sub-transactions that can be committed or aborted independent of the top level transactions make it a bit more complicated to manage. The dynamic nature and behaviour of agents and hosts makes the transactions bit more challenging in mobile computing environment [7].

2 MOBILE TRANSACTION MODEL

A mobile transaction has two important characteristics that make it distinct from the traditional transaction: non deterministic lifetime and relocation [15]. The inherent characteristics of mobile wireless devices and networks such as low bandwidth, mobility, and constrained resources, pose several challenges for the research fraternity, in the development of mobile transaction models [2]. They include data consistency and concurrency control, infrastructure development, communications costs and relocation mechanisms and user profiles and scalability [15].

Mobile wireless transactions models are the extensions of the following base transaction models: (i) open nested transactions [22], (ii) split transactions [24], and (iii) Saga – compensating transactions [20].

Open nested transactions are designed for long duration transactions. Split transactions divide a transaction into two independent transactions that are serializable and can be independently committed or aborted. The split transactions can later be re-joined. Saga is a set of relatively independent component transactions [20]. Each component transaction has a compensating transaction, which can be used to undo the effects of the component transaction. The transaction models for mobile wireless arena can be categorized to these three base models - open nested, split and saga transactions [15].

Available works reported in the literature are the kangaroo transaction model [18], clustering model [40], isolation–only model [40], two-tier transaction model [38], [41], reporting and co-transactions model [16], multi database transaction model [42], promotion transaction model [37], [42], [43], toggle transaction model [45], XML/HTML based agent communication system [8],[13], twin - transaction model [49][51], adaptable mobile transaction model [36], shadow paging technique [41], surrogate object based mobile transaction model [39], connection fault – tolerant model [51], semantic-based mobile transaction processing [23] and time based consistency model [17]. Most of the models described in the literature are distributed and/or database oriented. Those models having features relevant to the mobile environment are considered for the survey. A brief discussion about their features and limitations of each of these models are presented, in the following subsections.

2.1 Kangaroo Transaction Model

This transaction model depicts the behaviour and data movements of transactions when the mobile host changes from one cell to another cell in a static network. It is named so because in the mobile environment hop transactions move one base station to another [14]. The Kangaroo model is based on the abstract idea of global and split transactions in a multi database system. The model follows a tiered architecture. The model is extended with the addition of a data access agent (DAA) in the middle, which is responsible for mobile transaction management. DAA accepts transactions express to need from a mobile user, and forwards the request to the corresponding database servers [27].

The model has been refined to another model called the modified kangaroo transaction model. Both of these models assign a unique identification number for each transaction. The identification number consists of the base station number and unique sequence number within that base station [14]. Both these models are purely database oriented and they are used to communicate mobile devices through base stations. For every transaction or queries generated by the user, the DAA generates a set of global and local transactions, referred as Joey Transactions, required to control the scope of the mobile base station. When the mobile devices change from one base station to another, the control of the transaction is given to a new DAA in that base station. The DAA at the new base station produces a new Joey transaction [32]. The client devices request services based on the current location and is more important to be addressed [21].

Merits of this model include (i) message splitting, (ii) unique sequence numbering for transactions, (iii) mechanism for status tracking, (iv) improves the data concurrency by committing the split transactions quickly, and (v) use of a data access agent for managing transaction requests [15],[25],[36].

Demerits of this system include (i) communication is done between the host database and base stations, (ii) all transactions are channelized to the database either in the device or in the base station, (iii) the model is not used for transactions between an application server and mobile device, (iv) base stations will have to be enhanced to accommodate the DAA, and (v) the system doesn’t put forth any suggestions about the format used for message transportation [15], [25], [36].

2.2 Clustering Model

Clustering model is an open nested transaction model proposed for fully distributed systems. A cluster is a collection of related data items either by meaning or storage location. Clusters can be characterized statically or dynamically [30]. Each cluster is composed of reciprocally consistent data. The level of consistency may change calculating on the accessibility of network bandwidth among clusters [31]. The transactions from the mobile devices are classified to strict and weak transactions [54]. Weak transactions consist only of weak read and weak write operations which can be accessed only within the clusters. Strict transactions consist only of strict read and strict write operation which can access all the clusters [34]. Weak transactions from a host are committed within its cluster first and later communicated to others clusters.

Merits of this model include (i) supports distributed model, (ii) support for connected and disconnected mode to execute the transaction, and (iii) maintenance of data consistency in a fully distributed environment [15].

Demerits of the models include (i) non scalable - cost of maintaining clusters and their cluster inconsistencies increases with the increase in the number of clusters, (ii) the model is purely database oriented and data is transported as database queries, (iii) the unavailability of a middle ware or a proxy system for conversion hinders the communication between heterogeneous systems, and (iv) the model suffers from processing overhead as the changes need to be communicated locally and outside as well [25],[15],[36].

2.3 Isolation Only Model

This model is designed for the coda file system. This is purely a succession to normal file operations. Coda is a distributed file system that uses file hoarding and concurrency control for mobile clients which provides disconnected operations [40]. This model resolves read/write conflicts, considering the value or importance operation.

Merits of this system include: (i) mechanism to resolve read/write conflicts and, (ii) supports database communication in disconnected and distributed environments [25], [36]. However this system is only suited for devices supporting coda file systems [25], [36].

2.4 Two Tier Transaction Model

The model is based on the data replication scheme where the data is replicated to master and many replicated copies. The transactions are classified into base and tentative transactions. Base transactions act on master data but the tentative transactions work on replicated copies. When the mobile host is abrupt, tentative transactions modify the replicated data copy [25]. When the host reconnects, the tentative transactions are converted to base transactions and get re-executed.

The important advantage of this model is the support for disconnected distributed transaction processing [25]. The demerits of this model include (i) the model suffers processing overhead issues due to multiple executions of transactions. When the number of mobile hosts increases, this overhead increases dramatically, and (ii) the need for a mechanism to ensure the data integrity and consistency when taking replicas [25], [36], [38].

2.5 Report And Co Transaction Model

This model is proposed for the context of specific multi database systems. This model is considered as a collection of sub transactions either belonging to nested or open nested transaction models [22]. Nested transaction is a parent transaction that yields many child transactions, which doesn't share the results with the parent when executed. This model classifies the transactions to four types: (i) atomic transaction (normal transactions with begin, commit and abort sequences), (ii) non-compensatable transactions - it is not linked with compensating transactions. It can execute at any time and the parents of these transactions have the responsibility to commit and abort [28], (iii) reporting transactions - similar to the intermediate state between transactions. The reporting transaction will not assign all its results to its parent transactions [35], and (iv) co transactions – transactions executed together and share the results. In this model, in case one transaction fails, then both transactions are considered as failures as it shares the results.

Advantages of this model include (i) support nesting and split transactions, (ii) mechanism to individually commit child transactions, and (iii) buffering of transactions and intermediate results [15],[25],[36].

2.6 Multi Database Transaction Model

It is a model used in a multi database environment. In this model, calls for messages from a mobile host to its coordinating sites are dealt asynchronously allowing for the mobile host to unplug it [42]. In this model for each mobile work station there exists a message queue and a transaction queue [29]. Apart from these queues, additional queues such as input queue, output queue, and allocation table are used to manage local or sub transactions in the mobile end.

Merits of the multi database model include (i) support for multiple databases, (ii) queuing of transactions, (iii) mechanism for concurrency control, and consistency, and (iv) less costly compared to other models [15]. The demerits include (i) the use of interface layer over conventional databases to support mobile communication, and (ii) the queuing mechanism can cause performance bottlenecks [15], [25], [36].

2.7 Pro-Motion Model

This model is grounded on the nested transaction model [26]. This model supports distributed, disunited mode of transaction processing based on client server architecture. Mobile transactions are conceived as long and nested transactions where top level transactions are executed at fixed hosts, and sub transactions are accomplished at mobile hosts [33]. Disconnected transaction processing is a dominant transaction processing in pro-motion [30]. Advantages of this model include (i) support for nested and sub transactions, and (ii) disconnected architecture [25]. The demerit of this model is that the model demands for high resource content at the mobile host [25].

2.8 Toggle Transaction Model

This model is a transaction model similar to the multi database model. In this model a mobile multi database system is determined as an assembling of set and mobile databases [44]. Mobile multi database management system is the software which occupies a determined network and operates several database systems. Similar to DAA in the Kangaroo model, this model makes use of a mobile support station (MSS) to support the global transactions. When the mobile changes location, different MSS systems support the transactions [45].

2.9 Xml/Html Based Agent Communication Model

There are two models in this category: (i) a distributed processing architecture based on XML [8], and a M-Commence Transaction Model (MCTM) [13].

A distributed processing architecture based on XML is discussed in [8]. It uses XML for sending and receiving data between the nodes (referred as agents in the system). In this mode, the mobile agent is a FIPA (The Foundation for Intelligent Physical Agents) compliant mobile agent platform. The model uses FIPA Agent Communication Language (ACL) messages for both inter-agent communication and inter-platform migration [8]. In this case, messages are sent and delivered according to the FIPA specifications namely transport-message format. A transport-message consists of a payload and an envelope. The envelope includes the sender and receiver transport descriptions, and the payload encodes a message [8].

The main advantage of this model is that it provides a distributed processing feature similar to a client- server based system [8]. The model uses XML as the payload to transfer data to the client node. It is widely used for communication between applications over networks, irrespective of platform [19]. The demerits include (i) the use of an agent module which is to be installed on the communicating base stations, (ii) some devices may need to communicate data with the application server while some other devices need to synch/update data with the server. These issues are not properly considered in the system, (iii) due to the resource constraints, wireless mobile devices and wireless networks may impose a limit on the size of messages transmitted over the network. To overcome this, large messages should be chunked before transmitting and on the receiving side the messages should be reunited. This issue is not addressed, (iv) the sender is not acknowledged for the receipt of data chunks, (v) the model uses queues for keeping messages to be transmitted, but no provision is made to address the non-availability of the network at the time of/during sending, and (vi) the model make use of XML for data exchange. Size of XML messages is considerably big due to the abundant use of tags [13]. This may hinder the suitability of the model in the constrained mobile wireless environment due to the possibility of huge size of messages [56].

M-Commence Transaction Model (MCTM) [13] is a distributed database oriented transaction model used in e-commerce mobile applications. The model analyses and characterizes the transaction requirements, diverse transaction protocols and their suitability for group-oriented m-commerce services [13]. The model is specially designed for e-commerce applications - used for buying and sending products online. The model covers only one side of the mobile transaction requirements and the other side (from server to device) transaction is still unaddressed. The changes in the server after the user has logged to the system is unaware to the handheld devices since there is no way to handle unsolicited messages from the server. Another issue is that the data is moved in the form of html/xhtml. Considering the network traffic and the handheld device processing capability, this is not always entrusted [55]. This model is nothing more than a mobile web.

2.10 Twin Transaction, Adaptable And Surrogate Model

For transaction models listed in this section, only peripheral level details are available.

Twin transaction model support both connected and disconnected models of operation [49]. A mobile web related transaction model is proposed in the P system-based mobile transaction model [51]. This model has two transition rules namely membrane rules (defines the structural modifications) and object rules (defines the structural modifications).

Adaptable mobile transaction model permits defining transactions with several execution alternatives associated to a particular context [36]. This model is suitable for a variety of transaction executing contexts. Also improves the commit possibilities and permits to select the way transactions will be executed according to their costs.

Surrogate object based mobile transaction model is an improved version of kangaroo transaction model. It supports data caching features for improved data accessing and operating during transaction processing [39].

In Mobile-Shadow technique, a new and enhanced shadow paging technique is used for handling mobile transaction processing in disconnected environments. This model discusses the use of notation actionability taken during the transaction validation phase with respect to affected attributes [41].

Connection fault - tolerant model was proposed for the mobile environment which reduces the blocking time of resources at the fixed devices and provides fast recovery from connection failures, thereby improving the number transactions executed [36].

3 SUMMARY

From the literature review presented so far, it can be concluded that the available transaction models offer a lot of advantages for mobile applications. Among these models, the split transaction model, two-tier transaction model, multi database transaction model and XML/HTTP agent based model are of particular interest due to their common/distinct features that are suitable for handling mobile transactions in a reliable and consistent manner. A summary of the relative merits and demerits of these approaches are presented in the table below.

Table 1
Relative merits and demerits of prominent transaction models

Label	Type	Relation
Kangaroo transaction model	●Split/ rejoin of messages ●Heterogeneous multi database ●Movement in connected mode ●Agent based	●Fixed network ●Does not support disconnected mode of operations ●Thin middleware architecture
Two-tier transaction model	●Fully distributed database ●Movement in connected, disconnected mode	●More processing overhead due to multiple execution ●No mechanism to control data integrity and concurrency issues
Multi database transaction model	●Fully distributed database ●Movement in connected, disconnected mode ●Queuing mechanism ●Concurrency and data integrity control mechanism	●Queuing can create bottlenecks ●Use of interfaces layer over conventional databases, not supported by modern mobile systems
XML/Html based agent communication model	●Distributed, client-server based message exchange using XML	●Fixed/fully connected network architecture ●No queuing mechanism ●No message split/rejoin ●No middleware system to support data conversion

4 CONCLUSIONS

Transactions in mobile environments are common nowadays. A transaction model in a mobile environment is a necessity to maintain consistency and maximize concurrency of applications. The requirements for managing the transactions in a mobile environment are quite different from conventional database oriented models as these schemes should consider the factors such as bandwidth constraints, distributed and disconnected environment and mobility in addition to the heterogeneous nature of data. A lot of works are reported in the literature related to transaction models. In spite of the numerous advantages offered by the existing systems, it can be seen that a lot of issues are to be addressed in the area such as [8][15][25][36] (i) all the available transaction models, are database oriented, (ii) majority of them do not support distributed and disconnected architecture in the database level (which are essential in a mobile wireless environment), (iii) since the transaction models are database oriented, predicting the behaviour of these models in GPRS/mobile data connection is challenging, (iv) queuing mechanism is applied only in multi database transaction model – but the transaction queuing creates bottleneck, (v) proper acknowledgement mechanisms are not addressed, (v) particularly in XML/HTTP message exchange models, the huge verbosity of XML format can be a limiting factor for the resource constrained devices and wireless networks, (vi) data synching mechanism is not adopted, and (vii) lack of a middleware component to support heterogeneous server communication.

Transaction models in a wireless environment should be a blend of base models - open nested and split transaction model. Existing distributed database oriented models are rephrased to use in wireless environments. The reuse of existing transaction models in wireless environments hinder the efficiency of transaction and leads to resource overuse. From the literature survey, it can be noted that there is a scope for a transaction model that is suited for a resource constrained wireless environment, that inherits the features of models such as split transaction model, two-tier model, multi database model and XML/HTTP agent based model, and at the same time complementing with features such as lightweight, multi-tired, store and forward, non-blocking communication, reducing message conflicts, handshaking mechanism to reduce inconsistencies and middleware support. In addition to this the provision to include a generic semantics that is suitable for any message exchange can also be incorporated. Thus a novel transaction model specifically suited for a mobile environment with features as discussed is to be proposed and its efficiency is to be substantiated with experimental analysis. These are the future research directions of the proposed work.

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