A DESIGN MODEL OF DISTRIBUTED DATABASE IN REAL-TIME CONTROL

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Abstract. The problem of traditional distributed database implementation in real-time control is discussed. According to features of data in real-time control distributed system, a enhanced performance design model (EPADM) of distributed database control is presented. Lastly, measurement analysis and some appraizement on EPADM is gived.

Keywords. Distributed control system; distributed database; real-time control; data distributity; communication network; enhanced performance design.

INTRODUCTION

In recent year, distributed computer control systems are extensively developed in real-time control. In distribute control system, the control functions are distributed among many local control units connected by the communication network, and go concurrently. For processing efficiency reason, the data should also distributed among local control units. The closer the data to the processing, the higher the efficiency is. In other hand, many data in distributed control should be shared by many local control units. Processing in one cite may be interested in data in other cite. The solution to meet the two requirements is to develop distributed database. The distributed database provides a global database logically, and can be accessed by each local control unit, so as to achieve data sharing objective. Physically the data are spread over the local control units, so that the data are close to the processing, achieving the processing efficiency objective.

We have many studies in distributed database in information processing. According the ISO OSI reference model, distributed database is implemented in application layer , and data often stored in secondary storage(whenchester disk, floppy disk, etc). In traditional design, the data query process is : first check if the data is in the cite, if not , then fetch it from other cite data resides through network, then return back to user application(refer to Fig. 1.)

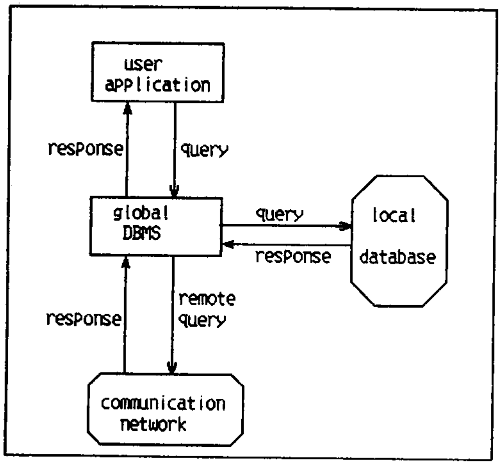

Fig. 1. Traditional query process

When we use traditional method design distributed database of real-time control system, the first problem faced is the long access response time can hardly applied to real-time control. The host of local unit should take enormous time to process distributed transaction. The second problem is the complicated design system can not implemented in local controller, for many local control units are lower end processer, and have limited memory and processing capacity. Many secondary storages can hardly suite for harsh industrial environments. Therefore , we should find a simple and efficient design method used in real-time control distributed system.

In my opinion, the main objective of the design of a distributed data base in real-time control is the efficiency. Therefore, we should place data to its processing as close as possible, achieving high processing locality. Also, the system should have high reliability and high availability. Secondly, comparing to the information processing, the data quantity of real-time control are much less, the key is efficient handling of the limited information. Based on above idea, I would like to present a enhanced performance architecture design model (EPAPM) of real-time distributed database based on industrial local area network and do some analizing and appraising on it.

REQUIREMENT IN HARDWARE AND NETWORK

let's consider distributed database with computer communication network. Fig. 2. is a implementation model of a distributed system. It can be divided into two subnet-

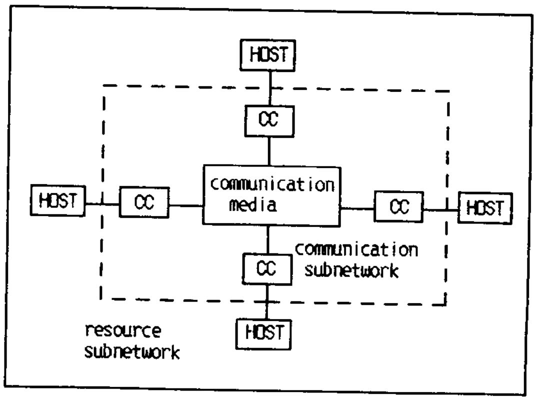

Fig. 2. A model of distributed control system

work ; communication subnetwork and resource subnetwork. Communication subnetwork is responsible for information exchange between computer hosts. CC is communication controller(called IMP in ARPA network).Resource subnetwork consists of all the host computers (or controllers).Traditional distributed database is implemented in resource subnetwork ,the communication subnetwork only used to exchange information.

We define a concept,"data distributity", that is access a data need to do distribute processing.Data has no distributity, that is the data is just in the own cite,user can access it like access a data in centralized database.In traditional distributed database implementation,data distributity is in resource subnetwork,so the host is always perplexed by the distributed transaction,and high efficiency can hardly achieved.Drop the data distributity down to communication subnetwork,make the host free from distribute transaction,is the start point of design model present here.If so,the data seen by the host are no distributity,the host access the data is like access a individual centralized database.The distributed processing is done by communication subnetwork.To implement these,we should have a database,in one hand,is accessed by host;in other hand ,it is used to do distribute processing by communication network.The storage of database should be shared by host and CC. Thus, we have first requirement of design,the hardware requirement: building a shared storage(SS) to store the database.The host and CC can access SS independently.SS can be battery backup RAM,bubble memory,and the like.

The second requirement of the design model is that the network can do broadcasting service,that is a data frame can be transmitted onto network and received by all the stations.Modern local area network,especially that used in industrial control,can provide this service.IEC PROWAY standard provide GSD broadcasting service.New developed MAP network provide broadcasting service by broadcasting address (or group address).

These two requirements above is the base of the design model EPADM.

DATA ALLOCATE STRATEGY

The first problem faced by design distributed database is data allocation.First of all,let's study the features of data in real-time control,that is features of process variables in distributed control system.Typically,the variable is produced in some stations of the system (collected from industrial process,or calculated by the processing,or set by human,etc),these stations are the sources of the variable.The variable is used by other stations of the system,these stations are the leakages of the variable.As a matter of fact,a variable usually has only one source (leakage may be more than one),that is process variables have a feature of single source. The EPADM assume the data all are single-sourced.Yet, multi-soureced data can be defined as multiple single-sourced data.The process variables also have a stable stream feature.The process variables usually have no existance-variaton,they only have value-variation.They exist from begin to end,but their value periodiclly variate.The data sharing by multi-stations means its value sharing.The change of value of the data in source should be known by its leakages immediately,so that processing in leakages take actions.

Considing the features of "single source" and "stable stream" of process variables,considing the idea that the main objective of distributed database in real-time control is maximizing the processing locality,EPADM take data allocation strategy as follows:

Allocate data (process variables) in source station,and replicate it in all its leakages.Each station user build a local database in its SS.The local database consists of two parts.one is the this station oriented (that is source is this station),called TOD.Another part is other stations oriented (this station is the leakage) data, called OTD.Thus,all the data used by this station are in this station own storage SS,data is close to the processing,achieving a totally processing locality.

DATA CONSISTANCY UPDATE AND DATA ACCESS

As stated above,EPADM replicate the data in all stations using it,to achieve a totally processing locality.However,how to gurantee the data consistancy among so many redundancy backups.In EPADM,this is done by communication subnetwork.

We have assumed that the communication network provides data broadcasting service.From the point of effectiveness,updating the redundancy backups by data broadcasting is the best method.EPADM select it.Each station CC periodically broadcasts the data of TOD in its SS,other stations if interesting in the data,receive the data;and update its OTD. These consistancy updating manage mechanism go forever,and is completely independent to the host data access.We known that broadcasting service of network has no guarantee of data reception. Usually , point-to-point data transfering assume positive acknowlegement with retransmission (PAR) technology,that is transmitter not receive acknowlegement from receiver until time out,it retransmit the original frame.These process repeats until data is correctly received by destination station or multi-retransmission failed and abort.The data updating in EPADM is periodically going. We can think it as a spontaneous retransmission.This spontaneous retransmission is a compensation of the no guarantee data transfering of broadcasting service.

Through this kind of data broadcasting update,each local database combined into a global database (Fig.3).

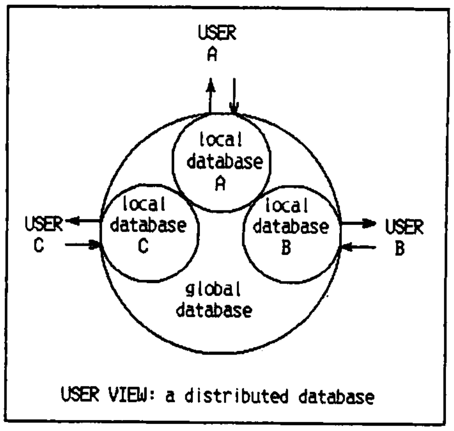

Fig.3. Local database and global database

Through defination of TOD and OTD,that is a set of global database and dynamic variation of the set,one station can access any data in global database,thus achieveing data sharing.Physically data decentralized to each station,data is close to processing,achieving high efficiency.In other word,there is a distributed database in communication subnetwork shared by each station.The data distributity totally drop down to communication subnetwork,achieving original design objevtive.

Feature of data in real-time control requires that data consistancy update should guarantee determined time.That is once data value changed in source station,the data in leakage stations should update in determined time. This problem of EPADM is associated with local area network used.Industrial local area network standard,such as IEC PROWAY,IEEE 802.4 that MAP standard used,assume token passing method to share common media.This kind of noncompetitive media access method can guarantee a determined maximum response time after a data transmission request. In fact, it is the time required that token round the network a circle. EPADM data broadcasting update is done by the network data transmission, so the maximum updating time is therefore determined. Once the variable in source station being changed, broadcasting update mechenism produce a broadcasting request immediately, after a determined time, the variable in all its leakage stations are updated. May be the variable is broadcasted every two token round circles(depending on the quantity of TOD in source station, and priorites requirement), but the updating time is determined.

Another feature of real-time control data is its various time requirements. Some data should be updated in milliseconds, some only require not more than one minute. For this, EPADM take a priority strategy. Giving a priority to each variable (set in creating definition). The higher the priority, the higher the updating frequency. In detail, that is the highest priority data updates in each token pass circle, the lower priority variable is updated in multiple token circle time(a counter is enough to implement this). This simple priority design strategy can make use of network bandwidth more rational.

For saving the network bandwidth, EPADM divide one data into two parts, one is its update part, which should be updated continously; another part is description part, which is set when data being defined, and can hardly change, such as a varible description message, etc. Only the update part of data is broadcasted on network. In another hand, the data update can also be designed that it is to be broadcasted determined times after its value being changed in source station, and then stop its broadcasting until its next value change. Many strategy can be used to optimize the design.

Last, let's see the data access. For the data allocation strategy and data consistancy updating stated above, the host access the database become very easy. It is the host access its own storage SS, and response can be almost immediately, this brings high host processing efficiency. Another data updating mechenism executed by communication controller proceeds total independently(Fig. 4). All the query optimization technolegy and complex accessing structure can be used here(may be not nessary). No problem of distributed transaction, no problem of distributed concurrency control, etc. All is just like a centralized database.

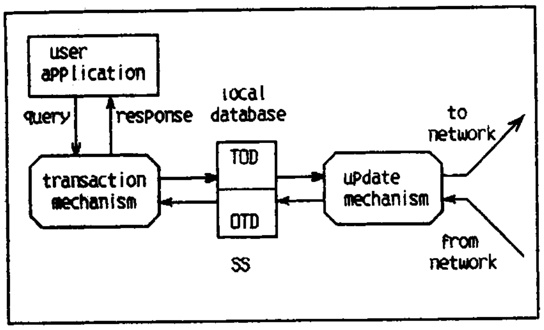

Fig. 4. Data access and update

MEASUREMENT ANALYSIS

I have present a real-time control distributed database desine model EPADM. It is based on storage sharing and data broadcasting. EPADM provides a distributed database that is shared by every station hosts of network. Physically, data is stored in each station storage SS, providing a total processing locality.

There are two new questions arised:

. if the frequency of data broadcasting update is acceptable by real-time control distributed system.
. if the capacity of database is acceptable by real-time control distributed system.

To answer these questions, I am going to do some measurement analysis on EPADM.

In EPADM, data is replicated in each station use it. The data redundancy consistancy update is done by broadcating provided by network service. To do analysis, we consider a EPADM implementation based on IEC PROWAY standard network. IEC PROWAY standard assume token passing method to share common media(refer to IEC PROWAY standard). The token is a broadcasting frame. Each time a station hold the token, it can transmit a point-to-point frame, and broadcast a frame (as data part of token frame). That, the broadcasting banbwidth is about a half of the total bandwidth. The data rate is 1 Mbps. PROWAY token pass strategy can give 86% utilization. That is its data throughput can achieve 86K bytes/sec., and data broadcasting throughput is about 43K bytes/sec.

In real-time control, the process variable is often called as point. A point can be a digital input/output, a analogue input/output, a pulse input/ouput, a calculated variable, etc. For calculating convenience, we assume all point are 4 bytes long, and identifier of a point is 2 bytes long(identifer of a point is used to identify a data point in system range). Considering broadcasting throughput provided by PROWAY, we have total updating frequency

$$TUF=43K / 6 =7000 \text{ points/sec.}$$

In actual execution, allmost all the bandwidth be used to broadcast(point-to-point data transfering is occasional), so the TUF can be upto above 10000 points/sec.

We have discussed the priority deisgn of EPADM. According the design, the individual update frequency of points is actually the allocation of TUF. Suppose there are four priority classes, the update frequency for each is U1, U2, U3 ana U4, the number of update points for each priority class in one second is X1, X2, X3 and X4, then we have

$$X1*U1+X2*U2+X3*U3+X4*U4=TUF$$

For PROWAY network, that is

$$X1*U1+X2*U2+X3*U3+X4*U4=7000 \text{ points/sec.}$$

The allocation of X1, X2, X3 and X4 in EPADM is done by application user, so that user can use bandwidth rationally and well match the individual data update frequency to application requirements.

Here is analysis on a implementation based on IEC PROWAY standard. Also we can do same analysis on implementation based on MAP standard MINIMAP, which will provides much higher data update frequency.

From the analysis above, we have the conclusion. For modern communication network can provide high broadcasting throughput, the data update frequency in EPADM is acceptable by a common real-time control distributed system.

Now let's look at second question. In EPADM, data are stored in each station storage SS. The capacity of database is limited by the capacity of SS. Suppose internal organization infomation for each point in source is S bytes, In leakage is L bytes, each point has K redundancy backups. Suppose the capacity of SS in each station is M bytes, there are N stations in system, the update part of a point is X bytes, then we have total database capacity

$$TV = M*N / ((L+X)(K-1)+(S+X))$$

we have single database(local database) capacity

$$SV = M / ((L+X)(K-1)/K+(S+X)/K)$$

Suppose M = 512K bytes(this is not hard for modern memery technology), N=30, K=4, X=4 bytes, L=6 bytes, S= 16 bytes, then

TV = 307.2K points
SV = 40.9K points

We can draw conclusion from above that the capacity of database in EPADM is acceptable by common distributed real time control system.

CONCLUSION

The goal of EPADM is to provide high processing efficiency. The most advantage is its total processing locality, its access response promptness. This is quite suite to real-time control. Further more, EPADM also have following advantages:

.high reliablity and availablity. There is no master station in EPADM, each local database damage does not interfere other local database and global database. Data is multiple backuped . All these bring high reliablity and availablity.

.Implementation simplicity. Comparing to traditional distributed database design, EPADM is much more simple. For its data sharing and data broadcasting update, and down of data distributity, the host access database just like access a centralized database, no distributed transaction processing, no all problems of distribution. This make implementation simple, and well suited for common industrial controllers.

.Expandiablity. Adding of new local database to global database is just like the new station adding to the network (usually be done at same time), no interference on other local database and global database.

Yet, EPADM adopts storage sharing and broadcasting data update, the upbound of SS capacity and communication bandwidth limit the capacity of database and data update frequency. Systems that have higher requirement for database capacity and update frequency than we gived above may not apply to EPADM.

However, EPADM can be well used as a enhanced performance design model of distributed database in real-time distributed control. It can be implemented directly upon data link layer of network. We have developed a EPADM experimental implementation on IEC PROWAY network. Execution proves its efficiency. The analysis data gived priviously are come from this implementation. Further more, the model is well matched to the new developed MAP Enhanced Performance Architecture(EPA) of local industrial control network.

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