

## Open manufacturing system using MMS service and object oriented manufacturing equipments

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### Abstract

Manufacturing equipments should be integrated to construct CIM (Computer Integrated Manufacturing) environment, but several economical and technological difficulties may be arisen in case heterogeneous systems are integrated into each other. MMS (Manufacturing Message Specification) can be effective in such a case, but the problem is that MMS-related products are comparatively expensive and the existing manufacturing equipments mostly do not support MMS. This study was focused on developing a gateway suitable to a non-MMS-compatible CNC machine-tool, and on implementing OSI (Open System Interconnection) upper layer on TCP/IP. The development system was applied to a cell controller by means of heterogeneous equipments under CIM environment, and to evaluate interoperability and portability.

*Keywords:* CIM; MMS; Machine-tool; Cell controller

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### 1. Introduction

In case a machining cell is constructed by using MMS service, the problem may be how to effectively integrate the manufacturing equipments made by various vendors. It may be more problematic in case a machining cell is constructed by using the existing manufacturing equipments. Up to recently, the function of controllers has been analyzed and then one-to-one interface has been performed as to analysis result in order to construct a machining cell through various manufacturing equipments. Fig. 1 shows the process. The process is advantageous in construction, but at the same time is disadvantageous in extensibility and portability. In addition, it was difficult to exchange information due to hierarchical control structure [1].

To solve such problems, MAP (Manufacturing Automation Protocol) appeared since the 1980s [2,3].

As MMS introduced an object-oriented concept into the communication among manufacturing equipments, it was positioned on the top-level of MAP and was proposed as the standard of upper application layer messages and services. Afterwards, it was appointed to be ISO/IEC 9506 standard [4,5].

MMS defines the standard of the exchange messages and services in application software tasks scattered on the network, as well as supports CNC (Computer Numerical Control), robots and PLC (Programmable Logic Controller). As shown in Table 1, the communication protocols, supporting MMS, are being developed into MMS on Full MAP, MMS on Mini-MAP, MMS on Ethernet, MMS on TCP/IP (Transmission Control Protocol/Internet Protocol) and others. The MAP, based on OSI (Open Systems Interconnection), has not been come into wide use and also its marketability has been lowered due to its complexity. On that account, MMS has been so researched that it can be implemented on TCP/IP or Fieldbus. Several producers commercialized \*MMS

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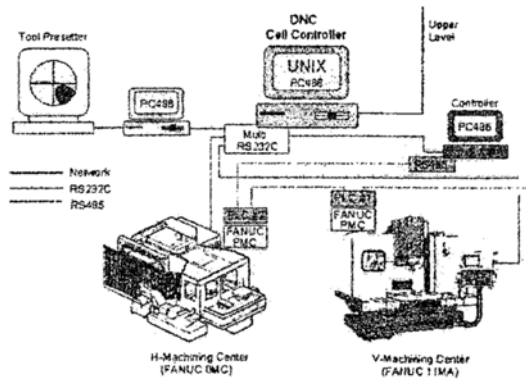


Fig. 1. Machining cell with heterogeneous CNC.

Table 1. MMS protocol.

Layer	MAP 3.0	Mini-MAP	MMS on Ethernet	MMS on TCP/IP
Application	MMS, FTAM, ACSE	MMS, directory	MMS, FTAM, ACSE	MMS, FTAM, ACSE
Presentation	ISO8822	None	ISO8822	Mapping/Adaptation
Session	ISO8326		ISO8326	
Transport	ISO8072		ISO8072	TCP
Network	ISO8348			IP
Data-Link	CSMA/CD, LLC 1/3	CSMA/CD	CSMA/CD, LLC 1/3	Ethernet etc.
Physical	Token bus (Nbits Broadcast) Token bus (Mbits Combined)	Spreadband/Carrierband optical fiber	Ethernet	

on Ethernet' that uses the 3rd, the 4th, the 5th and the 6th layer, out of OSI 7 layers, to OSI protocol, but the problem is that it is comparatively expensive and also it is difficult to set up environment and operation.

In conclusion, MMS cannot be universally used when FMS (Flexible Manufacturing System) or CIM is constructed despite the fact that it was appointed to be the international standard. There are several reasons; firstly it is difficult to use the protocol that configures the MMS applicable to the existing system and also MMS-supporting products are expensive. Secondly, the existing manufacturing equipments mostly do not support MMS [6-8].

MMS protocol itself had been implemented on Ethernet, but it is so researched that it can be implemented on the TCP/IP protocol of the internet network and can be set in CNC and PLC with intent to solve the above-mentioned problems. There are several methods to map MMS into TCP/IP, but a standard was not settled as yet [9-12].

The MMS service, which can satisfy popularity and economical efficiency the same as TCP/IP, should be developed as well as an intermediate technology, which can use MMS standard through objectifying the existing equipment the same as gateways, should

be researched in order that the characteristics of MMS such as interoperability and portability can be considered in cell environment. In line with this purpose, the CNC of the existing machine tools was researched so that it can be objectified by using a gateway that supports MMS service [13,14].

This study attempted to apply 'MMS on TCP/IP', which matches MMS service to TCP/IP, to the machining cell controller in consideration of popularity and economical efficiency. On this score, the CNC VMD (Virtual Manufacturing Device) suitable to MMS standard was developed and was applied to a gateway. An office LAN was used to the MMS service-based model cell, by using 2 machine tools having heterogeneous controllers. The machining cell was tested whether cell controlling and monitoring are normally performed, at the positions that are 20 m and 1 Km distant from heterogeneous controllers respectively. As the result, many advantages were observed in portability, extensibility and data access.

## 2. Characteristics of MMS

MMS is a standard of application service element in the 7th layer model of OSI (Open System Interconnection) designed to support programmable devices to exchange messages with each other in CIM environment. Specifically, MMS is to define services and protocols so that the control objects connected with Host or manufacturing equipments can be organically communicated with each other, with regard to a company-wide LAN. MMS, proposed as the standard of the top-level application layer message or service of MAP, has developed into MMS on Mini MAP, MMS on Ethernet/OSI, MMS on TCP/IP and others, based on the concept of object-oriented automatic communication. As MMS on Ethernet/OSI uses the layers between the third and the sixth to OSI protocol, OSI protocol has several problems with popularity, price, configuration and operation. Consequently, MMS on TCP/IP trends to be popular because it matches MMS service to the TCP/IP of which stability was verified through LANs and internet protocols.

### 2.1 Characteristics of the adopted MMS

Adaptation Layer and Compressed Stack are representative methods to implement MMS on TCP/IP. Most of MMS on TCP/IP Vendors, such as SISCO, Marben, Cycle Software and other, adopt extensible

Table 2. Mode of MMS on TCP/IP.

Mode	Adaptation Layer Mode	Compressed Stack Mode
Advantages	<ul style="list-style-type: none"> <li>*The advantages of OSI 7 Layers can be maintained</li> <li>*Other OSI application protocols can intactly used</li> <li>*WAN can be linked up with this mode</li> </ul>	<ul style="list-style-type: none"> <li>*Response time is rapid (real-time application)</li> <li>*Network can be simply configured</li> <li>*Economical efficiency is high</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>* Response time is slow</li> <li>* OSI 7 layers are all needed</li> </ul>	<ul style="list-style-type: none"> <li>* Protocol cannot be simply designed</li> <li>* The advantages of layer concept are restricted</li> </ul>

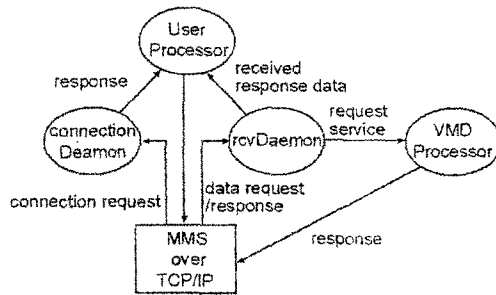


Fig. 2. Structure of applied MMS.

Adaptation. However, compressed types are more advantageous in the environment that needs real-time response because its network configuration is simple and inexpensive. Table 2 shows such characteristics. The adaptation type means putting RFC1006 Adaptation Layer between TCP/IP and Session Layer in order to drive OSI Session Layer and Presentation Layer on TCP/IP. The compressed type means using ISO/TC184/SC5/WG2 N578, which provides MMS protocol, on 2 Layer Stacks. Each type has its advantages and disadvantages, but it is considered that the compressed type may be universalized in view of a long-term efficiency [9].

The MMS on TCP/IP, adopted in this study, was implemented in consideration of the above-mentioned advantages and disadvantages. It seems to be similar to N578, but users are unrelated with it [10-12]. Correctly, it consistently provides API to users irrespective subordinate protocols. As shown in Fig. 2, The structure of MMS applied in this study consists of connection daemon playing a role in message transmission, receive daemon playing a role in processing received message, and application processor playing a role in managing client and server.

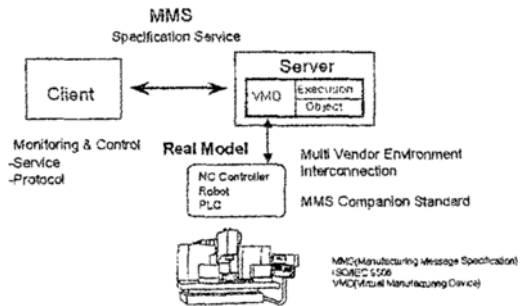


Fig. 3. Concept of MMS implementation.

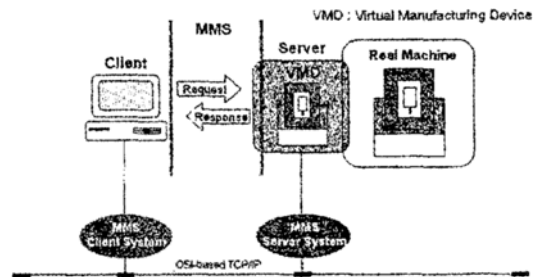


Fig. 4. Concept of VMD implementation.

### 2.2 CNC-centered MMS

In MMS, the control object and the manufacturing equipment designate CNC, Robot and PLC. Fig. 3 shows the concept. According to the figure, the client can use VMD with MMS service, and the server is VMD application system. Likewise, VMD is a virtual manufacturing device of function and object, necessary to control and monitor, are abstractive. Fig. 4 shows the concept of MMS limited to CNC. A real machine can be controlled and monitored via VMD from the characteristic service called 'MMS'.

On this wise, MMS treats these manufacturing equipments as VMD through introducing an object-oriented programming concept. For this reason, specific equipments such as CNC, a robot, PLC and others should be clearly defined. The followings are functions of NC device-related MMS-CS (Client-Server) among the standards accompanied with MMS.

- 1) Defining the communication service of manufacturing message, necessary to apply NC devices
- 2) Defining NC models as application functions; Defining the connection between these functions and VMD
- 3) Providing the standard name to the specific object of NC

4) Defining NC application models and classes

VMD always remembers the status of real equipments on the basis of variables, domains and semaphores, and shows the related data at the request of a client. Likewise, it can control the real equipment on request.

3. MMS operating environment construction

Fig. 5 shows the communication layer applied to serve MMS. It shows the system application hierarchy reconfigured to operate MMS under the situation that it is really applied to OSI 7 layers. There are an application program, MMS and MMSI (Manufacturing Message Specification Interface) in application layers. MMSI is a standard API that uses MMS in application layer, and common mutual interface was set up in respect that MMS is being used. Synthetically, an application program was made out by using a standard API called 'MMS Interface'.

Fig. 6 shows the MMS Client/Server system to connect MMS service with real equipments. The server and the client are connected with TCP/IP through standard network interface. In the MMS application program that is connected with MMSI, the server is more complicated. The application program

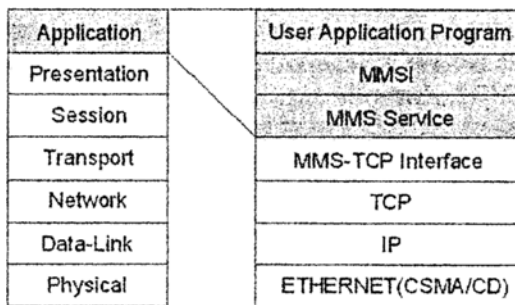


Fig. 5. Application layer of MMS on TCP/IP.

in the server is constituted by VMD module, a protocol conversion module, device local mapping module and an equipment driver module. VMD module is a virtual model related with mechanical characteristics and functions, and device local mapping module is to control or monitor real equipments.

The machine tool, which is controlled by OAC (Open Architecture Controller; PMAC, Delta Tau) and FANUC controller, was used to test the operation of MMS on TCP/IP. VMD server was configured to control and monitor real equipments, and a client was separately connected to TCP/IP base. The VML server, which is to control and monitor the machining center based on PMAC (Programmable Multi-Axis Controller), was configured to test the operation of MMS on TCP/IP as shown in Fig. 7. Also, a client was separately connected with the TCP/IP-based LAN. The DLL (Dynamic Link Library)-typed middleware, which manages MMS Interface and Communication Socket Service Interface on multitasking Window, was set in the client and VMD server.

As shown in Fig. 8, many middleware-level processes are necessary to operate MMS. Thus, the APIs provided from DII are used after the MMS service-related library was designated. The related APIs can be externally interfaced after they were appointed to be 'extern'.

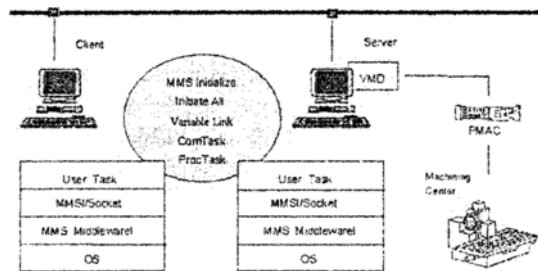


Fig. 7. Environment of MMS on TCP/IP service.

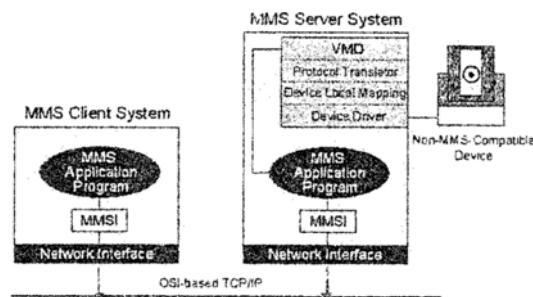


Fig. 6. MMS client/server system.

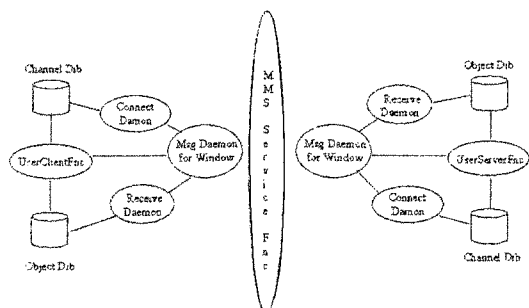


Fig. 8. Mechanism of MMS service.

```

extern "C" __declspec(dllimport) UINT MMS_initialize();
extern "C" __declspec(dllimport) UINT Initiate_all();
extern "C" __declspec(dllimport) UINT Initiate(char *CH_name);
extern "C" __declspec(dllimport) int _get(char *VarName);
extern "C" __declspec(dllimport) int get(char *VarName,int VmdNo);
extern "C" __declspec(dllimport) int _put(char *VarName);
extern "C" __declspec(dllimport) int put(char *VarName,int VmdNo);
extern "C" __declspec(dllimport) UINT PI(int pi_command,char *pi_Name,char *pi_arg);
extern "C" __declspec(dllimport) UINT _link_variable(char *VarName,void *Phys_Addr,int Var_Len);
extern "C" __declspec(dllimport) UINT link_variable(char *VarName,void *Phys_Addr,int Var_Len,int VmdNo);
extern "C" __declspec(dllimport) UINT link_functionpointer(char *pi_objname,void (*PI_FUNC_NAME)());
    
```

**4. Open machining cell configuration**

In case CIM environment is constructed by integrating manufacturing equipments distant from each other, RS485 and similar devices can be applied. However, distance, cost and communication reliability may be problematic. In this study, such problems were solved by using the existing TCP/IP network. To test MMS on TCP/IP operation, a machining cell was configured on KIMM model plant as shown in Fig. 9.

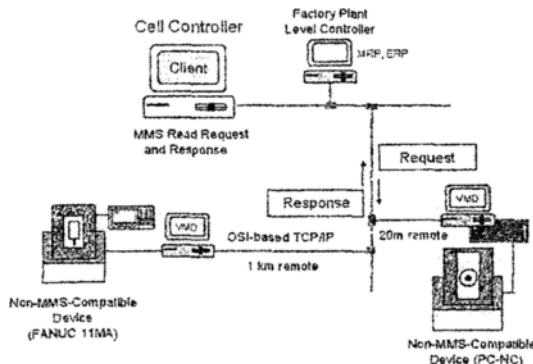


Fig. 9. OAC machining cell.

FANUC 11MA and PC NC (non-MMS compatible devices) were put on the underpart of the cell controller that takes orders from the server, which manages schedules and production control under CIM environment, and manages subordinate manufacturing equipments, and also VMD was mounted. PC-NC is about 20m distant from the cell controller, and FANUC 11MA is 1Km distant. Remote model plants designates machine tools, CMM (Coordinate Measuring Machine), AGV (Automatic Guide Vehicle), ASRS (Automatic Storage and Retrieval System), a transfer machine, tool presetters and others, but this study was focused on only CNC machine tool. PLC board functioned as the interface layer between FANUC 11MA and VMD, and PMAC board functioned between PC-NC and VMD.

The VMD, based on the open control board, was implemented in Window environment, and defined the object to configure the VMD recommended by ISO/IEC 9506-4. The VMD, set in the application process of MMS, is constituted by an executive function and finite variables. Table 3 shows the objectification mapping of a unit control device and a process model [5].

**5. Cell controller operating test and evaluation**

With regard to MMS operating test, a variable object and a program invocation object were defined as shown in Table 4. Initialization process is necessary to really transmit messages between a client and a server, aimed at the defined objects. Fig. 10 shows the

Table 3. Model of VMD object.

Object : VMD		
Type	Function	Content
Key attribute	Executive function	Application program
Attribute	Vendor name	FANUC
Attribute	Model name	11MA
Attribute	Revision	E
Attribute	Logical status	(STATE-CHANGES-ALLOWED, NO-STATE-CHANGES-ALLOWED, LIMITED-SERVICE-PERMITTED, SUPPORT-SERVICES-ALLOWED)
Attribute	List of capabilities	Null
Attribute	Physical status	(OPERATIONAL, PARTIALLY-OPERATIONAL, INOPERABLE, NEEDS-COMMISSIONING)
Attribute	List of program invocations	NC_Program_Execution
Attribute	List of domains	NC_Program
Attribute	List of transaction objects	
Attribute	Lists of other VMD-specific objects	

process. In view of information processing, the client and the server initialize each object and channel information through DIB file. An object information file defines various and detailed information related with reciprocable variables, and designates communicable channel names. The designated channel name defines the name of the host connectable with a channel information file and parameter. In succession, it should be initialized so that the APIs provided from MMSD II can be used; it is managed by the API 'MMS\_Initialize( )', and all servers should perform the job before using MMS service such as 'link\_variable', 'link\_fact\_ptr', 'get', 'put', 'PI' and others.

Table 4. Definition of object variable.

Object	Variable	Attribute
Unnamed Variable Objects	N_PgmNo	Variable Name
	N_CurPosX	Variable Name
	N_CurPosY	Variable Name
	N_CurPosZ	Variable Name
Program Invocation Objects	N_OpStatus	Variable Name
	N_PgmSearch	Program Invocation name
	N_PgmUpload	Program Invocation name
	N_CycleStart	Program Invocation name
	N_CurPos	Program Invocation name
	N_Stop	Program Invocation name

After the initialization, the function of a cell controller was tested under CIM environment by means of the automatic plant shown in Fig. 11. In performing a function test, a program should be downloaded to each machine tool by the schedule made out above or the program in the controller should be called out. After program download, the machine tool should be started as shown in Fig. 12 (Cycle Start). Its motional status can be monitored any time, and the positions of machine tools can be checked in case of need. The client transmits codes to the control information, such as 'Cycle Start' and 'Position Value', through inter-operable object variables. VMD server performs the control function of the machining center, and after that it transmits 'Status Value' in case of need. In this case, the motional status of the machine is monitored at regular intervals as shown in Fig. 13, and as shown in Table 5, status information and present state information are monitored between the present positions of X, Y and Z-axis and job contents. After the job is completed in that way, the result is sent out to the client. Such information is useful for the client to operate a simulator. Also, repetitive tests were performed to examine whether the start-stop function of the machine tool normally works.

Altogether, it took 1±0.05 second(s) to receive the data requested from the cell controller functioning as the client to VMD server. In such a case, the response

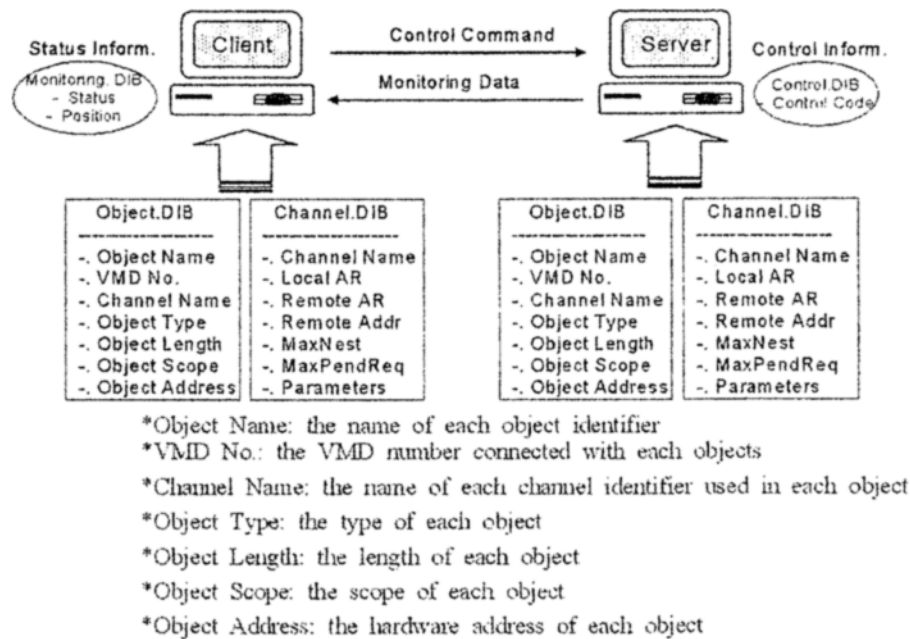


Fig. 10. System initialization process of MMS service.

Table 5. Items example of monitoring data.

Machine Status	Work Status
- Working/Idle/Stop	- Work In Standby
- Machining On/Off	- Work In Completion
- Spindle On/Off	- Machining Start
- Clamping On/Off	- Machining Completion
	- Work Out Standby
	- Work Out Completion



Fig. 11. Machining cell on MMS service.



Fig. 12. Manufacturing by MMS service command.



Fig. 13. Display of MMS VMD server on OAC CNC.

time of equipment may be  $0.5 \pm 0.03$  second in case the client requests the function of start-stop. Response time can be more shortened according to the specifications of the network card (Testable Condition: 10mbps) and network version. Test results are considered to be controlled in real-time from the viewpoint of Cell/Area in CIM reference models.

## 6. Conclusion

In this study, the network was constructed by using the MMS on TCP/IP that matched MMS service to the TCP/IP come into wide use, and also the machining cell was constructed by objectifying the non-MMS-compatible device in order that cable system, including the line change of machining cell, can be possible. In the system constructed as mentioned above, it was ascertained whether VMD is normally mounted on MMS on TCP/IP and whether MMS is normally operated. In consequence, the interoperability, which can solve the isolation of the automatic line configured by heterogeneous equipments, should be secured as well as real-time remote control and monitoring was verified.

1) An open machining cell was constructed by using a machine tool based on CNC\_VMD gateway.

2) MMS service can be popularized and universalized by applying the MMS on TCP/IP come into wide use.

3) The cell controller, developed in this study, can be flexible, interoperable, portable and extensible as respects line change.

## Acknowledgement

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