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Application Research of Mobile Database Model Based on Ad Hoc Network

Ying Qi[1] and Tao Zhang[2,*]

[1] *Songshan College, Heilongjiang University of Science and Technology, Harbin 150080, Heilongjiang, China*
[2] *Information Commission Office, Heilongjiang University, Harbin 150080, Heilongjiang, China*
**Zhangtao2668@126.com*

Abstract

Mobile database is a kind of distributed database which is able to support mobile computing. For traditional mobile database model, there are some problems in Ad hoc network such as significant increase in the number of transaction conflicts, in communication costs, etc. Therefore, it is necessary to improve the traditional mobile database model. The paper aims at proposing algorithms of data synchronization and transaction redo etc. to enable mobile host to get access to the database efficiently and correctly. The experimental results show that the new mobile database model has good stability.

Keywords*: Mobile database; Database model ; Ad Hoc; Transaction redo;*

1. Preface

With the development of network technology, information technology and database technology, mobile application has gradually changed people's life and work. However, as a main support of mobile application -- mobile database is able to meets the needs of getting the information that one needs anytime and anywhere. That is to say a new era has opened up and it would have gradual impact on us in every aspect. Traditional mobile database model mainly includes server, mobile support node and mobile host. The traditional mobile database has the following problems: the location of the mobile node is not fixed, the network communication is not symmetrical, and disconnections of the network occur frequently, the storage capacity and the processing ability are limited. However, the network based on traditional mobile database model has a large number of basic communication facilities such as base stations, mobile switching centers, etc., and most of them have been built around the city. Therefore, it is not necessary to consider too much about the effects of environment. As a multi-hop, centerless, self-organizing wireless network, Ad hoc network is adopted mostly because the environment or other factors are not conducive to laying infrastructure or the infrastructure has been damaged. In reality, one of the typical applications of Ad hoc network is for the investigation teams to perform field missions, to help disaster relief, and mine surveying, etc. In Ad hoc network, in view of the reasons such as limited capacity of energy and storage of the mobile host, limited bandwidth, and frequent disconnections with the master server, etc., it will bring about a lot of problems to apply the traditional database model to Ad hoc networks, it is necessary to improve the traditional mobile database model to accommodate Ad hoc network.

Many experts have done in-depth study on mobile database, including Mallikharjuna Rao, N. Naidu, etc. who have applied fuzzy database to mobile database model, thus it solved the problem of uncertain data storage, improved the performance of mobile database model; Le Gruenwald, Shankar M. Banik, who also provides the methods of

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managing real-time database transaction in Ad hoc network. Renmin University of China has made a research and development on "Kingbase Lite" which is a successful project based on embedded mobile database system of Pocket PC; Professor Zhou Xingming, etc. of National Defense Science and Technology University has proposed tertiary replication systems structure of mobile database [1], it divides the data replication into three levels: replication between servers, air replication, replication among move nodes. Besides, they have made a theoretical explanation of three-tiered structure; it is a great contribution to data replication techniques.

Nowadays the related technologies of mobile databases we have studied both at home and abroad mostly based on Ad hoc network. It usually contains a lot of base stations and other infrastructures such as data exchange centers. The communication quality of these facilities is relatively good; the mobile facilities are able to supplement or replace the power timely; network disconnections of mobile host may occur frequently, but the mobile facilities as well as server communication can be restored timely and the cost is not high; the geographical location and environment which human beings often do activities are not very bad. However, with the expansion of the scope of work, the environment is not conducive to building communication infrastructure or the communication facilities in such environment have been damaged. Thus, the existing network can't meet the corresponding requirements, so they need a new network technology to solve these problems. As a centerless, no infrastructure, self-organizing wireless network, Ad hoc network is a good choice which can meet such needs. However, the traditional mobile database model didn't design for Ad hoc network, for example, the Ad hoc network nodes may join or exit at any time, changes in network topology occur at any time, the communication cost with the remote server is high, and disconnections with remote server often occur. Besides, the environment may affect the communication quality [2]; the power capacity is limited, etc. Therefore, the traditional mobile database model cannot adapt to Ad hoc networks well. It is necessary to improve the traditional mobile database model, propose some new algorithms, and provide some solutions to the problems. These are the main research content of this paper.

2 Mobile Database Model based on Ad Hoc Networks

Ad Hoc network is a multi-hop, centerless, self-organizing wireless network. Owing to its poor communication quality, limited bandwidth, small coverage, limited energy and storage capacity of the mobile host, as well as frequent disconnections with the master server, etc. the application of traditional mobile database model in Ad hoc network may bring about many problems such as increase in communication cost, increase in the number of transaction conflicts, delay in transaction, and rise in failure or error rate of transactions, increase in false transaction operations, even cause breakdown of the entire network because of long time disconnection with the master server. In order to apply mobile database technology to Ad hoc networks, it is necessary to improve the traditional mobile database model to accommodate the Ad hoc network.

2.1 Mobile Database Model

Mobile database model consists of four major elements, as shown in figure 2.1.1:

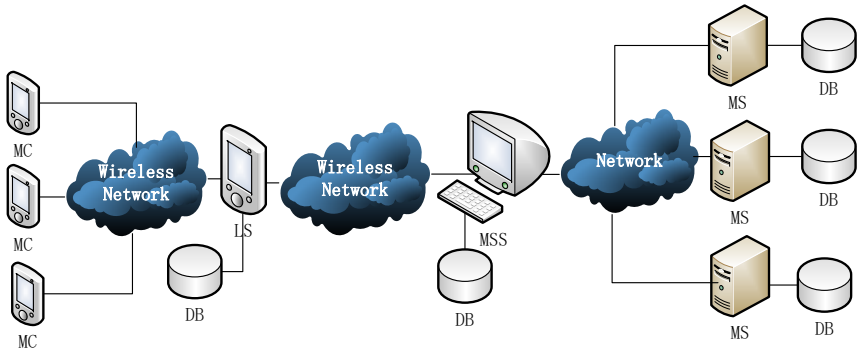

Figure 2.1.1 New Mobile Database Model

(1) Master server (MS): - generally it is a fixed node in the network which has its own database that saves all the data for users to use. It only contacts with local server.

(2) Local server (LS): it is selected randomly from a mobile host which belongs to mobile nodes in Ad hoc networks. It saves the copy of partial data of the master server. As an intermediary between the master server and the mobile host, it is responsible for processing the transaction requests of mobile host. In addition, since it is mobile node itself, the performance will be affected by environment, self-configuration, power and other factors [4].

(3) Mobile host (MC): The processing ability, storage capacity and energy are limited; the cache can store frequently-used data. Since it is in Ad hoc networks, network disconnection often occurs, thus its reliability is relatively low, and the time of network delay is long.

(4) Mobile support node (MSS): it is located in a fixed network. It can be a general host as well as a server which is responsible for data transmission between the mobile host and the server.

The relationship between the mobile host and local server still complies with traditional mobile database model. The difference is that the local server is selected from the mobile host, and it is located in Ad hoc networks. Mobile host still has cache which saves part of frequently-used data in order to reduce the frequency of users' accession to the database server, thereby improving the performance of the system.

2.2 Operating Mode

Add local server to mobile database model. The local server acts as the role of local master server, connects the mobile host and the main server. The operating mode changes from the original one: mobile host – master server to the existing operating mode: mobile host – local server - master server. This will bring new features which are different from traditional mobile database.

When the mobile host needs to access the data:

Step 1 First, check whether there are data the mobile host need in our own cache. If we have, access to it directly. If we don't have, apply for data requests to the local server, execute Step 2.

Step 2 If there are application data in the local server's database, apply for accessing the data and returning the results to the mobile host [5]; If there aren't any data for the mobile host to access in local server's database, execute Step 3.

Step 3 local server accesses the main server, downloads the data to local server's database, and then offers it for the mobile host to access. If data updates occur on a local server, the updated data will be uploaded to the master server.

The core idea of the improved mobile database model is to take the local server as an intermediary between the master server and mobile host, to act as master server in local Ad hoc network. Its operating principle is shown in Figure 2.2.1:

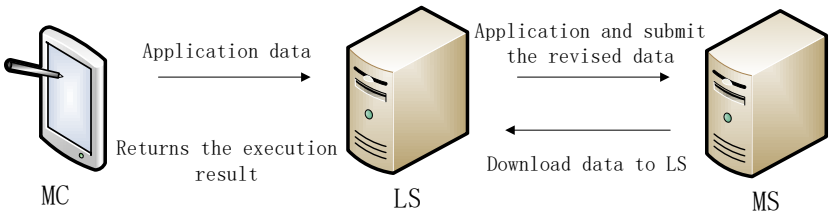

Figure 2.1.1 The Operating Mode of Mobile Database

2.3 Main Features

(1) Save a copy of partial data of the master server on a local server. It is responsible for obtaining data and submitting data updates to the master server, and when all the mobile hosts want to access the data cache [6], if they don't have, they just send a request to the local server rather than contacting the master server directly.

(2) Considering the characteristics of Ad hoc networks and one of the applications is in the wild, ocean or remote places, the communication will be affected by the environment. So it is not practical for all the mobile hosts to contact the master server. Therefore, in the new mobile database model [7], all the mobile hosts will contact with the local server only. This can avoid that the mobile hosts contact with the master server because they do not have the data needed in the cache and thus bring a large number of data requests, reduce unnecessary bandwidth waste of uplink and the time delay of data requests. Therefore, it saves energy of mobile host, processes transactions faster, and gives feedback of the execution results to the clients as soon as possible.

(3) The master server adopts the combination strategies of the real-time broadcast and periodic broadcast: after updating the data on the master server, the reasonable choice of broadcast strategy will be decided based on data usage frequency; data updates of local server will use immediate update strategy which will upload to the master server immediately. It can reduce the probability of a mobile host reads invalid data and ensure that the mobile host uses the latest version of the data as far as possible. Meanwhile, to guarantee that the data stored in the database of master server is always the correct version and the latest.

(4) The cache of the mobile host can store frequently-used data, but the storage capacity is small. The database of local server stores a copy of all or most of the data of the task, the data in the cache is only a subset in the local server's database. Ad hoc networks can be considered as a small self-running network, the local server is equivalent to the master server, so the updated data in the cache will promptly upload to the local server. For mobile cache and the local server in local Ad hoc networks, always guarantee that the data in the database of the local server is the latest version.

(5) Since the mobile host only contacts with the local server, local data server stores a copy of all or most of the data of the task [8], once disconnection occurs with the remote server, the local Ad hoc networks will not be affected much in a period of time, the mobile host will work properly, all updated data of transactions will store on the local server, after reconnection of the network, these updated data will upload to the master server.

(6) The new mobile database model based on Ad hoc adopts data update strategy of weak consistency. In view of frequent network disconnections, limited communication bandwidth and other conditions, the strategy allows inconsistencies between data copy stored on the local host and partial data of the major version on the master server for a certain time. Then, maintain data consistency between the data of major version and the copy data through corresponding data update.

3. The Study of Data Synchronization Strategy in Mobile Database

3.1 Outdated Data Detection

In Ad hoc networks, due to frequent disconnections of wireless networks as well as network communications etc., it is impossible to make consistency between the data in the local server and the master server, even the immediate updating strategy has been adopted. In addition, the accessed data of mobile host in the new model are data on its own cache or on the local server. It is inevitable for some transactions to use outdated data, but for clients, they expect to use the latest and correct version of the data.

Firstly, give the format of storing data in the database. It is composed of two parts, including the data content and the data timestamp of master server updates respectively. The data timestamp of master server updates refers to recently updated time took place in the master server; data contents also contain several items which have been reflected in the program.

Definition 3 Outdated data refers to data which has not been updated timely and became invalid data.

Clients want to use the latest version of the data, the newer of the version, the more accurate, the greater value it creates for clients who use the data. Therefore, the outdated data should be identified as soon as possible. However, how to judge the data that transaction uses on the local server is outdated? [9] This is the problem we're going to discuss below. Assume that the update time of master server of data d on the local server is T_{nu}, set the start time of using data d on the local server T_{ls}, the methods of judging the use of outdated data on the local server are as follows:

1. If $T_{ls}<T_{nu}$, data d used in the transaction is not outdated.
2. If $T_{ls}>=T_{nu}$, data d used in the transaction is outdated.

The algorithm of judging the outdated data used in the transaction is simple. When the start time of using data d in the transaction on the local server happened before the updated time of data d on the master server, the transaction is considered not to use the outdated data; otherwise the transaction is considered to use the outdated data.

3.2 Redo Network Transactions

Algorithm 1: Read transactions redo

Step 1 If $T_{ls}<T_{nu}$, execute Step 3; otherwise, execute Step2.

Step 2 If $T_{ls}>=T_{nu}$, check the level of the transaction:

1. If it is a slight level, you do not need to redo, turn to Step 3.

2. If it is a general level, continue to execute the transaction, meanwhile the local server sends a prompt of outdated data to the mobile host, let (mobile host) users choose whether to redo: If the user decides not to redo, then turn to Step 3; If the user decides to cancel, then cancel the transaction, restart and execute Step l; If feedbacks haven't been received, it defaults not redoing necessarily, execute Step 3.

3 If it is an important level, cancel the transaction, restart and execute Step 1.

Step 3 the end of reading transaction.

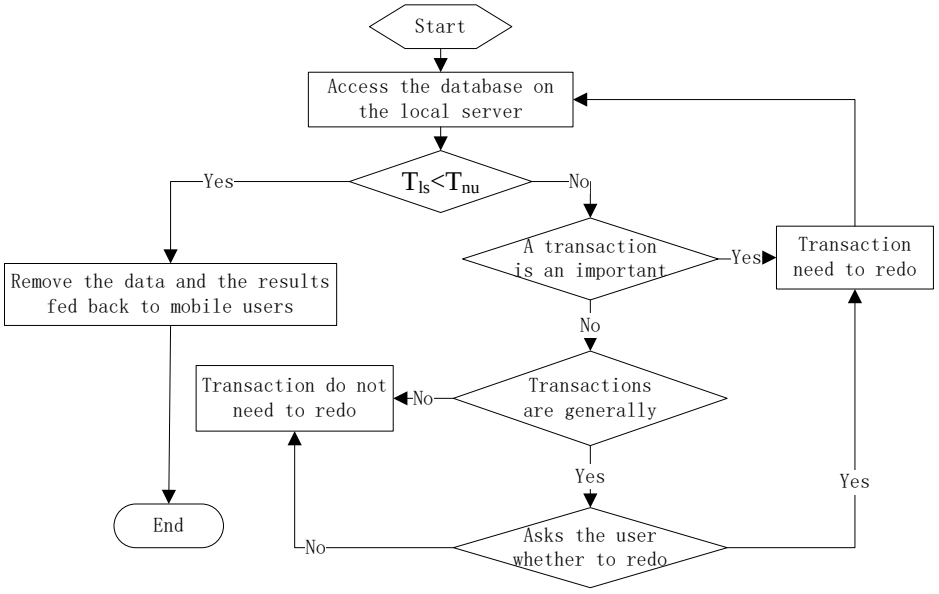

Figure 3.2.1 Read transaction Flow Chart

Algorithm 2: write transactions redo

The whole execution process can be divided into two stages, the first stage is to update the data of the local server, and the second stage is to update the data of the master server.

Step 1 In the first stage, when $T_{ls}>=T_{nu}$, cancel the transaction and initiate a new transaction to do the same work; otherwise, continue to execute Step 2.

Step2 In the second stage, before updating the data of the master server, to apply for adding a write-lock to the corresponding data of the master server.

1 If the application is failed, it shows that the data is being used, then cancel this transaction, and initiate a new transaction to do the same work, execute Step 1.

2 If the application is successful, submit the local data updates to the master server to conduct the corresponding data update, and then execute Step 3.

Step 3 complete the data updates on the master server, that's the end of write transaction.

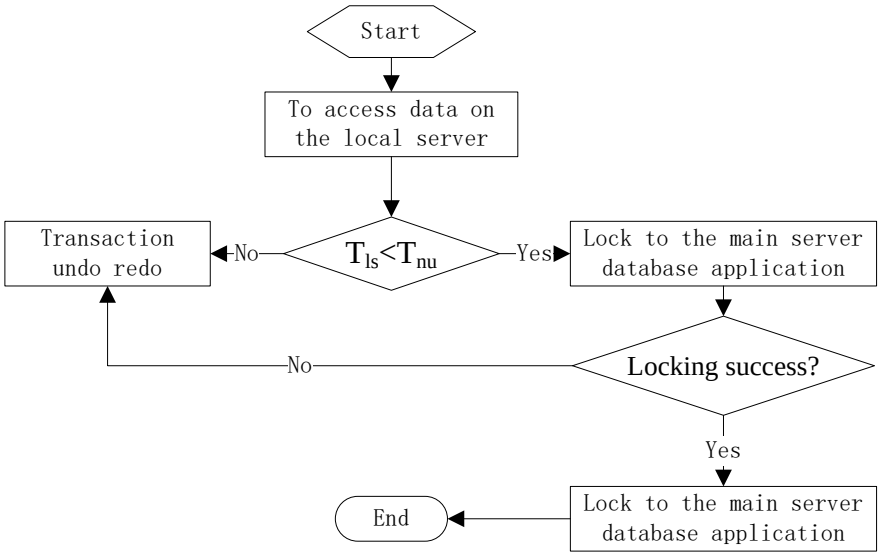

Figure 3.2.2 Write Transaction Flow Chart

3.3 Redo the Network Transactions

The above algorithms of transaction redo are suitable for the situation when the disconnections between the local network and the master server are not frequent. However, for mobile network, frequent network disconnection is a feature of its own and it needs a further discussion. When disconnection occurs frequently between the master server and the mobile network, the transaction executes on the local server, but because it cannot receive the updated data of the master server, so whether the data used in the transaction is outdated is unknown. However, the longer the network disconnection lasts, the data is more likely outdated, and there are a greater number of outdated data. In the process of network disconnection, the transactions should be recorded in the log. After reconnecting the network, the server will send the updated data during the period of disconnection to the local server and identify the outdated data through detecting mechanism, then determine whether it is necessary to redo the transactions which has used the outdated data [10]. Since the detection method of the outdated data is the same as above, the following will explain the research whether it is necessary to redo the transaction which the outdated data has been used.

4 Experiment Results Contrast

It has already mentioned above, the traditional mobile database model usually contains a lot of base stations and data exchange centers. The communication quality of these facilities is relatively good; the geographical location and environment which human beings often do activities are not very bad. The communication cost between the mobile host and the remote server is not high. Disconnections between the mobile host and the master server occur frequently but the mobile host can supplement the power or replace the batteries timely. However, there aren’t any fixed communications infrastructures in Ad hoc networks, the network nodes will exit or join at any time, and the network layout will change as well. It can not be restored timely after the network disconnection, the communication range of the mobile host is limited, etc. Thus, it is difficult for the traditional mobile database model to adapt to Ad hoc networks well. Therefore, the article has improved Ad hoc networks and designed a new mobile database model. In the simulation test, we have applied the new model to the local Ad hoc networks. Through experimental data, a comparison has been made between the traditional model and the new model, it shows that the new model can adapt to Ad hoc network better and improve system performance thus achieve the purpose of the research.

4.1 Program Execution Steps

Step 1 a number of mobile phones apply for data to the local server (this is achieved through multi-threading), the transactions obtain the right to use the data, execute the corresponding transaction on the local server, if reads the transaction, the transaction ends; if writes the transaction and update the data on the local server, then execute Step 2. During the time, if there is updated data arrives, through one-digit array, if the data which the transaction used has been updated then revoke the transaction.

Step 2 If the transaction is a write one, the local server submits data updates to the master server, apply for the server's lock. If the lock is successful, send the updated data to the webpage of the master server; otherwise, revoke the transaction.

Step 3 master server obtains the updated data via the webpage, and it updates the data of the primary database and pass the successful update message to the local server, thus, the transaction ends.

4.2 The Experimental Results

Definition 1 The average length of transaction refers to the length of time required for the transaction to run independently. (Other transactions do not exist)

Definition 2 The complete time of transaction refers to the time taken from the beginning of data application to the normal termination of transaction.

Definition 3 The number of times of transactions redo refers to the number of transactions redo times after using the outdated data.

The performance and stability of the new model have been tested through experiments in this paper. Take the following factors into account such as the number of concurrent execution transactions of the investigation teams, mineral resources reconnaissance is generally several to dozens. The average time of executing a single transaction on the mobile terminal is from tens to hundreds milliseconds [11]. When the given number of transactions are 10, 20, 30, 40, 50, 60, 70, 80, 90 respectively, the average length of each transaction is 400ms, 800ms, 1200ms, the changes of average completion time of transactions through the experiment are shown in the following figure, the horizontal axis is the number of transactions, the vertical axis is the average completion time of the transaction. NMDN stands for the average length of transaction of new mobile database model; TMDN stands for the average length of transaction of traditional mobile database model.

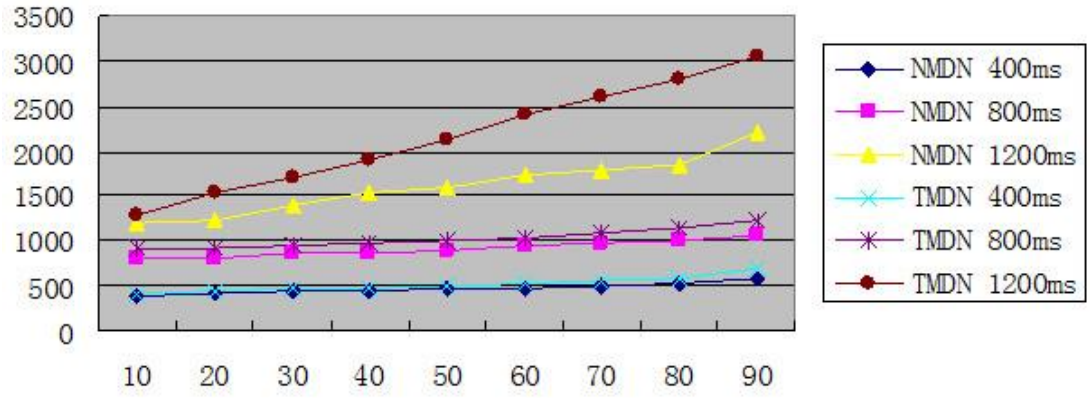

Figure 4.2.1 The Changes of Average Completion Time and the Number of Transactions

As shown in Figure 4.2.1, in the same operating environment, a comparison of average completion time has been made between the traditional mobile database model and the new mobile database model. The experiment shows that under different average length and number of transactions, the completion time uses of the new mobile database model is less than the traditional one. With the increase in the average length and the number of transactions, the trend will become increasingly evident. This fully shows that the new mobile database model is superior to the traditional mobile database model.

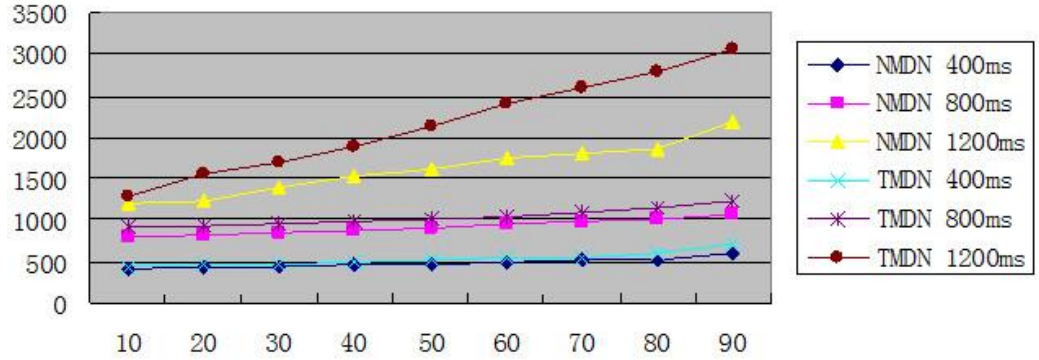

Figure 4.2.2 The Changes of Average Completion Time and the Number of Transactions when the Master Server Get Disconnections

Figure 4.2.2 is a targeted experiment of MDAN model when disconnections occur frequently between mobile host and master server. Figure 4.2.2 shows that with the increase in the average length and the number of transactions, the average completion time increases correspondingly, but exponential increase does not appear. In Ad hoc network environments, this is acceptable. It shows that MDAN model also has good performance in the case of frequent disconnection.

Experimental results indicate that new mobile database model has preferable performance and stability which has a high application value in practice.

5 Conclusion

Since the traditional mobile database model cannot adapt to Ad hoc network well, the paper has improved the traditional model and added local server. Based on research and analysis, new model adapts to Ad hoc network well. In addition, aiming at the problems of data collision and transaction redo because of using outdated data which the new model has brought about, methods have been designed to solve the corresponding problems. Finally, the execution time and data conflicts of the transactions have significantly reduced. It shows that the new model can adapt to Ad hoc network better, and it has achieved an ideal result; besides it explains that the approach to the problem which the new model has brought about is feasible. It guarantees that the new model is able to run steadily in Ad hoc network.

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Authors

Qi Ying, She is a Master of Foreign linguistics and Applied linguistics. She has graduated from Heilongjiang University in 2004, majored in English Language and Literature. In the year 2006, she was admitted to Heilongjiang University as a postgraduate whose major is Foreign linguistics and Applied linguistics and got a master's degree in 2009. Her main research directions are English

language teaching, Pragmatics, the combination of computer technology and English teaching.

Zhang Tao, He is a Master of software engineering, Senior Engineer. He majored in Information Management and Information and has graduated from Heilongjiang University and got Bachelor's Degree in Management in 2003. In the year 2008, he was admitted to Heilongjiang University, Software Engineering major as a postgraduate and got a master's degree in 2010. Mr. Zhang has hosted or participated in about 20 provincial, university research projects, published a monograph and more than 20 research papers have been published in academic journals both at home and abroad, among which 6 have been indexed by EI.