

High Speed Ethernet — The Enterprise Integration Enabler

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Abstract

High Speed Ethernet (HSE) will make it possible to more tightly integrate the plant, using H1 Fieldbus devices, HSE enabled host equipment with the business computing / enterprise environment. This presentation will demonstrate several possible ways this integration can be done, an overview of its benefits, and some of the security considerations that can arise as a result of this tighter integration.

Communication Networks

Everyone is aware that there are eight fieldbus protocols approved by the International Electrotechnical Commission (IEC). In fact, this represents only a small portion of the ‘buses’ available to industry. There are over 26 different protocols that call themselves ‘fieldbus’ and each of them has a niche they serve. Figure 1 represents a sampling of these protocols and where in the fieldbus communications ‘spectrum’ they work best.

The communication network, on which this talk will focus, are the two offered by the Fieldbus Foundation based in Austin Texas. The Fieldbus Foundation is a non-profit organisation supported by over 120 automation manufacturers and a total of 1000 members from around the globe. In fact, a very active subgroup, Foundation Fieldbus End User Council Australia Incorporated is based in Australia. The Foundation has 12 other similar groups in various regions elsewhere in the world as well.

Foundation Fieldbus is unique from other buses because of the following:

➤ Interoperability testing at the device and host level

“Interoperability has one important meaning: ‘Capability of devices of different manufacturers to communicate and work together.’ This meaning has great appeal and benefits, but it should not be used against improved and more elaborate designs of transmitters and hosts.¹”

To insure devices are interoperable as per this definition, the Foundation requires that at least two devices contain a feature or function before the feature can receive the Foundation Fieldbus (FF) check mark. In some cases, this conservatism can inhibit adoption of new devices, though they will be available on a “use at your own risk” basis.

The Foundation also “tests^a” host systems using the Host Interoperability System Test (HIST) to verify that all Fieldbus operations are available in the host. To date, three manufacturers have submitted their systems and received letters of compliance indicating how well they compare

^a The Fieldbus Foundation does not test host systems. A letter of compliance is issued at the conclusion of the test indicating how the host system fared against the test criteria with a simple pass/fail being noted for each test category.

against the standard. More information on HIST and its uses is available from the paper “*HIST and its Affect on Fieldbus*” presented at Jumping Aboard 2001.

➤ Single loop integrity

Foundation Fieldbus is the only bus that supports control in the field. Because of this, it is now possible to return regulatory control functions to the field devices, just like in the old pneumatic control loops. This means that as long as there is power in the field, control will continue.

➤ “Plug and Play” configuration

Because of the Device Description and Capabilities file associated with every Fieldbus device, Fieldbus devices are electronically ‘plug and play.’ As soon as a device is connected to a network, it is recognised and added to the system. The user then only has to set the configuration, or way the devices on the network interact with each other to enable the loop to start functioning.

➤ Function Blocks

These blocks of memory in the device determine its characteristics and since they are memory based, they can be configured and updated as additional features are defined for the device.

Control Networking Requirements

Due to the requirement for “real time^b” response in the control environment and the need to insure the integrity of the system at all times, there are a number of basic requirements that must be met by any system used for process control. Bob Kirk has defined the following as the minimum requirements for a system to be considered for uses in a control environment:

“To connect IT and fieldbus, the four basic requirements are:

Gateways — any one of several devices that regulates traffic between IT/administrative and process control/plant levels.

Network routers — usually internet-based hardware, which communicates at the network level of the Open Systems Interconnect (OSI) stack, and is configurable for specific users and functions.

Firewalls — software or hardware, usually embedded or distributed behind a router, which limits network access to predefined users; and

Intrusion detection — hardware and software that monitors networks for unauthorised users or events and notifies the system administrator when any are found.²”

With the introduction of high speed (100Mbps +) and full duplex Ethernet, the above requirements can now be met with commercial Ethernet equipment. Until recently, there remained some concern about too much information on a system causing it to bog down due to too much traffic. This is no longer the case,

“the concerns over collisions and non-determinism for control applications have been largely minimised with the introduction of switch technology. So as long as you use switches and the resulting star topology for control, you can get excellent repeatability in most applications.³”

^b Real Time has different meanings in different industries, dependent on the process response time. In some environments, such as compressor surge control, real time requires a loop response time of milliseconds, while for others the response time can be in minutes.

This quote, based on some work by Anixter, an Ethernet hardware supplier indicates to what extent Ethernet will affect the future.

“Any technology based company that isn’t at least thinking about how to use the Internet and Ethernet is missing out on the next major wave of product opportunities. By the end of the next five years all products having anything to do with measurement, control and information gathering will be networked.⁴”

All that remains, to take advantage of Ethernet, is to make the connection from the Ethernet world to the process control environment in a standard way.

Ethernet defines only the hardware, or lowest levels of the Open System Interconnect (OSI) 7-layer model. Add to this that TCP/IP and UDP then define the next or data layer and one can quickly see that some standards need to be in place for the user to be able to access this information in a meaningful way. In the case of the Internet, this interface is normally Hypertext Markup Text Language (HTML) but in many ways, HTML is not rich enough to describe all the information required for the control environment.

HSE

The newest “feature” with Foundation Fieldbus connects the IT world to the process control world using Ethernet. This new “feature” is called High Speed Ethernet, HSE or H2. HSE was designed to integrate seamlessly with H1 Fieldbus and use standard Commercial Off The Shelf (COTS) Ethernet hardware. Because HSE uses regular Ethernet hardware it mostly requires development and deployment of the protocol and user interface which is software. Required new hardware developments are for the H1/HSE interface or gateways. These new hardware products will be available by year-end. Fieldbus HSE, is also one of the eight protocols included in the IEC standard mentioned earlier.

The speed and data transfer rate of Ethernet comfortably exceeds those of Profibus, Foundation Fieldbus H1, and ControlNet. Profibus has a maximum transfer rate of 12 Mbps; Foundation Fieldbus H1 operates at 31.25 Kbps, while ControlNet is 5 Mbps.

The biggest risk to preventing the adoption of Ethernet in the control environment, is another round of “fieldbus wars” as was evidenced by the lengthy debate over the H1 standard. The sad news is, that it appears no one learned the lesson the first time, since there are now almost as many versions of process control capable Ethernets, as there are ‘lower level’ protocols in existence today AND none of them will talk to each other.

Digital Control System (DCS)

Most major Distributed Control System suppliers are migrating from a proprietary network backbone to one based on some form of Ethernet. This is consistent with the trends observed in the computing world, especially as this provides economies of scale and ready access to the various components needed to manufacture computer based equipment. This trend has been evident for a few years now as most DCS, now called host, manufacturers have moved to a Windows environment, for their Human Machine Interface as a minimum, and in some cases their advanced applications environment as well. As a result of this move to a common platform, host suppliers are now focusing more effort on how to gain maximum value from the information available in that environment and hence the increased shift to concentrate on software and services. This thirst for more information, will be one of the key drivers to support the need for all digital networks as represented by fieldbus and Ethernet.

The migration to all digital communication networks for the host system / human machine interface of the future will eventually lead to the acronym DCS meaning Digital Control System along with all the extra data flow and information associated with it.

System Environment

The integration trend is clear and gaining momentum, Control System Engineers, and Process Control practitioners in general are in a period of transition from the analogue to the digital world. More and more, that digital world is based on the Microsoft operating system.

“Windows NT is suitable for 80% of manufacturing and process control applications, Windows CE’s proposed real time capabilities will allow it to address 16% of the remainder, leaving a mere 4% for specialist embedded solutions.⁵”

The above quote reveals one reason why the Windows environment is the operating system of choice for the majority of host systems today. Add to this the fact that if the process control and corporate environments are similar, integration of data across the enterprise also becomes easier.

The majority of Corporate Local Area Networks (LANs) also operate on Ethernet; in fact the Windows 2000 environment makes it possible to create one large domain from the desktop to the control system. Once again, this emphasises the pressure on network designers to merge to as common a hardware platform as possible, and that platform will be Ethernet and Internet based.

Documentation

Any time there is a change in systems, there is also a need for change in the documentation of those systems. Conventional loop diagrams are now replaced by network diagrams. The question becomes how far should the network extend and how does one document the interrelationships between the various data transfers and network/information paths possible in this new environment.

The field devices themselves will also have some additional documentation requirements; the most important of which is the need to maintain some form of software revision control. For Fieldbus to work, the software in the host and field devices must be the same revision.

Control without Host

Since Fieldbus uses a Publish/Subscribe environment to transfer information between devices and system components, while supporting control in the field, HSE also makes it possible to deploy a control system without a host as part of the control loop.

Figure 3, represents how it will be possible to implement a widely distributed Fieldbus control loop without any of the signals being shown on the host. A Virtual Private Network (VPN) can be created to connect two HSE gateways and their associated devices. The control is implemented in the field and it is not necessary to have any intervention by the host. The host will connect to the network by another port on the switch and can receive the process variable updates as a passive subscriber whenever they get published.

Since the switching equipment could be also be located in the field, how will this sort of control loop be represented on a drawing and how will control engineers be able to verify and troubleshoot its operation?

These questions need to be answered at the onset of any engineering project.

Data Transfer Mechanisms

As stated earlier, Ethernet, TCP/IP and UDP represent only the lower layers of the OSI model. How is all the information on the network communicated to the other layers of both the OSI model and the computer networks in a facility? HSE and the other fieldbus networks all describe the necessary protocols to move data to the User layer but it still remains to transfer this information between the various applications at the User layer and above.

One option that is receiving a lot of attention and appears viable at the Process Data Management (PDM) layer used for control is OLE for Process Control (OPC). OPC is another open standard that links information from one database to another, in real time with minimal overhead. And since it is an open standard it too is vendor neutral. OPC is supported by most host system suppliers of all the fieldbuses and therefore has the opportunity to be the 'glue' linking disparate systems at higher levels in the organisation/network.

At higher layers, where the Internet and corporate information transfer occur, eXtensible Mark-up Language or XML is the present odds on favourite. XML has recently been approved by the World Wide Web Consortium as a standard language for use on the Internet and Microsoft has adopted this technology as the core for its new .net operating system. Certainly good news for XML's acceptance at multiple layers in the network.

The convergence of tools for the entire plant network is well on its way, we the engineering community must take action on this area as we plan for the future. Not only at the data collection layer as represented by process control systems, but also by working with the corporate information people to insure data can flow seamlessly throughout the organisation.

Physical Media

Corporate information network equipment is not suited to the industrial environment. Conditions such as high humidity, vibration, shock, heat and cold require that it be modified. This includes, not only the processing devices themselves, but also the cabling and connectors. A number of manufacturers have worked together to develop hardened connectors. The benefits of hardened Ethernet connectors include:

- Sealing against environmental contaminants
- Protection against the effects of vibration
- Secure robust connection

and

- Performance in electrically noisy environments.

There has also been an ongoing concern about the suitability of Ethernet in the industrial environment with its requirement of real time control. With the rapidly growing increase in bandwidth, this concern has now been removed.

“...by using full-duplex, switched Ethernet you avoid collisions. Now all the objections are gone.”⁶

It also appears that the increase in bandwidth will continue for the foreseeable future. This is great news for everyone, especially those fieldbus systems that reside on top of conventional Ethernet, such as HSE. Why? Because as Ethernet speeds increase so do those of the fieldbus using Ethernet.

Security

Of course with tighter integration also come risks. Almost everyone has had some exposure to computer viruses of one form or another and this emphasises the need for security measures starting with proper design at the onset of a project.

““With hubs and repeaters, there is no isolation, and so there is no protection against problems propagating throughout the facility. This is why it’s so important to use switches that can check the validity of every message.” There are two basic switches, Layer-2, a multi-port bridge that check packet integrity before forwarding, and Layer-3, a router that checks packet source destination and function before forwarding.”⁷”

It is therefore recommended that switches be used for process control Ethernet routing. This will not only ensure messages are transmitted in a timely manner to the correct recipient but also that in the event of a failure in one part of the network, the resulting noise and traffic will not bring down the remainder of the network as well.

The need of security as represented by a switch will need to be balanced against the situation described below:

“Deciding between cut-through and store-and forward depends on the application. Time-sensitive applications may need the former.

Most switch implementations consist of a switch with many stations (demand) and few servers (resources). It is best to keep a 1:1 ratio between demand and resource. Or, increase the number of access pipes to the resource. (I.e. multiple lines into one server)⁸”

This shows once again that installation of process control environments will continue to require a well thought out engineered solution.

On the software side, all the procedures used to protect a corporate LAN from outside attack should be implemented to isolate and protect the process control networks from write attempts initiated in the corporate environment.

“Proper software security measures include:

- Strong access control over local controllers;
- Encryption for all data leaving the building;
- Activity logging for employees;
- Reverse trace routing that tracks where employees are logged on;
- Automated backups and recovery systems, and:
- Firewalls.”⁹

Safety Applications

The next hurdle for Foundation Fieldbus is to start applying it on safety applications and there are a number of activities moving forward to do just that. One bus that has been used for safety is SafetyBus P and as indicated in this quote, Foundation Fieldbus can easily implement a similar system.

“SafetyBus P works by constantly polling every device in a short time period to be sure that the network is working and that they can connect to every device. ... Foundation Fieldbus H1 use bus arbitration with the Link Active Scheduler. It would be possible to set up an H1 network as a safety bus by specifying a suitable link time for Emergency-

Stop input. Failure to communicate would then shut down the process/machine. I think this is simply a configuration of any Foundation Fieldbus control system using the same logic that was used to get the Pilz SafetyBus P approved for safety use. The fact is that no company has ever tried to get approval for H1 as a safety bus.^{10,}

Foundation Fieldbus has a subcommittee working with the volunteers on ISA S84 to develop an engineered solution or as a minimum a technical report on how to apply Fieldbus to safety installations. With the high reliability of digital transmitters along with the associated diagnostic and status information for every value sent from the field, it is the author's opinion that this should inherently be more reliable than an analogue system. Analogue systems use a redundant signals and software with a set of rules to determine if a signal should be trusted and hence used, while Fieldbus provides this information directly.

Needed Developments

The integration of the plant and business environments will continue for many years to come. Here are some requirements for future work in this area:

Based on work by researchers at the University of Purdue¹¹, the "four R's" of information integration are:

Response — Short responses times or "real time" are required at the controller level while at the business level this could be defined in units as large as years.

Resolution — averaging and integrating should be done at the lowest level possible to reduce the volume of data transfer to higher level systems.

Reliability — field level and process control systems are frequently installed as redundant systems since no downtime is acceptable. Business systems on the other hand normally can tolerate delays of minutes or hours.

Repairability — This means the time it takes to repair, replace or upgrade hardware and/or software. Control systems are designed to make this process easy, and without process disruption.

Tighter integration of the enterprise will require improvements and expectations for Reliability and Repairability to increase in the future.

A number of challenges have been identified above, and most of them have teams of individuals working to address them. But, what else needs to be done to insure the high reliability of networks once they are installed, Eric Byres, suggests the following,

"what should users do? First of all, insist that good maintenance tools are part of the initial package whenever a new fieldbus or industrial network is installed. IF the vendor can't demonstrate tools that are both useful and easy to use, don't buy the network. Second, purchase the tools for the networks you currently own and make sure someone on the maintenance staff really know how to use them. It's a lot more expensive to be learning troubleshooting skill after the network crashes (or to rely on consultants all the time). It also helps to encourage manufacturers to develop tools if they see that users are actually buying them."^{12,}

Some of the other developments that have been identified include:

- Power to Ethernet Devices — Ethernet devices require that four wires be run to them. One set for power and a second set for the Ethernet communications function. Work is underway to develop a four wire cable capable of performing both functions.
- IS Ethernet — Many installations, especially in the hydrocarbon industry require that they be Intrinsically Safe (IS). Ethernet is not IS.
- Integration with upcoming technologies such as Bluetooth and Microsoft .net / XP and IEE 803.11b (wireless Ethernet)

This is an exciting time in our industry, with many challenges to be addressed by those brave enough to do so. Fieldbus not only provides a quantum leap in information available throughout the enterprise, it also provides multiple opportunities to use this information in useful ways.

Today & Tomorrow

To provide some indication of what all this information means and its implications, consider the following two quotes:

“Distributing manufacturing data is also a bandwidth intensive proposition. Over the next four years, manufacturing plant information generated by DCS equipment is expected to increase by 20 or 30 times the current level. Similarly, a 10 or 20 times increase is expected in PLC equipment collecting information from the factory floor.¹³”

“The new factory floor network will also affect network capacity planning in the same way as switched networks impacted on traditional shared LAN designs. In future, IT/network managers will also need to be aware of developments on the factory floor generating additional traffic which will impact office LANs (Local Area Network) and servers, and eventually WAN (Wide Area Network) traffic.¹⁴”

In addition, Automation Research Corporation recently published their 2001 Top Ten Technologies to watch list. It is interesting to note that the following are on their list: 2. XML, 4. Wireless and Bluetooth, 5. Fieldbus HSE, and 9. Publish/Subscribe technology.

As described above, these are technologies that will form the basis for the integrated control system of the future.

More information, faster, and available everywhere is the story of the future, our challenge will be to ensure the right information gets to the right place at the right time so that it can be acted on in real time. These are the new “3 R’s” for the early 21st century.

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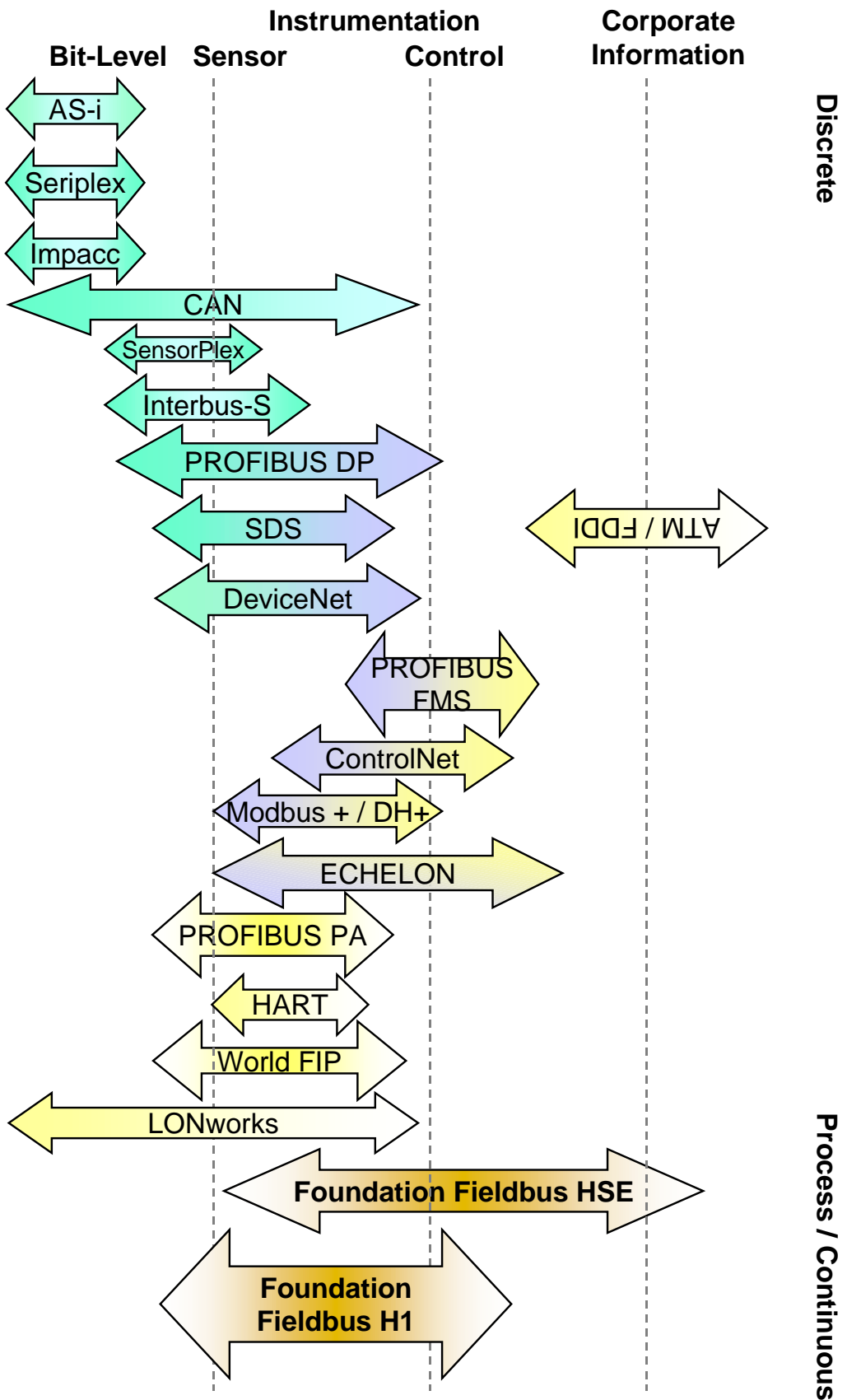
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Figure 1 Fieldbus Protocol Application Regime



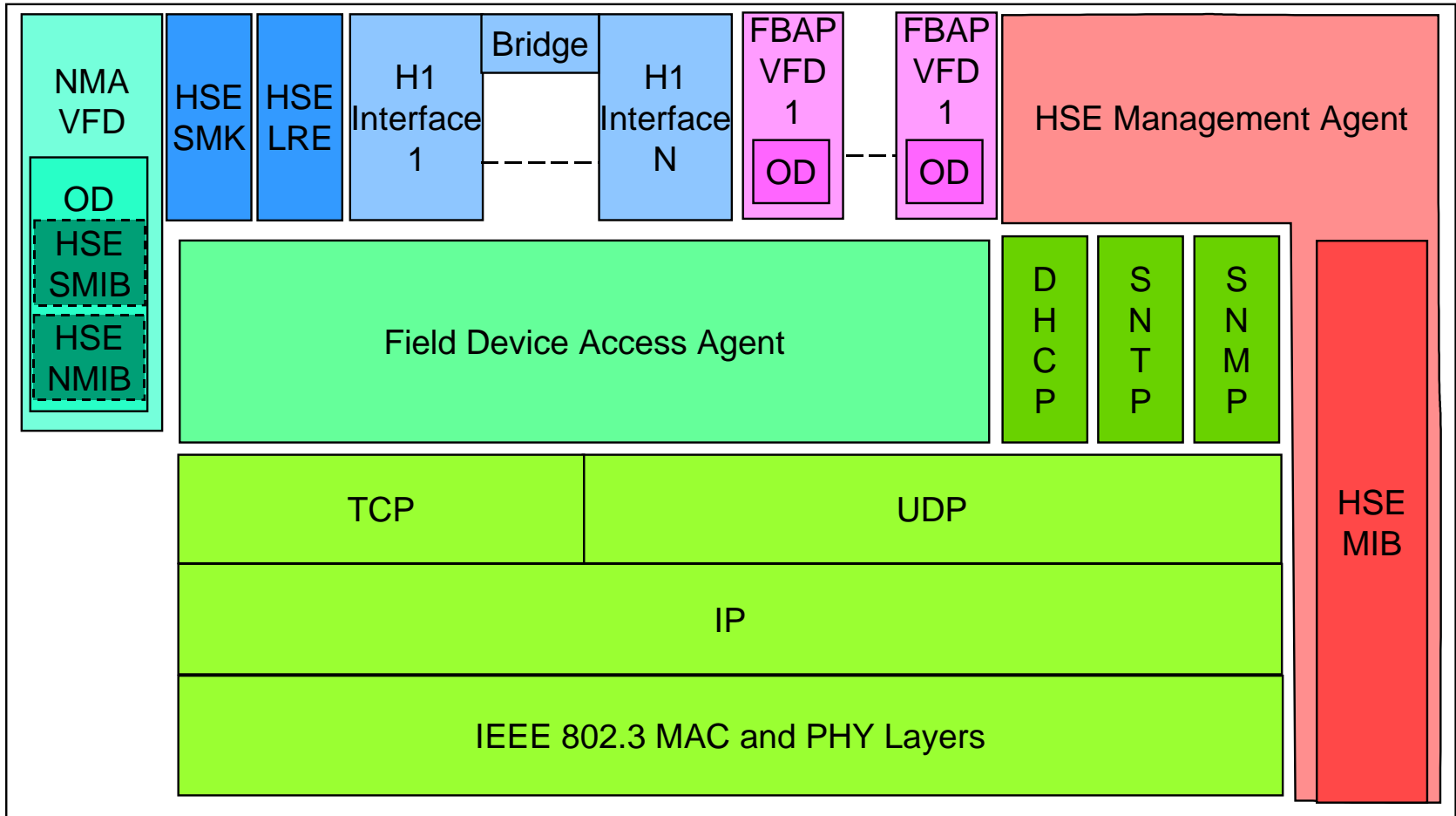


Figure 2 Fieldbus HSE Profile Functional Areas

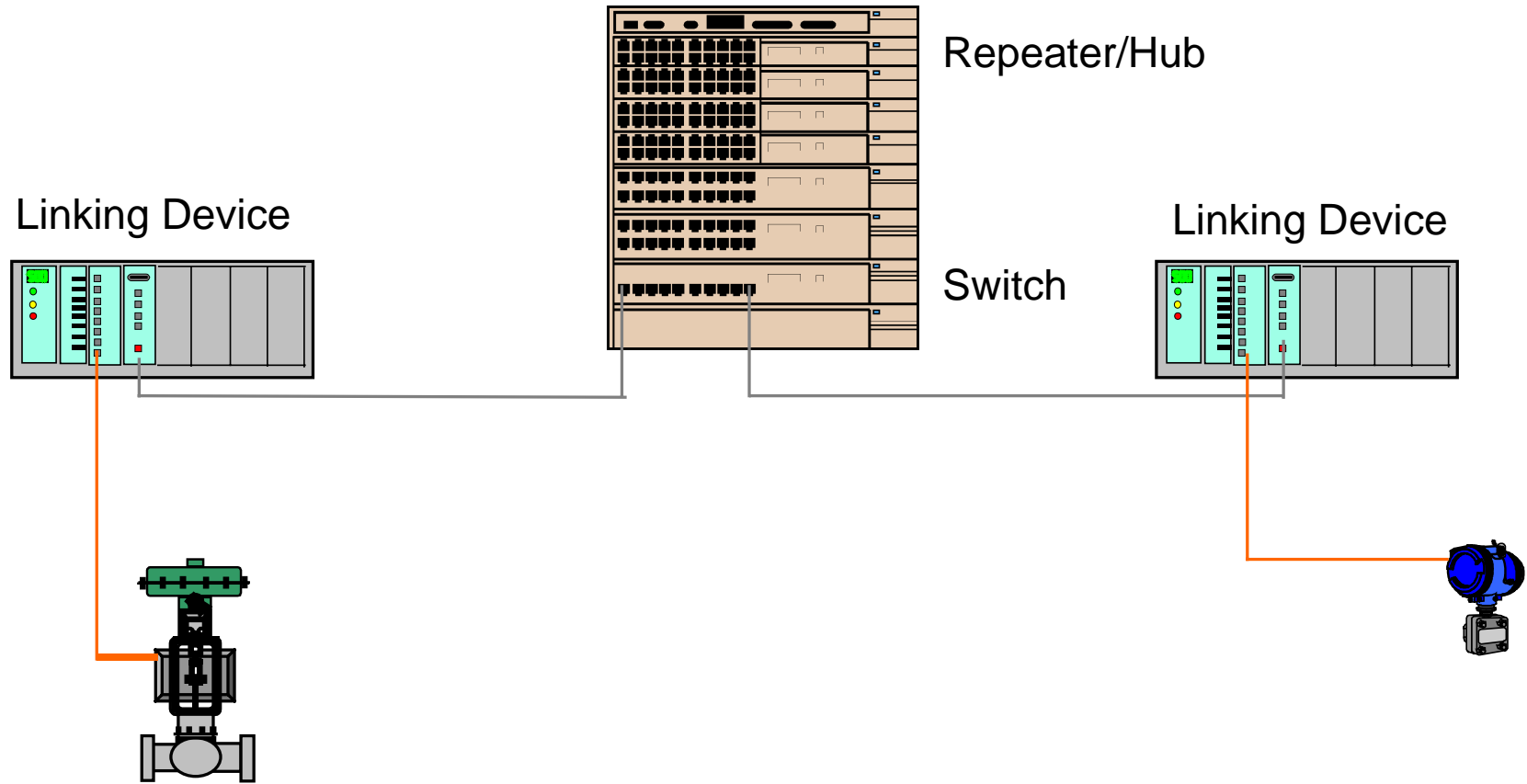


Figure 3 Virtual Fieldbus, Fieldbus without a Host

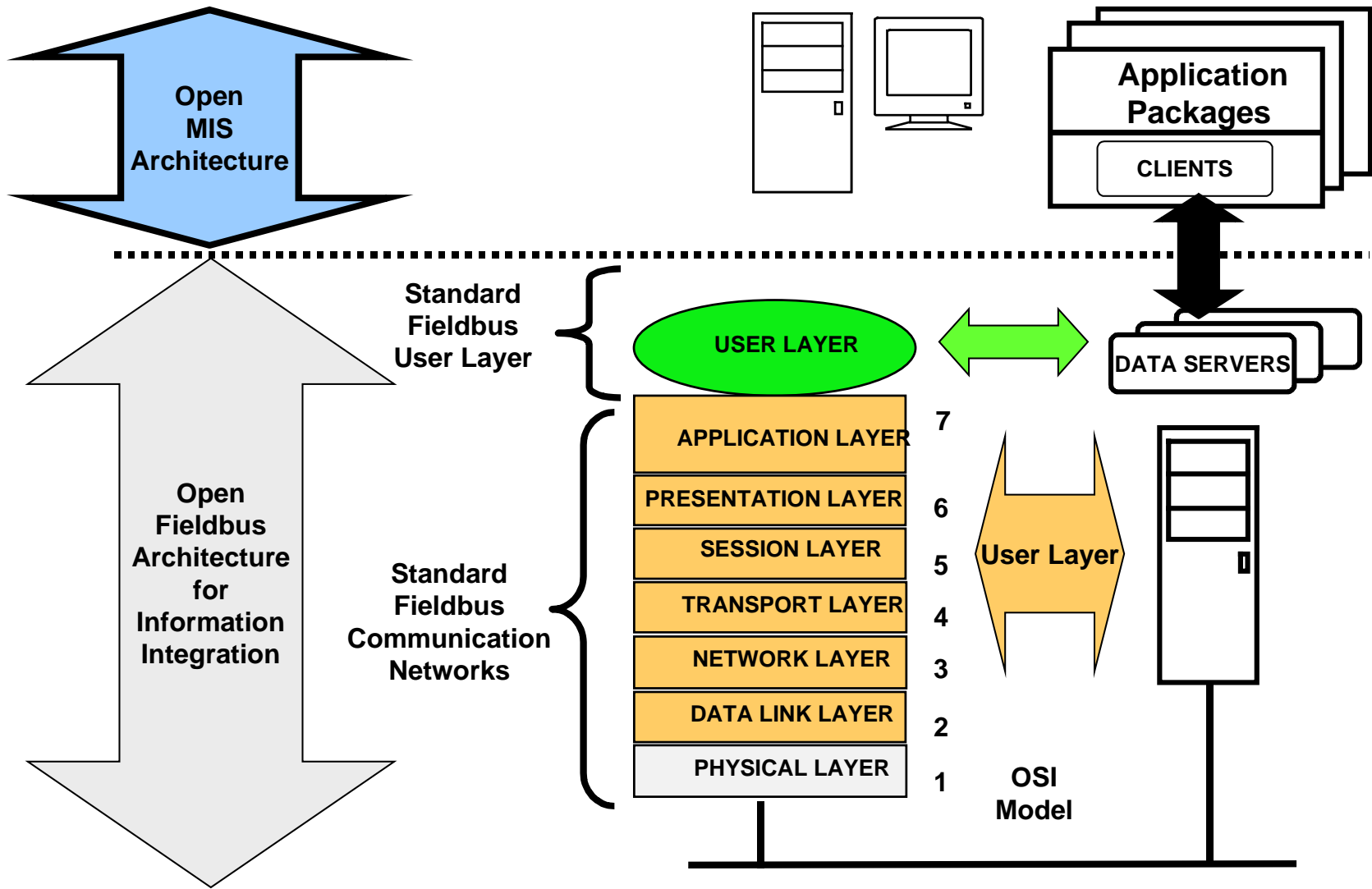


Figure 4 Information Integration Architecture