

A DATA REPLICATION FOR MOBILE ENVIRONMENT

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Distributed database systems and distributed database management systems have been developed in response to trend of distributed computation. In distributed models of computations several sites are connected via a communications network. However, the need for mobile access to large databases leads to problems with mobile computers connectivity. Mobile computers often suffer from limited connectivity or lack of network access. Existing replicated databases are not well suited for mobile scenarios as well as algorithms used for data replication, in spite of fact that it is the most desirable environment. In the following paper we introduce algorithm for adaptive data replication including mobile computers connected by wireless network based on IEEE 802.11.

Keywords: distributed database systems, distributed database management systems, wireless networks, data replication

1 INTRODUCTION

The advantages of data distribution involve increased availability, distributed access to data and improved performance of parallel processing. Disadvantages, on the other hand, are given by increased overhead and complexity in the system design and implementation. Traditionally, database is processed by static processing units such as servers or clients [1], [2], [3]. This model of information management has some limitations because it is unable to grow with the current information processing needs. The growth of distributed models of computation requires the ability to provide services for both, wire and wireless clients. Mobile computers often suffer from limited connectivity. Even the complete lack of network access can be observed for TCP/IP based protocols [4]. Nomadic computers mostly use a wireless access and, because of limited bandwidth, this type of connection is more expensive than wire communication. Therefore is important to access mobile databases in minimal communication cost. We will show how mobile clients can be involved in the replication schema and propose solutions for problems we observed during our research.

2 DISTRIBUTED DATABASES

The term distributed databases is used collectively for distributed database systems and distributed database management systems. Components of distributed database consist of database portions spread out over multiple *sites* — *nodes*. The sites are connected by a communication network with a given topology. Local site may have its own local database which behaves as a common database management system. Each site contains *fragments* — parts of global database distributed over the set

of nodes. Fragmentation of global database is managed by application and communication processing software.

2.1 Advantages and Disadvantages of Data Distribution

Advantages of data distribution include local autonomy, performance, reliability, availability and scalability. One of the most important features is availability which refers to the probability that a system is continuously available during some time interval. For centralized system means the failure of a single site failure of the entire system. In distributed database failure of a single site affects only data located at that site. Another advantage is the performance improvement since local access to data is much faster than remote query. The performance depends on *replication schema* which defines data distribution over the sites involved in distributed database system. This is mostly an advantage when the database is distributed geographically over different locations.

Disadvantages of data distribution are given by a significant cost in terms of performance (when replication schema is not optimal), software complexity and administration difficulty. The response time for transactions across different sites must be kept in acceptable range.

2.2 Formal description

In the distributed database systems is the design and replica placement a critical task. The objective of *fragmentation* is to achieve necessary level of data distribution. Consequently, optimal placement of fragments must be found over the available sites. This process is called *allocation* of fragments. Allocation must fulfill needs for

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consistency and efficient data access. Formal description of a basic distributed database allocation problem is shown in following text [5]. The traditional approach is based on methods of operational research. The criterion is based on *access pattern* defined by operations read and write. The result is decision, how to distribute the fragments over the sites. This kind of allocation problem can be transformed to the bin packing problem by adding restrictions for use of requirements matrix and zero transmission costs. The bin packing problem is known to be NP-complete. The DDB allocation problem is even more difficult so it is NP-complete too [5]. Thus we must use heuristic methods to find near optimal solution [6], [7], [8].

3 MOBILE COMPUTERS IN REPLICATION SCHEMA

By the static fragment allocation are fragments located at the sites from which they are most frequently accessed. Since the distributed database system is rather dynamical, the main problem with previous, static, allocation of fragments is changing workload. This occurs when the access frequencies to various portions of database from a particular site vary with time. Even very simple methods for dynamic data allocations are able to improve system throughput by 30 percent. Experimental evaluation of dynamic data allocation strategies can be found in [9]. To determine when a re-allocation is needed, algorithms proposed in [9] maintain weighted counters of the number of access from each site to each block. For effective estimation the aging factor is used to update counters. The main problem can be divided into the two problems: how to detect changes in workload and how to dynamically re-allocate fragments of database result in improved throughput.

Considering mobile clients, communication network characteristics must be evaluated carefully since they form transmission cost matrix. LAN characteristics for wire clients, such a throughput and latency (or round-trip time), can be estimated reliably by tools such a *tstat* [4] or *pathchar* [10]. For wireless client is estimation more difficult than for wire clients. Technology for wireless communication based on the IEEE 802.11 standards provides connection with variable transmission characteristics. Rather than throughput and latency a *signal-to-noise ratio* (SNR) is a characteristic that has to be involved in replication model. SNR affects both characteristics throughput and latency in significant way as shown in [11]. SNR directly impacts the performance of a wireless LAN connection. A higher SNR value (in dB) means that the signal strength is stronger in relation to the noise levels, which allows higher data rates and fewer retransmissions.

The linear mathematical model for throughput prediction based on previous observations looks as follow [11]:

$$\begin{aligned} T &= T_{\max}, & SNR > SNR_C, \\ T &= A \times (SNR - T_0), & SNR \leq SNR_C \end{aligned}$$

where T_{\max} is a saturation throughput, A defines the slope, T_0 is a breaking point where T_{\max} is changing to a curve described by A , SNR_0 is a cutoff SNR specified by hardware vendor and SNR_C defines critical threshold. Respective exponential model is also described in [11], for proposed solution linear algorithm is sufficient enough to describe communication network characteristics. Now we can define a set SNR_C of m elements, where each value snr_{ci} represents critical threshold for site i .

$$SNR_C = \{snr_{c1}, snr_{c2}, \dots, snr_{ci}, \dots, snr_{cm}\}.$$

When the site i is a wire client, critical threshold is zero. Finally, we need to define function which returns current SNR value. Such a function is necessary to implement on each site from replication schema since it depends on particular configuration.

4 ALGORITHM FOR ADAPTIVE REPLICATION

Now we can formulate the algorithm for adaptive replication based on simple algorithm described in [9]. The proposed algorithm deals with a problem of critical SNR value and thus SNR -specific operations have been added. The algorithm consists of two tests. The *test of expansion* is executed after the specified number of transactions and is responsible for replication schema expansion when such change improves solution. The *test of expansions* is defined by following steps:

1. The control process examines read counters for each fragment.
2. The site with the highest counter value is marked as a candidate for fragment re-allocation.
3. If the candidate is the site on which fragment is currently located, go to step 6.
4. For the candidate site get SNR and $SNRc$ values. For wired nodes return $SNR = 100$ and $SNRc = 0$.
5. If $SNR > SNRc$ then move fragment from original site to the candidate site. Otherwise, choose site with the highest counter value from the set of unmarked sites and mark it as a candidate for fragment re-allocation — then go to step 3.
6. Wait for specified number of transactions to be completed and then go to step 1.

The first step can be modified by using aging factor to improve efficiency. The *test of contraction* solves the problem with wire nodes included in the replication schema. The motivation is given by assumption that is easier to prevent site failure due to the communication network problem than to solve its failure. Since the test is performed repeatedly, is possible to release a site from the replication schema when requests for replica may cause failure. The *test of contraction* is specified as follows:

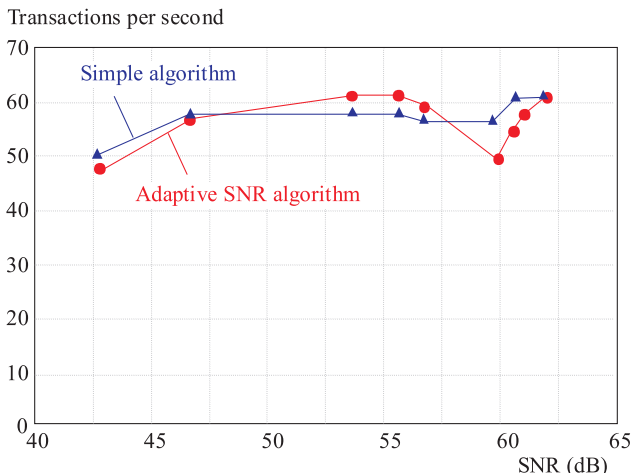


Fig. 1. To comparison of two algorithms under the ideal conditions

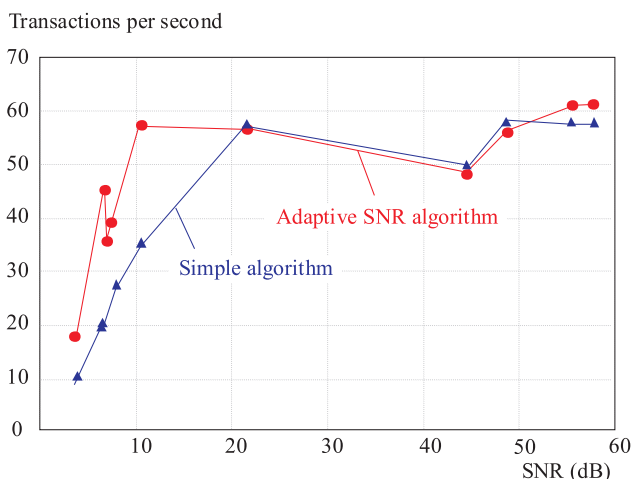


Fig. 2. Impact of SNR changes to results according two algorithms

1. The control process monitors SNR value for each site included in the replication schema.
2. If the site does not response then the site is released from replication schema and its counters are reset.
3. If $SNR \leq SNR_c$ then the site is release from replication schema.
4. Wait specified time and then go to step 1.

5 EXPERIMENTAL EVALUATION

The performance of the system under dynamic re-allocation scheme with and without (load sensitive algorithm [9] was used) proposed algorithm was compared during the experimental phase. We used communication network statistics produced by *tstat* tool and a set of tools we created for wireless connection evaluation. Network characteristics were acquired from the real network. Requests for data and replication process were simulated.

The first set of experiments is performed under the ideal wireless network conditions. The SNR value more

than 40 dB guaranties ideal transmission and thus we expected similar results for both algorithms. The situation described above is shown in Fig. 1. The number of transactions per second for both algorithms is similar, small differences are insignificant.

Conditions more close to reality are defined by another set of experiments. Here we check behavior of both algorithms under the situation when SNR changes significantly. These changes are caused by changes in physical environment such as number of users around the beacon, physical obstacles or position changes. Since proposed algorithm is SNR sensitive, we obtained better result than for the common adaptive algorithm. The results are shown in Fig. 2.

Finally, the overall replication cost is compared for both algorithms (Fig. 3). The results show that for the SNR greater than SNR_c our solution is from 1 to 4 percent more expensive than solution that is not using proposed algorithm. The percentage change represents the overhead caused by the algorithm. In the case that SNR oscillates around the SNR_c is the cost of solution with proposed algorithm for about 20 percent worse than for solution without the adaptive algorithm. Hence the SNR_c value must be evaluated carefully since the algorithm reacts to possible critical threshold but the communication network parameters are near to regular values. Finally, if the SNR is less than SNR_c our solution improves overall performance in a significant way. The observed results show about 60 percent better overall response time than for load sensitive algorithm. This is given by the fact that proposed algorithm is avoiding replica transmission to the site with communication problems.

6 CONCLUSION

Performance in distributed database systems is heavily dependent on allocation of data among the sites of the database. The static allocation provides only limited response to workload changes. The situation is even worse when mobile wireless computers are included in replication schema. We presented algorithm for dynamic re-allocation of data with a mobile computers included in replication schema. Proposed algorithm offers significantly increased performance for nomadic nodes with limited connection. Our experiments make a practical case for future development of algorithms for changing environment such as intelligent transportation systems, location aware application and information systems for mobile user.

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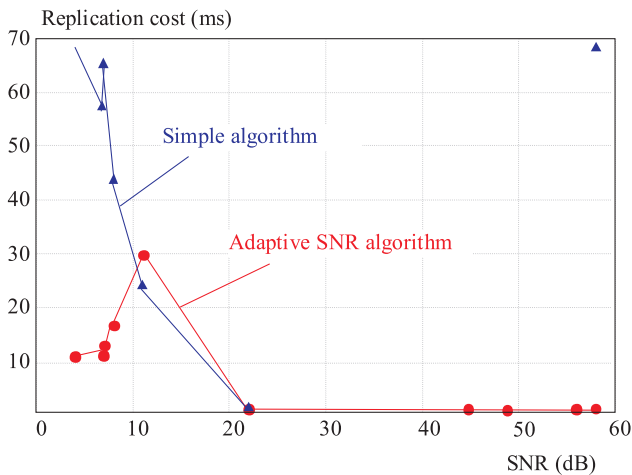


Fig. 3. Cost of replication

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