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ABSTRACT: Due to an increasing sophistication of assembly equipment and supporting software, CAMX standards have been introduced to leverage the shortcomings of legacy and proprietary communication protocols. CAMX standards make use of XML, and TCP/IP networks to provide a web-based, eManufacturing Framework. The standards are defined for all enterprise levels, allowing integration of the shop floor, execution systems, supply-chain management, development, and other areas. eX-MISSION is presented as a now commercially available software package for reliable deployment and management of a CAMX Framework. eX-MISSION is composed of applications developed to solve specific issues established at R&D stages, which have been deemed valuable for use in industry.

Key Words: Assembly systems, Electronic data interchange, Electronic equipment manufacture, Message systems, Manufacturing, Manufacturing automation, Manufacturing automation software, Manufacturing data processing.

1 INTRODUCTION

As manufacturing and assembly equipment are improved and get more sophisticated, there is an increasing need to develop and enhance communications interfaces. The present inadequacies are not only limited to production equipment, but also to associated software applications and the supporting enterprise information systems.

Currently, equipment vendors, as well as some large manufacturers, have developed their own proprietary and in-house solutions. This approach introduces serious drawbacks when deploying multi-vendor systems, since a layer of adaptation needs to be introduced to the communications interface of each component of the assembly line, as well as to any HMI, SCADA, or other applications. Estimates show that the costs for developing custom communications adaptation layers are around 4X the cost of the applications' software themselves [1]. The plant ramp-up is significantly delayed, increasing time-to-market of products and reducing profitability.

Standards have been proposed in order to support interoperability among components of the manufacturing enterprise. SECS/GEM, introduced with moderate success in the semiconductor manufacturing industry, has come short of meeting basic requirements for the electronics assembly industry. Vendors have not agreed upon standard use of the interface, ruling out interoperability. SECS/GEM interfaces are also designed on the virtually obsolete RS-232 physical layer, and although an Ethernet TCP/IP interface is now available, it has proven to be excessively expensive for most applications.

In order to leverage the shortcomings of the SECS/GEM protocol, NEMI (National Electronics Manufacturing Initiative, USA) launched the Plug and Play Factory Project [2]. The project goal was set to develop a standards-based communications framework for the electronics assembly industry that fosters seamless interoperability among equipment, applications, and enterprise information systems. The developed standards are endorsed by IPC and are based on XML, providing rich data content and compatibility among heterogeneous components, and are now referred to as the CAMX (Computer Aided Manufacturing XML) framework. In addition, recent NEMI Roadmaps have stated the importance of CAMX adoption by the electronics assembly industry, as well as proposing further enhancements for areas such as final assembly [3]

2 CAMX FRAMEWORK

The CAMX framework is defined by a set of IPC standards[1], known as the IPC-25xx grid shown in Table 1. Each row contains specifications for different enterprise levels, separated into columns according to sectional requirements.

[1] http://webstds.ipc.org/

IPC Number/ Function	-xxx1 Generic	-xxx2 Administ	-xxx3 Document	-xxx4 Board Fab	-xxx5 Bare Bd Test	-xxx6 Assembly Manufact	-xxx7 Assy Test/Insp.	-xxx8 Comp. & Mat'ls
IPC-2500 CAMX Framework	IPC-2501 Published							
IPC-2510 GenCAM Product Data	IPC-2511A IPC-2511B Published	IPC-2512A Published	IPC-2513A Published	IPC-2514A Published	IPC-2515A Published	IPC-2516A Published	IPC-2517A Published	IPC-2518A Published
IPC-2520 Quality Product Data				IPC-2524 Published				
IPC-2530 SRFF Process Data	IPC-2531 ANSI Draft							
IPC-2540 (CAMX) Shop Floor Comm.	IPC-2541 Published					IPC-2546 Published	IPC-2547 Published	
IPC-2550 (MES) Execution Comm.	IPC-2551 Working Draft			IPC-2554 Working Draft		IPC-2556 PIN Submitted		
IPC-2560 Enterprise Comm.								
IPC-2570 (PDX) Supply Chain Comm.	IPC-2571 Published					IPC-2576 Published	IPC-2577 Final draft	IPC-2578 Published
IPC-2580 App. Specific Data	IPC-2581 Proposed Std							

Table 1 IPC/CAMX standards grid

The first level defines the communications transport layer, specified by the IPC-2501 standard. IPC-2501 defines a protocol based on Message Oriented Middleware (MOM), using HTTP, XML, and SOAP.

The rest of the levels specify data content for messages related to product data, processes, execution, supply chain management, quality, etc.

2.1 *HTTP, XML and SOAP*

CAMX defines HTTP to be used as transport protocol. This approach enables all TCP/IP networks to be used for communications, including Intranets, the Internet, Virtual Private Networks (VPNs), and TCP/IP enabled industrial networks and buses, allowing the framework to extend from the manufacturing shop floor to an office anywhere in the world.

CAMX data is represented in XML format. XML is a language to store information that is structured, self-describing, platform- and implementation-independent, and also extensible.

Combining HTTP and XML, SOAP (Simple Object Access Protocol) was developed, and is now a W3C standard [4]. SOAP defines a simple request/response mechanism to access a resource available on the web. Because it is based on XML and HTTP, SOAP is:

- A protocol for sending messages
- For communication between applications
- Designed to communicate via Internet
- Platform independent
- Language independent
- Simple and extensible

SOAP was therefore a natural choice for communications protocol, ruling out any ad-hoc solution.

2.2 *CAMX Message Oriented Middleware*

Clients (equipment and software) within a CAMX framework use SOAP to access a centralized messaging service, based on Publish/Subscribe [5]. This layer of communication between clients and a centralized server is denominated Message Oriented Middleware (MOM). MOM is an emerging technology used for loosely coupled, enterprise wide communication that has many applications in Enterprise Information Systems (EIS) beyond the scope of Factory Information Systems (FIS).

The Publish/Subscribe mechanism allows producers of data to publish significant information to the MOM web server as available. The web server keeps a listing of subscription interests of other clients, that periodically check with the web server for published data. This mechanism allows equipment and software to exchange data in a flexible and asynchronous fashion, that responds robustly to temporary network failures or client unavailability.

2.3 *25xx Data*

Data in a CAMX framework is contained in XML messages, defined by the IPC-25xx series of standards. Table 1 shows the areas for which standards have been developed, as well as their current status.

Electronic product data is defined by the IPC-251x series, and are collectively known as GenCAM® 2.0[2]. GenCAM was developed, and is now supported, by a wide range of assembly equipment manufacturers, as well as CAD tool vendors.

Assembly processes are described following the IPC-253x series, which is based on SMEMA's Standard Recipe File Format (SRFF).

Models and events for assembly equipment of all kinds are specified in the IPC-254x series. The IPC-255x series in turn defines messages for Manufacturing Execution Systems (MES).

The Product Definition Exchange (PDX) IPC-257x standards are tools to handle technical data exchange among OEMs and EMS providers and suppliers. It is based on RosettaNet's[3] standards for supply chain management.

Finally, the 252x and 258x series define XML content for product quality data and product specific information respectively.

3 THE EX-MISSION™ SUITE

As OEMs strive to move into the eManufacturing era, requiring equipment vendors and EMS suppliers to support the CAMX standards, there is an essential need for CAMX middleware to support device communications.

eX-MISSION [4] is a commercially available software suite that provides all the necessary applications and tools required to deploy a robust, reliable, and scalable CAMX framework. It is the result of R&D work that started with the development of a CAMX web server, and was extended to a whole set of applications that address specific issues related to deployment, monitoring, maintenance, reliability, and others.

3.1 *BRAVE-MISSION*

BRAVE-MISSION is a CAMX MOM Web Server, the component known as the *Message Broker*. BRAVE (Broker Advance) provides both Publish/Subscribe and Point-to-Point messaging services, and guarantees full IPC-2501 compliance. Its architecture contemplates the possibility of introducing custom plug-ins to merge the CAMX framework with existing factory information systems.

3.2 *Administration and Monitoring*

COMBAT-MISSION is an application for system managers to administer the CAMX domain. Initially developed to upgrade the static configuration defined in the IPC-2501 standard, COMBAT allows a system administrator to remotely set publish/subscribe interests for equipment, as well as point-to-point messaging permissions. It also provides remote monitoring functionality for BRAVE servers and CAMX clients.

3.3 *Installing a CAMX Framework*

Validating the performance requirements and correct behavior of both network and client elements is a critical task when installing new equipment and applications. VIPER-MISSION serves this purpose by simulating a CAMX web server, and verifying the correct operation of equipment before it is introduced into the operational environment. Similarly, BOMBER-MISSION is used to test a CAMX web server by simulating production equipment, introducing (bombarding) messages into the network, and verifying that the server can cope with the traffic that will be produced during operations.

These tools were originally developed for debugging and validating purposes in development stages of BRAVE servers and CAMX compliant devices. However, they have been required by the industry as essential tools to guarantee suitable long-term performance of the framework.

3.4 *Migrating to CAMX*

In developing CAMX standards, existing equipment were modified, or adapted, to produce CAMX messages. This was achieved by special ad hoc software applications that have also found its place in industry.

As clear as the savings brought up by adopting CAMX are, it is economically unfeasible to dispose all existing equipment and software and replace it by new CAMX compliant devices. In order to adapt legacy equipment and applications to a CAMX framework, eX-MISSION introduces PEACEMAKER equipment adapters. PEACEMAKER applications take input from legacy communication interfaces such as SECS/GEM, and translate it into the appropriate XML messages. The messages are then published to a BRAVE web server, allowing other CAMX applications to interact transparently with the legacy equipment.

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[2] http://www.gencam.org/

[3] http:// /www.rosettanet.org/

[4] http://www.ex-mission.net/

4 CONCLUSIONS

In order to reduce costs, increase interoperability, and maximize enterprise-level integration, CAMX standards have been introduced for the electronics assembly industry. CAMX standards define XML messages that are exchanged in a web-based framework. eX-MISSION™ is a now commercial software suite that provides all the necessary tools to install, operate, monitor a CAMX framework, and to safely deploy new CAMX compliant equipment. CAMX and eX-MISSION are the result of extensive R&D work in the field of factory automation and communications, and are an enabling technology for multi-vendor assembly equipment interoperability.

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