An experimental setup for vertical integration in network systems for industrial use

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Abstract

In this paper we discuss emerging networking technologies to achieve better horizontal and vertical integration in industrial information systems. XML is being accepted as the standard format for data exchange across platforms in the Internet, and it can also be used to describe industrial processes. We propose use of such general-purpose descriptions of information, together with the use of the next generation Internet protocol, IPv6, to achieve future transparent information systems throughout the organization.

We propose an experimental setup for evaluating the current status, with possibilities and shortcomings, of the IPv6 protocol in industrial applications. The experiments will be carried out during the summer of 2003, and will involve several labs with real-time networks and processes. Remote operation through an IPv6-enabled link will also be tested.

1. Introduction

Traditional industrial information systems typically consist of a number of different networks, based on a number of protocols. Information is spread around in the organization; from sensor and actuator data at the field level, through production and support, and to logistics and orders at a more administrative level. The many different protocols that are used make it a difficult task to access data freely throughout the organization, especially across organizational "layers". Rather, information is structured hierarchically in the organization.

For many companies this hierarchical structure becomes an obstacle when new methods of cooperation within the organization are being sought. Workers may be distributed around in *virtual teams*, and are increasingly working across the historical boundaries in the organizational hierarchy. These workers, or *entities* (they may well be machines), may also be distributed geographically across borders. There is a need for horizontal and *vertical integration* of the information systems, to enable information to flow transparently throughout the organization.

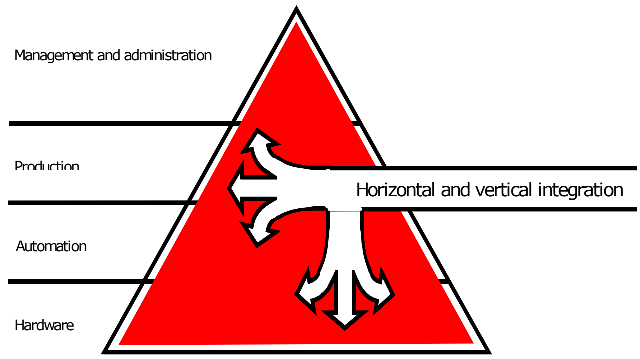

Figure 1. Industrial information system

2. Vertical Integration for Industrial Networks

The new challenges in industrial organizations call for a new way of designing these information systems, to allow for more transparent access of information. It is clear that a key issue for achieving this goal is to use *standards* that are shared across different business segments and throughout the organization. At the level of administration and management this work seems to have come further than on the levels on hardware and automation. Some industrial vendors are addressing these issues by offering products that allow a transparent flow of information throughout the organization, e.g. ABBs *IndustrialIT* concept [1], PROFInet [2] and IDA[3].

In the maritime industry the development of an open architecture for maritime fieldbus networks has come far. The Maritime Information Technology Standard [4] is currently being standardized, and is based on current TCP/IP technology.

The proliferation of the TCP/IP protocol makes it an ideal candidate for use within the entire information system. TCP/IP is currently in widespread use at the "top" levels of the organization; for administration, support and management purposes. At the field level, however, TCP/IP networks have not yet caught on, mainly because of the lack of *determinism* for delay within such networks, but also because the use of controllers capable of running the Internet protocol stack simply has not been viable, due to increased cost and overhead in network resources. With the advent of cheap microcontrollers capable of running the TCP/IP stack, high-capacity Ethernet networks being installed in plants, and the standardization of new frameworks to achieve end-to-end Quality of Service (QoS) across an IP network, this may well change.

Another option for introducing TCP/IP services at the field level is to integrate IP into existing Fieldbus networks. This can be achieved by encapsulating IP packets into frames on the fieldbus network, as can be seen in e.g. [5],[6].

2.1 XML framework for integration

There are several initiatives to support transparent communication between entities across the Internet, most notably the *Semantic Web* [7], which uses XML and *ontology classes* to extend the way WWW works today, and to enable better cooperation between machines and people.

The use of XML descriptions in factory communications, to enable web integration, and to integrate the information within an enterprise framework has been covered in [8],[9]. The information made available in XML descriptions can be used in different roles, depending on the style sheet used to represent the XML data, so that the same dataset can be used for web representation, support purposes, or as real-time information. Several initiatives to describe fieldbus profiles as XML have also been started, such as [10],[11].

Recently there has also been a trend towards the use of the open SOAP [12] standard, which also makes use of XML, to replace the more proprietary DCOM protocol in process control applications, where OPC is the de facto standard. All of the above makes XML an exciting choice for general interchange of data.

2.2 IPv6 for transparency

The new Internet Protocol, IPv6 [13], is a likely candidate for future transparent networks across the organization. IPv6 defines methods to achieve QoS, and fixes several other shortcomings of the existing IPv4 protocol, like security and the number of available addresses. The use of IPv6 in industrial applications has been discussed in e.g. [14], where it is concluded that the implementations are not yet mature enough for industrial deployment. There are several issues that need to be addressed before it will gain widespread use, but we still feel that the protocol has much to offer.

A major problems with the IPv4 protocol in widespread use today, is that there is a rapidly decreasing number of available addresses for new devices being deployed on the Internet. This problem has in part been solved by use of so-called NATs, where enterprises can have their entire network infrastructure hidden behind gateways designed to provide Internet services. This may be fine, but it does not work well with the kind of transparency we want. While NAT solves some problems, it also creates some new ones when introducing new services, like peer-to-peer (P2P) networks and IPSec. IPv6 is designed to overcome these problems, and with a 128-bit address space there is enough addresses for billions of nodes on every square meter on earth.

The IPv6 header has a reduced number of fields, which should make routing of packets more efficient than with the existing implementations, once implemented in hardware. The header also defines extra fields to differentiate between packet streams, and improved ability to implement QoS. Unfortunately the use of these fields is still largely undecided, and a topic of discussion in IETF forums.

The widespread use and deployment of IPv6 has taken longer than what was first expected, and the *killer application* of IPv6 has yet to be identified. However, it remains an exciting option for interconnecting all kinds of sensors and devices in the future, and it seems that Asia, where the need for IP addresses is greatest, is leading the way, e.g. for automobile devices [19].

Recently commercial RTOS vendors, like Windriver [15] and QNX Software Systems Ltd.[16], have also announced support for IPv6 in their TCP/IP implementations. For WindowsXP, Linux and *BSD systems IPv6 implementations have been readily available for some time now.

3. Remote operation over TCP/IP

There are several applications of remote operation over TCP/IP, some of which include remote medical operations, telerobotic devices, and future sensor networks. *Cyberlab* [17] is an initiative started by academic partners to share lab setups over the Internet. The motivation behind this being that labs can be expensive to set up, maintain and support, and are often left unused for long periods of time.

In the industry there is also a significant need for improved methods for remote control of field operations. By establishing central control centres for plants it will be possible to use support resources more efficiently, the organization becomes more flexible, and information and know-how can be used in a more widespread fashion.

We wish to establish an experimental setup with the purpose to study remote operations through TCP/IP networks, using technologies that enable transparent communications. It is also interesting to note what kind of performance drawbacks are accounted for by introducing various *application gateways* in order to achieve transparency, as opposed to having exclusively IP-enabled nodes. Because a lot of existing equipment will be in use for many years to come, it seems likely that such application gateways will be commonly applied.

4. Experimental setup

In an early phase of experiments, several IPv6-enabled machines, interconnected on a switched Ethernet network, will be utilized to measure delay and jitter across the local network, in a controlled environment. Since the machines, situated at the real-time lab at NTNU, are capable of running a “dual” stack it will be easy to compare results with the normal IPv4 stack. IPv6 implementations in various RTOSs, like RT-Linux and QNX, are candidates for testing.

Experiments involving control of processes can eventually be carried out in the real-time laboratory, using the machines with dual stack for remote control over IPv4/IPv6. This also enables us to experiment with cooperation between nodes. We also wish to control these real-time processes using an IPv6-enabled connection across the experimental IPv6 network *6net* [18]. In an early phase we have set up an IPv6 path between NTNU and ETH in Zürich, Switzerland.

4.1 Remote control of motor lab

Initial tests are being done on a laboratory that was previously used as an educational lab. It was programmed manually in a DOS environment, and abandoned because of the awkward programming of it. Since the lab is unused, and has some interesting real-time characteristics, it was a prime candidate for our tests. The lab has been beefed up with a modern PC running QNX6, which enables us with a nice development environment as well as IPv4/v6 support.

The lab has 2 large DC motors connected with a rubber-band loop (Figure 2). Here one motor gives variable load, while the other should keep constant position/speed depending on the experiment. During the experiment it is possible to read the position of the motor and the load, and, through sampling in proper intervals, to derive the speed of these. These state variables are in turn used in a controller algorithm to calculate the needed input values for control of the motor.

Figure 2. Control of motors

In the new implementation of the lab all of the data in the process are represented as XML structures. The driver of the I/O-card reads the position counters, and when reading from the driver an XML string is received. The state variables contained in the XML string can be sent directly to another process on the same machine, or used in a remote node, e.g. over a TCP or HTTP connection, for control or supervisory purposes. Within the real-time process there is some overhead connected with the use of XML data, and this is also something that needs to be investigated.

The real-time properties of this process make it suitable for investigating limitations and possibilities of using Internet technologies in the control network. A sufficient sampling frequency of the process state variables is 200Hz, and this allows us to test the performance with a controller node on the switched network. It might also be possible to extend the control “loop” further over the Internet. However, without a proper mechanism to ensure sufficient QoS with background traffic (like *RSVP*), this does not seem viable quite yet.

4.2 Further experiments

In a later phase we aim to use existing lab setups for other industrial processes (refrigeration process, level control in fieldbus environment) and control applications (control of model train, model ship) that are available at the department, and incorporate these labs into our experimental setup.

5. References

[1] Industrial IT, *http://www.abb.com/industrialit/*

[2] IDA- Interface for Distributed Automation, white paper spec, V1.1, *IDA-group,* 2002

[3] PROFInet Architecture Description and Specification, Draft V2.0, *Profibus nutzerorganisation, 2002*

[4] MiTS, *http://www.mits-forum.org*

[5] E. Nikoloutsos, A. Prayati, A.P. Kalogeras, V. Kapsalis, S. Koubias, G. Papadopoulus, "Integrating IP Traffic into Fieldbus Networks", *Proc. of the 2002 IEEE International Symposium on Industrial Electronics,* 2002

[6] L.L. Ferreira, S. Machado, E. Tovar, "Scheduling IP traffic in multimedia-enabled PROFIBUS networks", *Proc. on 8th IEEE International Conference on Emerging Technologies and Factory Automation,* 2001

[7] The Semantic Web, *http://www.w3.org/2001/sw/*

[8] M. Wollschlaeger, C. Diedrich, R. Simon, "Web Integration of Factory Communication System using an XML Framework", *Proc. of the 2002 IEEE International Symposium on Industrial Electronics,* Vol.1, July 2002.

[9] M. Wollschlaeger, C. Diedrich, M. Thron, "Generation of Role-specific Information for an Enterprise Integration Framework Using XML Descriptions", *Proc. of 8th IEEE International Conference on Emerging Technologies and Factory Automation 2001,* Volume: 2, Oct. 2001

[10] D. Bühler, "The CANopen Markup Language - Representing fieldbus data with XML", *Proc. of 26th IEEE International Conference on Industrial Electronics, Control and Instrumentation,* IECON 2000

[11] J.V. Korsakas, J.R. Moyne, "Moving DeviceNet Data Representations to XML", 6th Annual ODVA Meeting

[12] SOAP - Simple Object Access Protocol, V1.1, *May2000, http://www.w3.org/TR/SOAP/*

[13] S. Deering, R. Hinden, *Internet Protocol, Version 6 (IPv6) Specification* , IETF RFC 2460, December 1998

[14] N. D. Aakvaag, N. Nordbotten, *IPv6 - Implications of the next-generation Internet protocol for ABB*, ABB Review 1/2003, p.30-35

[15] VxWorks RTOS, *http://www.windriver.com/products/windnet_ipv6/*

[16] QNX RTOS, *http://www.qnx.com/products/new.html*

[17] Cyberlab, *http://www.cyberlab.org/*

[18] 6Net, *http://www.6net.org/*

[19] T. Ernst, K. Uehara, "Connecting automobiles to the Internet", *ITST workshop (http://www.sfc.wide.ad.jp/~ernst/doc/ernst-itst02.pdf),* 2002