Advances in Internetworking Technology and the Future of Control Systems

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Abstract

Internetworked Control Systems combine control networks such as LonWorks and IP networks to create powerful solutions to a wide range of monitoring and control applications. By combining the power and ubiquity of IP networks and the control-oriented and cost features of LonWorks designers can create solutions with unprecedented scalability, flexibility and value.

The pace of development in the internetworking technology arena continues to be staggering. Many of the current trends and technologies have a substantial impact on the internetworked control systems of the future. This paper presents several recent trends and technologies and discusses how they relate to telemetry systems and internetworked control systems. Among the areas covered are: Quality of Service (QoS), Virtual Private Networks, physical media (ATM, CATV, Gigabit Ethernet), security protocols, and distributed object technologies.

Keywords

Internetworked control systems, LonWorks, TCP/IP, connectivity, Internet, Quality of Service, VPN.

1. Internetworked Control Systems

Control networks such as LonWorks were designed to solve a specific set of application requirements relating to networks for monitoring and control. Key design criteria are cost, reliability, wiring flexibility, and orientation toward regular small message or event transfer rather than large file oriented data. By contrast, data networks were designed to support the needs of business applications including high data capacity, LAN and WAN support, and remote access.

But many applications which involve control systems also have requirements such as distribution over a wide area, and flexible remote access. It is also desirable in many applications to exploit existing IP networks as “carriers” of control network information to reduce wiring and installation costs for the control system. These facts have led the control network industry to embrace a system solution which brings together the control network with the IP network so that the resulting system has the best features of both types of networking technologies.

Such combined, or *internetworked control systems*, offer a great deal of power and flexibility over what is possible with standard control networks alone. By exploiting existing LAN and WAN infrastructure, users gain an additional return on their network investment by reducing control system costs. Likewise control system providers can offer customers greater functionality without reinventing functionalities like remote access.

The internetworked control system architecture has now proven itself and it is clear that the impact on all control systems industries and applications will be substantial. This impact is just starting to be felt. From a technical viewpoint many aspects of IP network technology have only begun to be exploited for internetworked control systems. The remainder of this paper explores these technologies and their impact on control systems now and into the future.

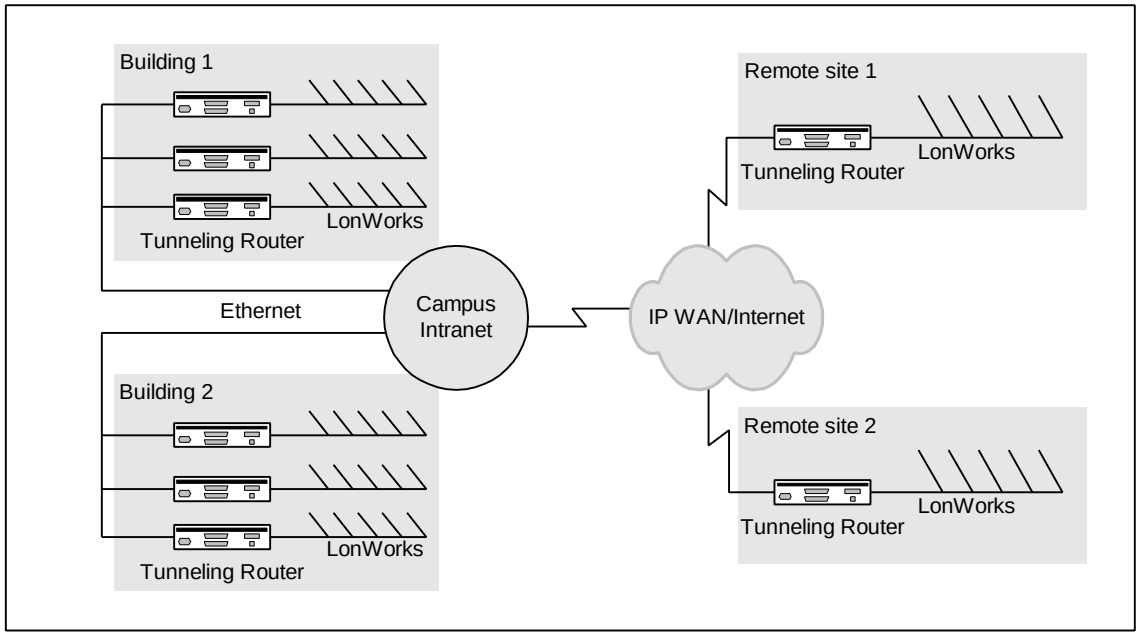

Figure 1: Internetworked Control System

2. Leveraging IP Technologies for Control Systems

The win in leveraging IP networks to create internetworked control systems is in both the use of the existing ubiquitous IP infrastructure (existing networks), as well as in the use of IP networking technologies to achieve increased connectivity and remote access.

The following sections discuss how each of several IP-related technologies impact internetworked control systems. Current uses and expected future impact and trends are presented.

2.1. Internet Protocols

The suite of protocols referred to as Internet Protocols (IP) such as TCP/IP, UDP, FTP, etc. comprise the basic platform of IP networks.

2.1.1. Current Uses

Many of these protocols provide important functionality for the internetworked control system. These functionalities include:

- Transport of packetized data - for example tunneling router devices transport LonTalk protocol packets over IP networks and onto other LonTalk networks.
- File Transfer - FTP is being used to download configuration files to gateway devices, and upload logged data and event histories.

- Network Management - IP standards such as SNMP are being used to manage router and gateway devices in a way that is familiar to IP network managers.

2.1.2. Future Impact

The basic IP platform is quite mature and established. All the basic features needed for internetworked control systems exist and are for the most part being utilized today.

One upcoming change to IP is IPV6. This expands the basic addressing space for IP networks. IPV6 is designed to be backward compatible with the current addressing scheme and so does not impose any immediate requirements on internetworked control systems. However increasingly devices such as LonWorks/IP routers and gateways will want to take advantage of the enhanced functionalities of IPV6.

2.2. Quality of Service (QoS)

Quality of Service (QoS) is a general term that refers to a specification of bounds or guarantees on end-to-end network performance. These guarantees can be with respect to one or more of the following parameters: latency, bandwidth, security, or network up-time.

2.2.1. Current Uses

QoS functionalities are relatively new to the IP networking world. They have not yet had much impact on internetworked control systems.

2.2.2. Future Impact

QoS potentially has a very large impact on the internetworked control system. In a sense guarantees on network service is one of the key differences often cited between control networks and data networks (IP-based networks in particular). Variable and/or long latencies for example are commonplace in IP-based WANs, and are often undesirable or unacceptable for control networks.

By coupling control networks with IP networks along with specified quality of service parameters, the control network can be extended over the IP network not only in terms of data, but also in terms of performance guarantees.

2.3. Virtual Private Networks

Virtual Private Networks (VPNs) are used to create secure virtual “circuits” within a public or non-secure network. By using a combination of key management, encryption, and connection management, secure virtual networks can be established that run “on top” of a public network such as the Internet.

VPNs are typically used to create secure remote access for branch offices or mobile workers. They are also used for commerce applications for connecting data input nodes, such as card readers or user terminals, with the commerce server nodes where financial transactions take place.

2.3.1. Current Uses

VPNs are not utilized much yet for internetworked control systems. Current internetworked control systems assume that the security level desired for the control information is no more than that provided by the LAN that the control systems are attached to.

2.3.2. Future Impact

While VPNs are potentially important for internetworked control systems, they will likely be a fairly transparent aspect of the LAN/WAN to which the control system is connected. For example if a VPN is used to connect retail

stores across the nation back to the headquarters offices, and energy information is collected in the store and passed over that network, it will benefit from being secured by the VPN.

As VPNs come more into play for internetworked control systems, designers may need to become more aware of certain technical details such as additional latencies or connection setup times.

2.4. Physical media

One of the great powers of the IP protocol family is that it is supported on a huge variety of physical media. It has proven itself as greatly adaptable in being able to support even new media that did not exist when IP was first created. By basing internetworked control system architectures on IP, system designers can be assured that they will have complete adaptability to various media as required by the application.
Some of the physical media supported by IP today include:

- ATM
- Hybrid Fiber/Coax
- Ethernet (10baseT, 100baseT, Gigabit Ethernet)
- Fiber Optic (10baseFL)
- PSTN (dialup)
- Wireless

2.4.1. Current Uses

Several different physical media for IP are used today for internetworked control systems. By far the most common is 10baseT ethernet. However other media such as 100baseT, 10baseFL (Fiber), ATM, Coax (or HFC), and of course PSTN dialup are being used.

2.4.2. Future Impact

New data networking media will no doubt continue to appear. By adhering to pure IP standards control system designers will be able to take advantage of these to create optimal system architectures and to exploit existing networks seamlessly.

2.5. Security Protocols

The full scope of security standards and protocols within IP networking is beyond the scope of this paper. This is a rapidly developing area of data networking standards that encompasses standards and technologies for keys, key management, identity, authentication, and encryption among others. These areas are currently being driven ahead very rapidly by e-commerce applications and increasing use of smart cards and kiosk applications.

2.5.1. Current Uses

Some advanced internetworked control system products and applications are beginning to incorporate standard security protocols. This allows control information to be transmitted over IP networks with the privacy and integrity that many control applications require. By adhering to accepted security protocol standards, manufacturers of control network connectivity products help system designers ensure compatibility with the existing network infrastructure and applications.

2.5.2. Future Impact

As a wider and wider range of control network applications connect to the IP infrastructure, security features will become increasingly important. It is important for designers to understand the exact security requirements of their applications. While many security requirements can be met by the IP infrastructure, some can only be met with features of the control network connectivity component. Equipment vendors will increasingly be required to include the security features needed for control applications.

2.6. Distributed Object Technologies

Modern software design techniques include structuring software modules as objects. This approach results in better quality and more flexible software. Distributed object technology such as CORBA takes that one step further and allows objects which are part of the same application reside in different machines or nodes across a network. The details of communication between objects to implement method (function) calls and data exchanges are handled by the distributed object infrastructure. This is an extremely powerful software technique which lends itself well to implementation of large complex systems. Some of the systems where distributed object technology has played a key role include satellite communications, banking, telephone network operations, and machine control.

2.6.1. Current Uses

For large distributed monitoring or control applications, distributed object technologies such as CORBA play an important role in creating systems which are scalable, robust, reliable, and expandable. A network protocol alone is not sufficient to create systems where there are many thousands of devices. Distributed objects provide the software discipline to create these large systems. At the same time the application gains flexibility since it is not so tightly tied to details of the control network nodes and protocols.

2.6.2. Future Impact

CORBA and other distributed object technologies will play a very important role in large distributed monitoring and control applications. In addition to the scalability provided, they offer simplified integration with enterprise applications, where the control information must ultimately be delivered.

Another impact in this area are standards the specify higher-level data interfaces for object-based systems. IEEE 1451 is a prime example of this. IEEE 1451 specifies object models specifically for data acquisition and control applications. Riding atop a distributed object standard such as CORBA these standards will have a tremendous impact on large-scale control systems.

3. Conclusion

Internetworked control systems benefit from the rapid evolution of the capabilities of IP-based data networks. Several upcoming aspects of IP networks will have a significant positive impact on control systems by providing additional features, such as QoS, security, and object interfaces needed to extend an even larger range of applications over the LAN and WAN. This will ultimately expand the role of control networks while at the same time lowering costs and increasing functionality.