AN INTERNET SOLUTION FOR VIRTUAL ENTERPRISES BASED ON AN OBJECT-ORIENTED REAL-TIME DATABASE

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This paper shows the challenges encountered by small and medium companies using e-business as well as e-manufacturing in order to remain flexible, fast and competitive. The combination of a standard ERP and a customised manufacturing execution system based on a novel object-oriented real-time database is the ultimate solution for many applications. It provides high flexibility at a reasonable price. This is important, because business is changing all the time. A very powerful management information system based on an Internet/Intranet approach completes the many advantages of the new main-memory based system. Such a system allows a very fast access to actual production information of all VE companies independent of their locations.

1. INTRODUCTION

1.1 Customised production of car parts

Nowadays the number of optional extras for cars is increasing, whereas at the same time the car manufacturers try to reduce their delivery times. Additionally, the adopted strategy is to manufacture components customer specific for each car to save weight and petrol. All this makes high demands on all sub-suppliers who have to deliver the right parts at the right time to the assembly lines.

Some car-parts' suppliers are specialised in producing customised high quality parts just-in-time at a reasonable price. An exceptional and very powerful IT system enables them to achieve these production goals.

1.2 A Virtual Enterprise for distributed production

The first requirement a supplier has to meet is to deliver the customised parts just-in-time, e.g. motors, bumpers, wire harnesses, etc., second to have only a few days to produce them in, third the production process involves sometimes extensive manual work and fourth the high number of variants complicates the production. For example, there exist after two years of production not less than 230,000 different Bill-of-Materials belonging to the wire harness of a middle-of-the market car. Repeatability is so low, that a car part is not manufactured before the order is received. As a result, total production-on-demand becomes necessary.

The car manufacturers send the information of the requested parts to the suppliers about one or two weeks before the goods are needed. This time span seems to be

plentiful but in reality the daily slices of planned cars for the assembly lines are sometimes changed around two or three days before delivery date in accordance with disturbances caused by suppliers or the car manufacturers themselves. Hence, the suppliers must be able to produce the needed parts in two or three days. Another problem for the suppliers is that the amount of needed parts varies with the number of sold cars.

All the particulars mentioned above necessitate the forming of Virtual Enterprises (VE) for manufacturing parts. For example, three independent companies established a very strong VE to enhance their power in producing parts for big car manufacturers.

This three companies act like one company. Together they plan the actual load of their factories and distribute the work in an optimal manner so that their customers are highly satisfied.

1.3 The three companies have seven locations, five big customers and four products

The Virtual Enterprise comprises 3 production facilities in Germany and 4 in Eastern countries, such as Poland, Czech Republic, etc. which enables the suppliers to combine both, the production in low-wage countries and the “last minute” manufacturing and assembly near the customers’ sites in expensive countries. The amount of workload performed by the partners is quite different (see Figure 1).

Figure 1: Distribution of work

Hence, the planning of the whole Virtual Enterprise has to take into account the special features of all three partners to reach the optimum. Figure 1 shows also the possibility to balance the workload between the five plants for the Product A and the two for the Product B. Therefore the IT system was built to fulfil this task efficiently and with less effort. The most important objective of this VE is the collaboration in manufacturing. Other VE approaches are mentioned in the references. There are decision support systems to decide whether a new member fits into the VE or not

[1], conflict resolution systems [2] and other approaches based on workflow systems [3,4].

2. IT SOLUTION

The ERP brochures make you believe you are able to do everything with such a system. But it is more favourable to use ERP for standard functions, such as finance and account, material procurement, etc. and use a Production-Leitstand (PLS) for the specific and customer-tailored manufacturing functions. In such a set up, ERP views the entire sophisticated production process as being reduced to a simple island that takes purchased parts from the warehouse and delivers finished goods to the customer (Figure 2). The basic data, such as bill-of-materials, are transmitted from the ERP to the PLS and the information about the delivered goods is sent back to the ERP. This IT solution is cheap, meets all requirements of the users exactly, is very fast and very flexible especially if the PLS is based on an object-oriented approach as it is described below.

Figure 2 - For ERP the entire production is only an isle

Figure 3 illustrates the Virtual Enterprise of the three companies and the locations which are closely tied together by the VE Intranet. All three partners possess ERP systems for the standard functions and a PLS for production control.

The PLS system is fully transparent so that a site is able to see the state of all orders produced by the others. This is a leading edge in respect to the co-ordination of the chained manufacturing. Some modules are produced in low-wage countries and others near the car manufacturing sites. The PLS enables the companies to shift work from one to another site during seconds and to see immediately the impact to work load and time schedule of both sites.

To control production-on-demand, the aid of computer programs and data radio hand-held terminals with integrated bar-code readers for shop-floor personnel is imperative. These employees do not have the time for long training courses and therefore the software must be easy to handle, robust in the case of operating errors and extremely reliable, because no production is possible, if the IT system breaks down.

Figure 3 - The IT systems around the Intranet

2.1 Receiving Orders via EDI

The three customers use similar EDI protocols which are based on the VDA 49xx standards (Verband Deutscher Automobilfirmen). In this paper we will not go into the details of these protocols. But we have to illustrate the continuous flow of information from the car manufacturers to the suppliers to understand the very high demands with respect to the organisation and the production system.

Let us take the Product A production as an example. The rough VE planning for the part A which comprises many modules is started weekly, triggered by the VDA 4905 which is the orders' forecast sent by the car manufacturer in a weekly pattern containing orders for the next 6 months. He additionally transmits the more actual order information for the next 10 to 16 days in a daily pattern using the so-called VDA 4916.

This information together with all basic data, such as Bill-of-Materials, is distributed simultaneously to all involved production sites. To plan resources, the orders are designated for a certain plant in accordance with features like right-hand drive, school-driver, etc. such features are later used to assign the order to certain work places.

The production of a particular module starts only with the VDA 4916 call and not earlier than 10 days before the assembly date of the car it is meant for because changes in production data are common. The timing of the production is controlled by the so-called "A-, B-, C-, D-, and M-impulses" (see Figure 4).

Only the most important impulses are shown in Figure 4. They all contain information about the parts whether it can be produced as intended in the original Bill-of-Materials or whether it has to be changed. For example, modules of car parts could be added or dropped or changed. Hence, all impulses have to be compared and in case of deviation the IT system PLS gives out an alert to exactly the person who is dealing with the product in a certain state. If a part order was not contained in the

forecast and is received with the A-impulse, both plants in Germany and abroad are able to produce it. If this occurs with B or later only the German plant is able to produce this late order. If an order was not known before D the part will not be ready in time and PLS has to inform the customer immediately since the car have to be taken out of the assembly line. M is for retrieving the part from the production area in Germany, to ship the goods and to hand it over.

Figure 4 – Average timing for production

2.2 Production Control

PLS controls the whole production, proposes the correct work steps and warns all involved locations of problems, failures and exceeded time limits.

Purchased parts and parts produced in other areas, stored in the warehouse 1, are PLS controlled by means of hand held radio pistols (RP) connected to PLS via TCP/IP over radio frequency. These devices comprise a bar-code scanner, a display and a keyboard. Hence, the worker is supported by the PLS through instructions displayed on his screen. For example, the worker sees the next picking-order, determining what has to be retrieved from the warehouse and also the next steps (Figure 5).

The worker replies by scanning in the bar-codes. In this way, PLS is able to track all orders and components and can alert the worker, if time limits are exceeded. It is also possible to receive high priority orders immediately, which are then displayed on the RP. This happens when an order was not announced by the forecast and appears suddenly through the impulses.

Another problem occurs when the sequence of orders changes, for example, when whole day's orders are changed. This is only recognised by the automatic comparison of the new impulse information with the actual state of production. The entire production has to react immediately.

PLS also organises the loading of trucks which bring the finished goods to the customer. Hardcopies of all delivery papers, such as dispatch notes, truck loading lists, etc. are printed as well as being additionally transferred by EDI.

All the different warehouses necessary for produced modules and finished goods have customised retrieval strategies, for example, the organisation may be random or the areas, rows, columns and levels are reserved for certain goods. There are pallets or boxes, one pieces or more are in one or more locations. All these requirements can be easily and quickly implemented by the OO-RT-DB, which is explained now.

Figure 5 - The configuration in the shop-floor area of one site

3. A NOVEL OBJECT-ORIENTED REAL-TIME DATABASE

3.1 Advantages using not a RDBMS but a OO-RT-DB

In many projects, tremendous problems occur with the performance of the Relational Database Management System (RDBMS) especially when lots of EQUI JOINS are necessary. This is always the case when tables of customer orders, production orders, work plans, BOM, and so on are being joined.

In contrast, DICONSULT is working with a RAM based database technology which is object-oriented [5,6,7]. Objects must be able to run independent of the each other. For instance, the orders' data is one object, namely the OO-RT-DB orders server, and the customers' data is also one separate object, and so on. The connection between both is only made by clients or agents which are described later (Figure 6).

Figure 6 - The data servers (circles) are technological objects

All the OO-data servers are based on the same program code which is able to satisfy the following requirements:

- to manage the data (create, delete, change, copy data)
- to co-ordinate all parallel requests from more than one client;

In contrast to a RDBMS the server is not blocked during a message sequence with one client. The requests can come from local clients or remote clients via network

- to automatically start/shutdown together with the computer start and shutdown
- to save all data intelligently on a hard disk drive, not to lose any data even if the power supply breaks down or other disturbances occur. In the end, the OO-RT-DB has advantages over a RTBMS in this respect as well.

The server gets specific properties, such as data structure, hierarchical structure, sort criteria, keys, etc., via a parameterisation of the appertaining tables. This creation of a new server is accomplished very easily by means of a graphical user interface which is shown at <http://www.diconsult.de>.

All these server objects (e.g. order, BOM, article basic data, ...) can be separately designed, developed, tested and maintained. This is very important and a tremendous advantage when establishing very fast good working software.

In contrast to systems with a central control program which manages all the sequences, we have realised the control also as being object-oriented. This means that the control of a system is also distributed, so that the other parts are able to work even if one part has broken down.

3.2 The object-oriented control of the system

The most important and most difficult part of a project is separate it into sections of independent objects. For this purpose one has to understand the current workflow and has to change it in accordance with these requirements:

- The pieces of the workflow as a result of the new approach must be straight forward and without back loops
- They must be designed so that they are independent of each other
- They are always designed individually together with the company and people affected by the new workflow
- They must be simple so that the employees are able to follow them. The easier the workflow, the better the whole project works at the end

Speaking in general, there are always Clients, Agents, Data Servers and actions of persons occurring in a workflow.

The servers only fulfil the requests of the clients and agents. There is no inherent initiative or control. A server is never transmitting data to another server.

The agents are programs which help in situations where servers want to speak to servers.

All objects can run together on one computer but they may also be arbitrarily distributed over a network (LAN, WAN, Internet, etc.) without any additional programming effort. The objects are always the same and connections to clients are handled by systems like CORBA, DCOM, or our own object-oriented communication system.

3.3 Object-Oriented Communication

According to the distributed objects which are located on various computers in a local network or/and a WAN, we developed a communication tool named Diconsult Socket Manager (DSM) and an Internet interface so that the access to the object-oriented database servers is possible via 4 different interfaces:

- 1) The Diconsult Socket Manager interface which is very fast and reliable based on TCP/IP and sockets
- 2) DCOM which is based on the Microsoft technology but is now also available for LINUX, HP-UX, IBM-AIX, etc.
- 3) ODBC
- 4) Internet interface for www-browsers to access data from the object-oriented real-time database servers.

3.4 Reliability

The reliability of an IT-system is the most important feature. As our OO-RT-DB server holds the data in main memory (RAM) for reasons of speed, we had to take special measures to avoid problems in case of a power failure.

Our standard OO-RT-DB server has the following features:

- All x minutes a checkpoint is written on the hard disk drive (HDD)
- Between two checkpoints all changes made by clients or agents are logged in a logging file on the HDD. In case of a power failure all the OO-RT-DB servers automatically restore their data by taking the last checkpoint and driving along the logging files so that all inserts, changes, etc. are again taken into account and the previous state is restored, exactly as it was before the power breakdown.

There are more features, but it is not possible to describe them all in this paper

Due to these measures, the risk that data could be lost is less than with a RDBMS because there the files are continuously open, whereas in an OO-RT-DB system only data packages are processed by the servers.

In testing this scenario and cutting off the power supply frequently the superiority of the OO-RT-DB servers over a system with a RDBMS was clearly shown.

3.5 High Speed, Less Resources, Supplied Operating Systems

The OO-RT-DB is at least 30 times faster than a RDBMS and needs 80 % less resources. Extensions of the data structure only cause changes in one OO-RT-DB server and they are easy and fast to perform. Via a graphical interface a field is changed or added and the old data are automatically transferred from the old to the new structure.

The OO-RT-DB servers are available under the operating systems UNIX (preferred because of its reliability) and Windows NT and 2000. With LINUX our experiences are excellent. The graphical user interfaces (clients) are based on Windows 95/98, NT, or Windows 2000.

3.6 Powerful Back-up and Archiving Strategies

The fact that the OO-RT-DB servers are file oriented is advantageous for back-up and archiving strategies. The most reliable way to avoid data losses and interruption

of production is to have a complete back-up system comprising hard- and software. In using OO-RT-DB the back-up system can be the production system for other functions. Hence, no extra hardware is necessary. In the case of hardware problems, another computer takes over all functions.

Another big advantage is the easy and transparent distribution of orders from one to another Virtual Enterprise partner. First the orders are distributed through an intelligent software agent which takes into account the restrictions of all plants, such as human resources, equipment, transport times, etc. A revised order distribution is necessary when a partner has problems to deliver what he has agreed to. Then by means of PLS the orders can be easily shifted to another partner with a simple mouse-click. All the necessary operations are undertaken by PLS automatically, for example locking the orders at the original partner, taking into account the impulses at the new partner site, changed label prints, etc.

4. INTERNET / INTRANET / WEB-BASED MIS

Due to the amount of information present in all the PLS's of VE partners involved, the partners decided to allow mutual access to information for a better VE management. Consequently, the daily or weekly discussions are now based on comprehensive and well-grounded data. It was obvious to apply the available Intranet. The new internet technology of OO-RT-DB made it easy to access all wanted data through standard web-browsers. There are two possible ways to use the new technique, of which one is the direct access to all OO-RT-DB servers to gather data. In this project there is no problem of security because an Intranet is used.

The second method is very secure and proposed for Internet applications. The relevant data are written cyclically from the VE members' PLS to an image OO-RT-DB. With the available tools of the OO-RT-DB this is easily done and has the advantage that the connection between the production data and the Internet application is cut from the outside view.

The managers of the VE use the Internet/Intranet access to view Management Information from any VE plant.

5. CONCLUSION

To produce customer specific car parts Just-In-Time, more than 3000 pieces a day, an additional PLS system was necessary to the existing ERP.

With the increasing business requirements the functionality of the system was increased to a powerful supply chain management and "e-Manufacturing" system, that is totally transparent for all Virtual Enterprise members. The Internet/Intranet solution combined with the OO-RT-DB approach brings immense advantages because the biggest problem in that business where orders are changing hourly is to keep all individual partners updated with the newest information.

In contrast to systems based on RDBMS that address exactly the same area, the customer has very positive experiences with OO-RT-DB which proved to be more reliable, much cheaper, more than 30 times faster, and more flexible when adding new functions. The time for implementation was only 5 weeks instead of 5 months. The set-up time was 2 days instead of 2 months.

Therefore the customers are quite certain that the combination of Standard-ERP Systems and flexible PLS systems is the optimal solution. They are convinced to have made the right decision to apply the new OO-RT-DB system together with an excellent object-oriented software concept.

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Abbreviations

BOM	Bill-of-Material	OO-RT-DB	Object-oriented Real-Time Database
EDI	Electronic Data Interchange	PLS	(Produktions Leitstand)
ERP	Enterprise Resource Planning system		Production control system
KSK	(Kundenspezifischer Kabelbaum) Customised Part	RDBMS	Relational Database System
MES	Manufacturing Execution System	RP	Radio Pistol
		VDA	Verband Deutscher Automobilfirmen
MIS	Manufacturing Information system	VE	Virtual Enterprise