Some Models of a Distributed Database Management System with Data Replication

Svetlana Vasileva, Petar Milev, Borislav Stoyanov

Abstract: *The article suggests a formal model of Distributed Database Management Systems (DDBMS) and an approach for Distributed Database Systems (DDB) modeling. It is suggested to use general purpose system simulation (GPSS) for simulation modeling. Queuing systems models modelling the execution of two-phase locking (2PL) in DDB with Data replication are suggested: centralized 2PL, primary copy 2PL, distributed 2PL and voting 2PL. Results from the simulation of the distributed 2PL are presented.*

Key words: *Distributed Database, Transactions, Simulation Model, Concurrency Control algorithms, Data Replication*

INTRODUCTION

One of the basic problems in Distributed Database Management Systems (DDBMS) is the concurrency control of concurrent executed transactions. There are 3 basic methods for transaction concurrency control (CC): Locking (two phase locking - 2PL), Timestamp ordering and Optimistic strategies (Certification approach and others) [3], [6] and [8]. Since in the last two methods in case of conflicts transactions rollback, and in locking the possible conflicts are preliminary excluded, this work suggests a model of DDBMS functioning according to the 2PL. The current investigation of distributed CC is focused on the four types of 2PL for Distributed Database Systems (DDB) with data replication: centralized 2PL, primary copy 2PL, distributed 2PL and majority copies 2PL (voting 2PL). These four protocols are described in [3], [8] and others, and the researched algorithms developed on their basis are described in details in [2], [10] and [11].

Detailed simulation models for the 2PL algorithms for DDB with Data replication are not found in [5], [6], [7], [9] and other resources we have studied. Almost all detailed algorithms for simulation of CC performance, which we have found model after Timestamp ordering protocols [9] or the protocols using optimistic strategies. This necessitates models of 2PL in DDB to be developed and investigated.

1. MODEL OF THE STRUCTURE OF THE DDBMS

As a base of the formal model we use the one suggested in [7]. We give the schemes of the two basic models of DDBMS. The modules which participate in the transaction processing are depicted with circles and the necessary data with rectangles. Fig. 1 shows the model of the structure of DDBMS in which CC is fulfilled in a centralized 2PL. In order to be clear, we do not depict the rest of components of the site S_0 (TM_0, DM_0, TC_0, LDB_0 and SC_0), which contain the only Lock manager LM_0 and the only Lock table LT_0. Fig. 2 gives the model of the structure of the DDBMS, in which CC is executed on distributed 2PL. Unmentioned signs: S – Transaction source, TC – Transaction coordinator (it also includes the component for data communication), SC - System Catalogue.

The scheme of the model structures in fig. 1 and fig. 2 are specific development of the same structure models for the two basic types 2PL in DDBMS with data replication: centralized 2PL and distributed 2PL.

2. BASIC PERFORMANCE SCHEMES OF 2PL IN DISTRIBUTED DATABASES

Fig. 3 and fig. 4 demonstrate an example of a performance of 2PL in DDB with 5 nodes (S_1 – S_5) for a global transaction T_2^n (updating data element x^j which has copies in local databases (LDB) of S_1 and S_5) initiated by site S_2. The transactions use the Strict 2PL where data elements are locked before they are accessed and locks are released after the transactions commit or abort.

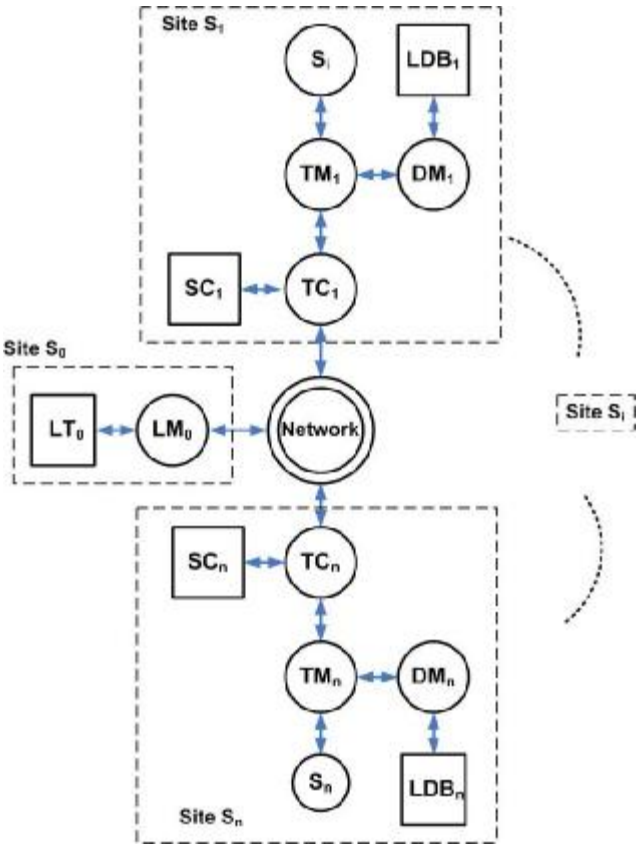

Figure 1 Distributed DBMS Model Structure in case of Centralized 2PL

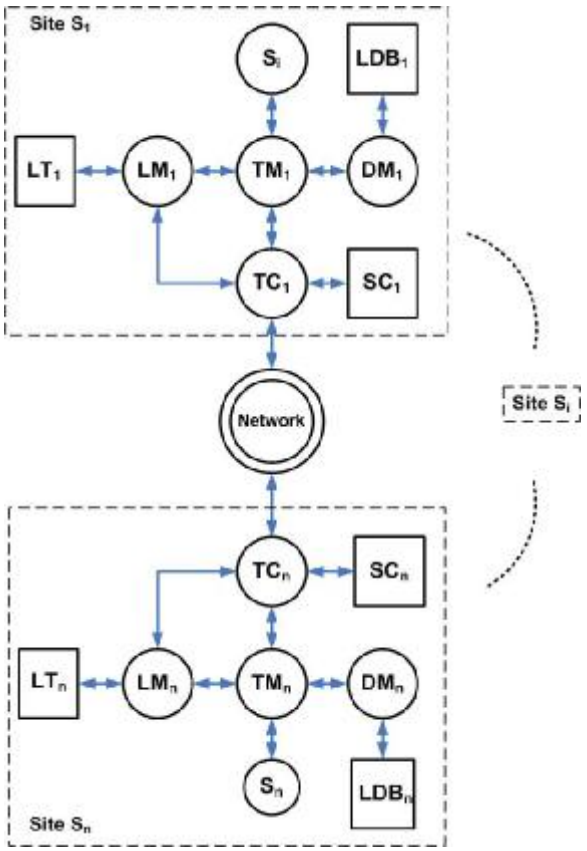

Figure 2 Distributed DBMS Model Structure in case of Distributed 2PL

In centralized 2PL the Lock manager and the Lock table, in which the transactions mark the necessary data elements with the corresponding locks are placed on one (central) site only, in fig.3 – S_0.

In the primary copy 2PL certain centralization kept, because for the locking of a data element a certain site is responsible and Lock table is divided among the sites, therefore fig. 3 illustrates also a Primary copy 2PL in the example of global transaction T_2 quoted above. (In general, the site, in which is the LM managing the locking of the primary copy, of the data element x^j does not contain this copy).

In distributed 2PL the Lock manager is distributed on the DDB sites and the Lock table of the site contains information for all the elements, which copies are stored in the LDB of the site. This distributedness is kept also in voting 2PL with the single difference that it is enough for the transaction to receive the blockings of more than half of the copies of the data element in order to continue its execution.

3. MODELING OF THE PROCESS FOR TRANSACTION SERVICE IN DISTRIBUTED DATABASE SYSTEMS

The preliminary analysis of the service transaction process in DDB systems with data replication, showed the complexity and the peculiarities of the process. It is possible to present the structure of such a process by means of queuing models which are characterized with the following:

- The input flow of the global transactions in the DDBMS sites is Poisson λ parameter – the length of the interval between the input time has an exponential distribution;
- The service transactions continuity has an exponential distribution with a parameter μ;
- The service devices (CC components) are situated in sequence in parallel channels with parallel queues;
- The order of service is „First Input – First Serviced";

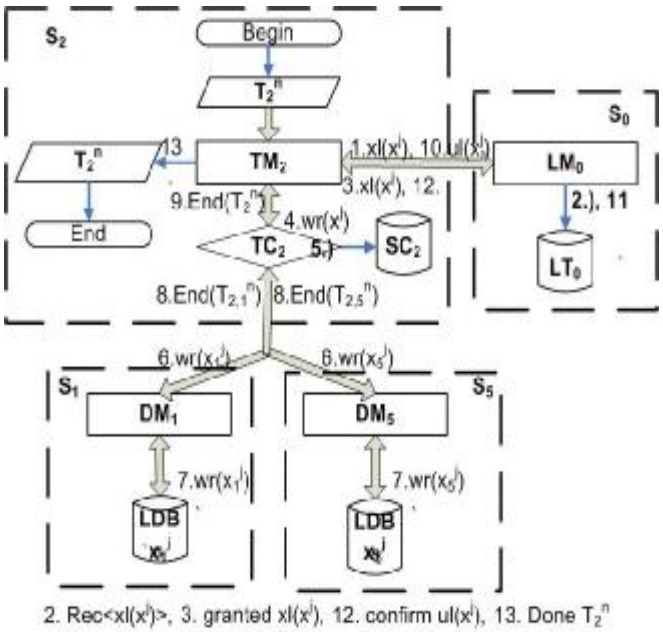

Figure 3 Schema of Centralized 2Pl and Primary Copy 2PL

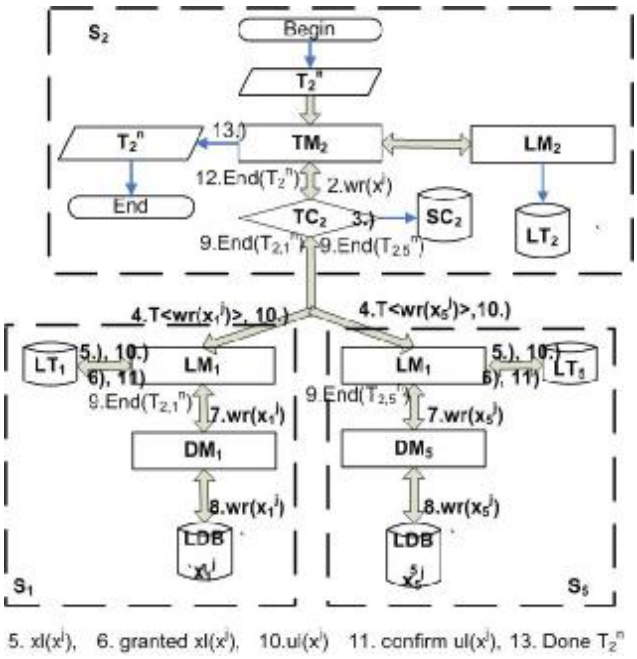

Figure 4 Schema of Distributed 2Pl and Voting 2PL

The incoming transaction does not leave the system before it is served.

The scientific analysis of the situation in DDB systems showed that the whole system can be presented as a combination of subsystems, functioning in parallel independently of one another. Such a system can be qualified as Queuing system with infinite multitude of serving devices and it is presented symbolically. It is difficult to summarize these assumptions for the cases with partially changed conditions. For example, if each transaction in the system receives the necessary locks (in 2PL), and also the elements processed by the transactions are distributed exponentially, it is clear that there would not be obscurities in the model interpretations.

It this case the transactions enter the sites exponentially. The same are sent via parallel channels, they are written in particular incoming and outputting buffers, reaching the sites with the necessary data and are submitted to the receiver (leave the system). This allows us to assume that the service process can be modeled by Queuing system with parallel channels.

The Mathematic model M/M/∞ can be used for a number of important operation characteristics as [4]:

- Transaction service time in queuing system;
- number of serviced transactions;
- full channel load;
- the length of the queues and others.

We assume that M/M/∞ model is not a precise copy of the real and complex transaction service process in DDBMS. Therefore simulation approach is used. By the general purpose system simulation GPSS World the model and algorithms for service on transaction in the system are described.

The global system catalogue (system_catalog) and data elements of the DDB (elementi), LDB of each site (Site_elementi) are modeled with 2-dimensional arrays.

Initially the simplest type of transactions is generated – transactions that process (read and/or update) one data element.

To syntesize the schemes of the models presented below in Fig.5-7, we used the schemes for CC described in [5]. The basic scheme of Logical queuing model has been used as a basis for the models developed here.

Figure 5 presents the queuing model of service of the concurrent transactions on the centralized 2PL. Some symbols: S_i – generator of transactions, with intervals of coming in which are distributed according to an exponential law; QLM_0 – queue of the waiting for processing transactions; LM_0 – Lock manager device. If the necessary lockings are granted the transaction is split and replicated by the corresponding Transaction coordinator TC_i and is executed in corresponding nodes DM_j, after that they are reunited in the transaction manager device; the busy locked are released – block LT_0 and leave the system.

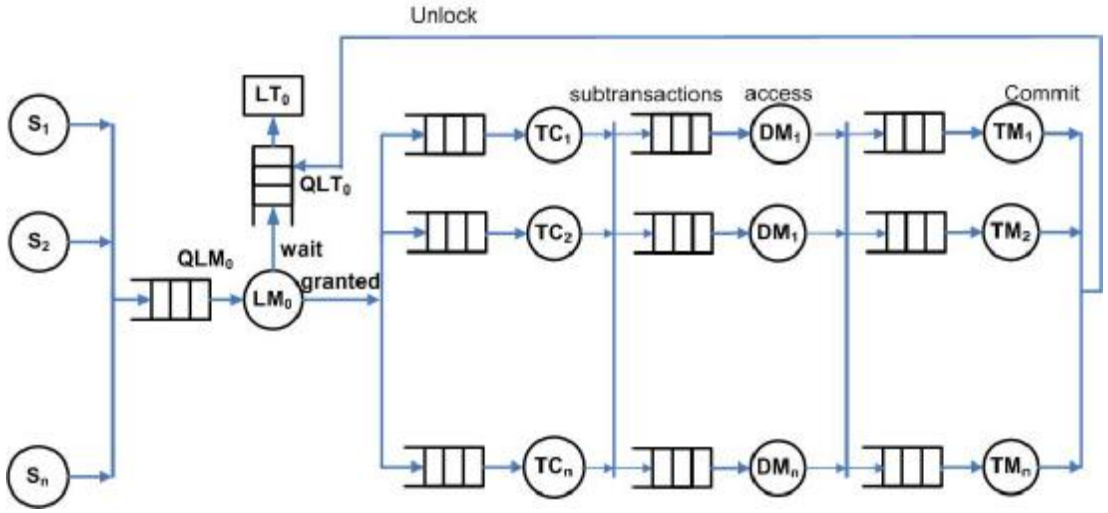

Figure 5 Simulation model of centralized 2PL

Figure 6 presents the queuing model of service of the concurrent transactions on the primary copy 2PL: S_i – Generator of transactions, with input intervals exponentially distributed; TC_i – Transaction coordinator, it splits the transaction, defines the necessary primary copies and points the transaction to the corresponding lock managers LM_j; QLM_j – queue of the transaction waiting for LM_j processing; If the necessary lockings are granted the transaction is replicated and is executed in corresponding nodes DM_j, after that they are reunited in the transaction manager TM_i block; the busy locked are released in corresponding blocks LT_j and the transaction leaves the system.

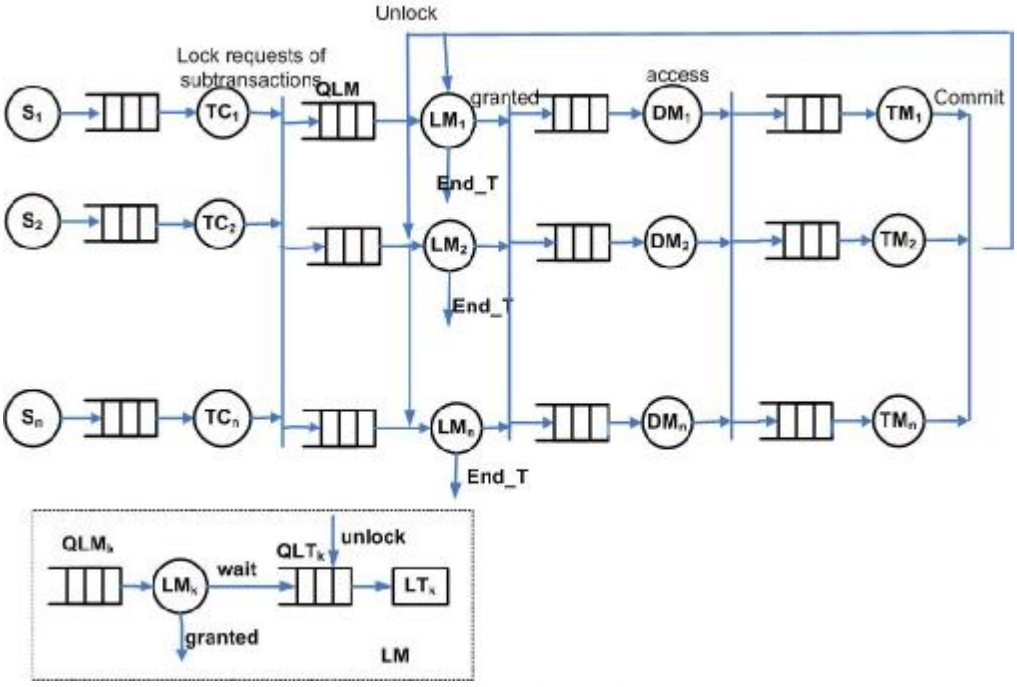

Figure 6 Simulation model of primary copy 2PL

Figure 7 presents the queuing model of service of the concurrent transactions on the distributed 2PL: S_i – Generator of transactions, with input intervals exponentially distributed; TC_i – Transaction coordinator, it splits and replicates the transaction defines the necessary executor nodes DM_j and points the transaction to the corresponding lock managers LM_j; QLM_j – queue of the transaction waiting for LM_j processing; If the necessary lockings are granted the transaction is executed in corresponding data managers DM_j, after that they are reunited in the transaction manager TM_i block; the busy locked are released in corresponding blocks LT_i and the transaction leaves the system.

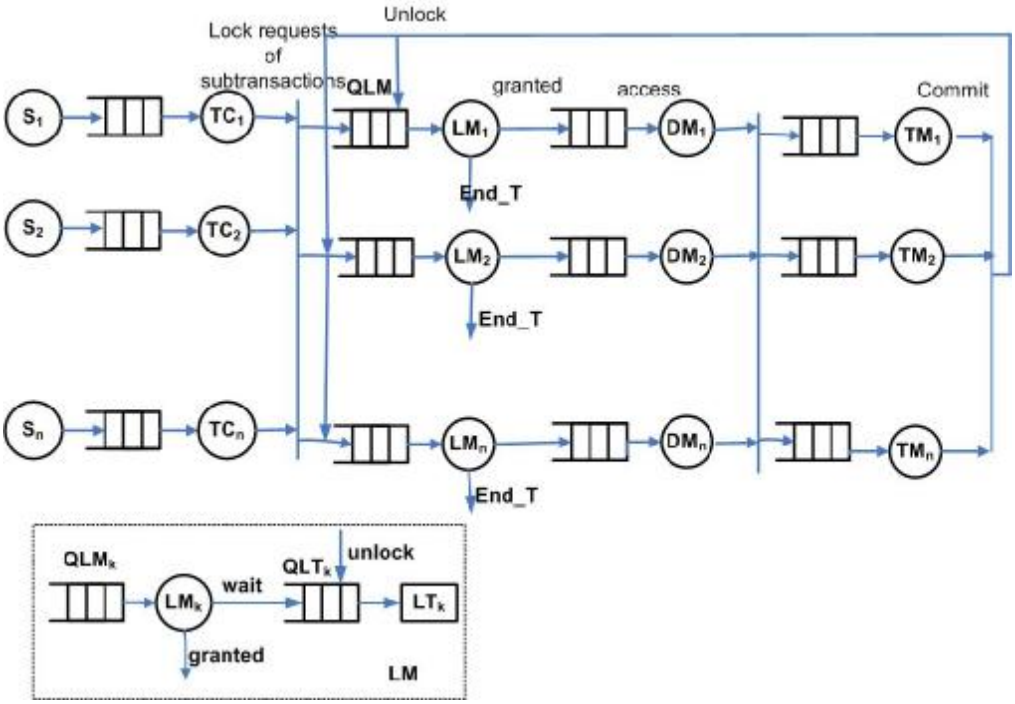

Figure 7 Simulation model of distributed 2PL

4. SIMULATION MODEL OF DISTRIBUTED 2PL

On the basis of the suggested distributed 2PL model on fig. 6a GPSS model [1] is developed which compares the system throughput with 2 and 3 copies of data items. For a unit model time we choose 1 ms. The diagram in fig. 8 shows the received simulation results.

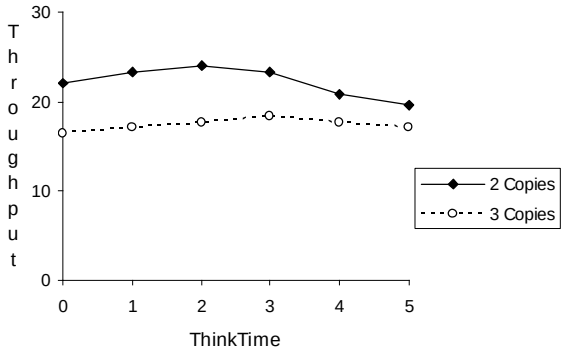

Figure 8 Throughput diagram with 2 и 3 replicas

The throughput diagram of DDBMS which works on Distributed 2PL shows that when the data elements have two copies each, the throughput capability for a short response time is about 25% higher than the case with three copies. If the response time is longer, the throughput capability in the case with two copies is close to that when we have three copies. This is due to the longer time necessary for global transactions processing and

subtransactions transferring and unification.

CONCLUSIONS AND FUTURE WORK

1. A formal DDBMS model and execution block schemes of 2PL in DDB are suggested;
2. An approach for formal model simulation with GPSS in definite limited conditions is developed.
3. Modeling centralized 2PL, and primary copy 2PL, and more complex performance regimes in DDB is forthcoming as well as their simulation, and processing the results from the simulation performance, and the verification of the models.

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