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## **FOUNDATION HSE for high availability at the host-level**

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**Abstract:** For use in factory and process automation Ethernet has to be made industrial strength. FOUNDATION™ HSE Fieldbus is based on Ethernet and is used at the host-level of the control system. The host-level network ties the whole system together linking the various subsystems to the host. Thus the visibility of hundreds and perhaps thousands of loops depends on the host-level network as does any intra-area control loops. A complete failure could result in heavy losses. High availability for the host-level network is therefore paramount. High Speed Ethernet (HSE) is the only open Ethernet based protocol to address the need for round the clock availability of network and devices. Because device and port redundancy requires interoperability beyond Ethernet and IP other Ethernet solutions do not support it. HSE is the first standard protocol to offer functionality to select which device in a redundant pair and which one of redundant ports that a transmitting device should address. Exchange of redundancy management information is part of the standard protocol. The paper covers a brief introduction to the HSE redundancy management technology, the various options for redundancy schemes, how these can be applied as well as a case study.

**Keywords:** HSE, Availability, Fault Tolerance, Redundancy, Fieldbus

### **1 Introduction**

The Fieldbus Foundation officially released the FOUNDATION™ HSE Fieldbus technology in early 2000 after an intense joint development effort by several companies. This technology is already changing the way systems perform control

FOUNDATION™ HSE for high availability at the host-level and will have an even greater impact on system architecture, interoperability and openness than the H1 technology.

There are four basic HSE device categories, but many are typically combined into a single device: linking device, Ethernet device, host device, and gateway device. A Linking Device (LD) connects H1 networks to the HSE network. An Ethernet Device (ED) may execute function blocks and may have some conventional I/O. A Gateway Device (GD) interfaces other network protocols such as Modbus. A Host Device (HD) is an operator workstation or an OPC server.

### 1.1. HSE at the host-level

The FOUNDATION™ Fieldbus technology tightly integrates system components making field instruments an integral part of the system just like the controls, i.e. field instruments and "system" are not two separate islands. The operator workstations and interfaces are referred to as the "host" of the system. Whereas the FOUNDATION™ H1 Fieldbus technology is used at the field-level making transmitters and positioners etc. interoperable the FOUNDATION™ HSE Fieldbus technology is used at a higher level in the system hierarchy, at the host-level where host devices and subsystems are networked (figure 1).

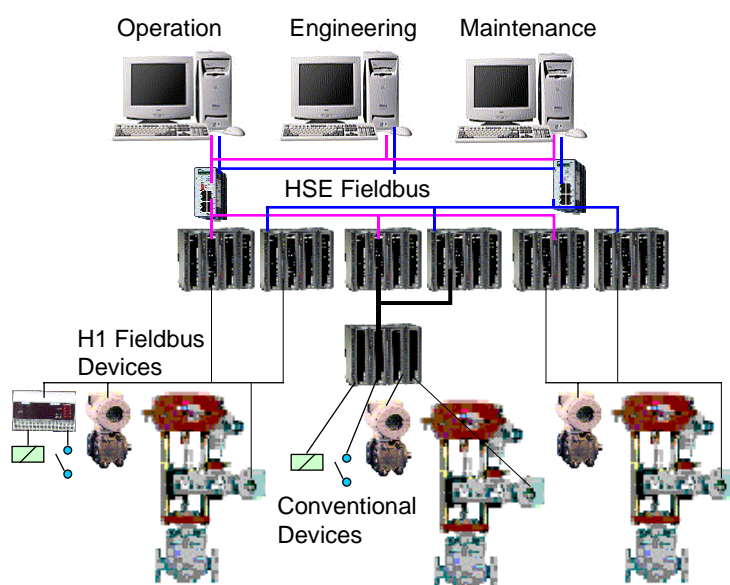


Figure 1 HSE at the host-level and H1 at the field-level

### 1.2. Homogenous network architecture

H1 and HSE is an excellent combination since the field-level and host-level technologies come from the same protocol family. The system can be completely based on FOUNDATION™ Fieldbus, open and interoperable without losing integration, functionality or accessibility due to intermediate proprietary network protocols or languages, or legacy networks that simply don't support the modern features of FOUNDATION™ Fieldbus. Only using HSE is it possible to truly benefit from H1 and vice versa because they are essentially the same protocols only traveling on different media. Using HSE the access to Fieldbus devices become transparent. Other network technologies do not support Fieldbus communication functionality such as publisher-subscriber and report distribution, are unable to support the object-oriented nature of the Fieldbus programming language such as tagged blocks and named

FOUNDATION™ HSE for high availability at the host-level parameters nor the status propagation. Without HSE important functionality may be lost or require time-consuming data mapping.

### 1.3. HSE will not replace H1

In the control system architecture H1 Fieldbus is used at the field-level to connect transmitters and positioners etc. HSE is used at a higher level between linking devices and the host workstations etc. I.e. HSE will not replace H1, but the two complement each other. H1 has many good features that HSE does not have and vice-versa.

Table 1 HSE vs. H1

	H1	HSE
Speed	31.25 kbit/s	100 Mbit/s
Distance (per segment)	1900 m	100 m
Two-wire	Yes	No
Multidrop	Yes	No (UTP)
Bus power	Yes	No
Intrinsically safe	Yes	No
Redundancy	No	Yes
Deterministic	Yes	Yes

Ethernet is limited to 100 m, which is too short for wiring the instruments in the field. Ethernet needs hubs and multi-core cable that although cheap, would be too costly and space consuming. Ethernet provides no power so additional wires are needed. Ethernet is not intrinsically safe so it could not be used in hazardous areas such as those found in the chemical and petrochemical industry. Likewise H1 has too low bandwidth to be used as backbone for the entire plant, and does not have redundancy making it unwise to make more than a few loops depend on each network. Thus the two complement each other perfectly.

## 2 HSE benefits

Without HSE networking much of the benefit of H1 Fieldbus technology would be lost. HSE has the capacity to transfer data from the entire plants current and future H1 networks to fully benefit from all the Fieldbus capabilities. HSE further simplifies system architecture and enables a very large system that is also open at the host-level.

### 2.1. High bandwidth

A modern control system needs more than just configuration and monitoring capability. FOUNDATION™ Fieldbus H1 has enabled asset management functions such as diagnostics, calibration, identification and other maintenance management operations to "mine" massive information in field devices real-time, therefore requiring large bandwidth at the host-level. Asset management allows users to move to a proactive maintenance scheme targeting maintenance resources where it is really needed. Users employing Fieldbus-based field devices and permanently connected online asset management software can expect a steep rise in bandwidth requirements. Legacy control networks of existing DCS are too slow for state of the art information intensive applications. HSE has the capacity to transfer data from all the plant's H1 Fieldbus devices to fully benefit from all the Fieldbus capabilities.

## 2.2. *Leaner second generation Fieldbus systems*

Just like H1 Fieldbus revolutionized the field-end of the control system architecture by drastically reducing wiring, I/O-subsystem and controllers, HSE is dramatically simplifying the control room-end of the system by simplifying enterprise, control and remote-I/O networking (Figure 2).

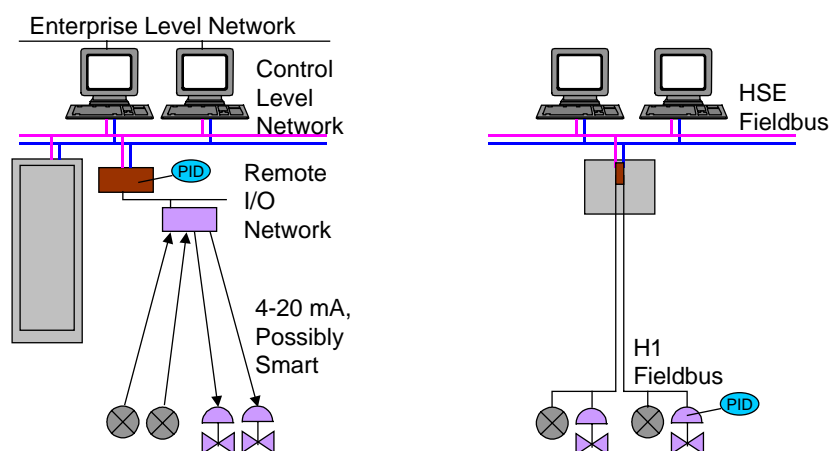


Figure 2 H1 and HSE Fieldbus "flatten" the system architecture by removing multiple levels of networking.

The first generation of Fieldbus-based systems required almost as much hardware as their conventional counter parts because Fieldbus was simply implemented as an interface card that plugs into the regular I/O-subsystem. HSE introduced the Linking Device (LD) that brings data from one or more H1 Fieldbus networks directly onto HSE. A second generation of Fieldbus systems has now emerged which brings a reduction in communication interface modules and traditional controllers, while maintaining the large system integration capability offered by a higher level network.

## 2.3. *Host-level interoperability*

Plants in addition to a basic control system usually have a number of package units and subsystems from third-party suppliers. Because these use diverse and proprietary technologies for control and communication integrating them is difficult and costly. In the future subsystems for burner management, gas chromatographs, paper web scanners, shutdown systems, compressor controls and tank farms etc. will instead use HSE. I.e. package units will come with a connector for HSE connectivity that just plugs in to the host like the rest of the system. Additionally, applications for advanced control, plant information and other functions use OPC (OLE for Process Control) on the same Ethernet media (figure 3).

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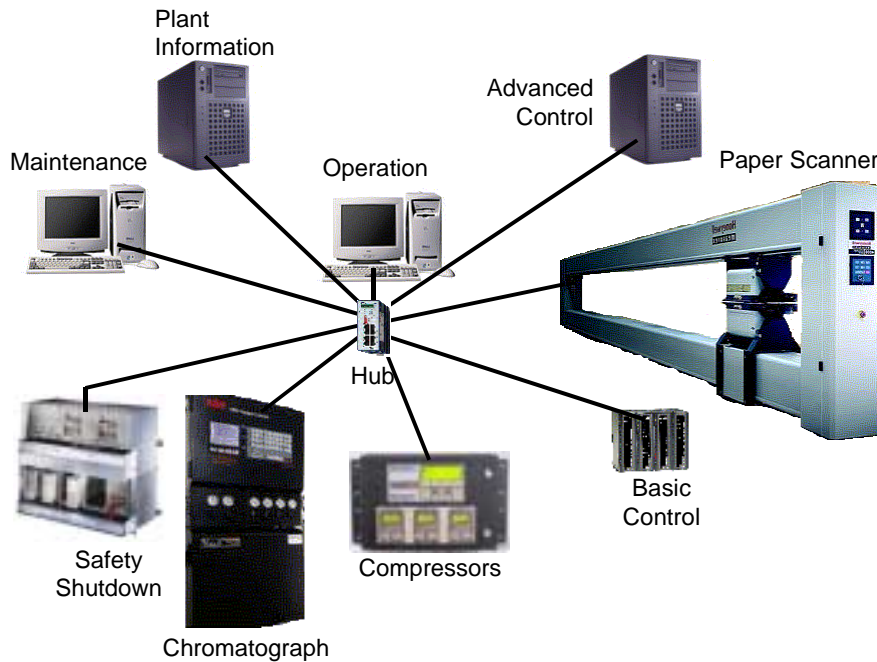


Figure 3 HSE integrates subsystems

Contrary to popular belief Ethernet alone does not make a device interoperable. That is because neither Ethernet nor TCP/IP make up a complete protocol stack (figure 4). Most networks based on Ethernet are in fact proprietary. A network technology therefore is also required to have an application layer and preferably a user layer that is an open standard. If not, special drivers are ultimately required to access the data. The HSE standard includes these layers thereby making it a completely open protocol.

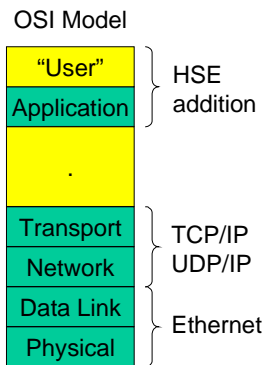


Figure 4 Most Ethernet based protocols are not fully open because part of the "stack" is proprietary.

The lack of higher-level standards has prevented easy integration of other subsystems of the plant.

With H1 users got the freedom to select any field device from any manufacturer. HSE does the same thing at the host-level. Users will because of this standard be able to mix and match subsystems for basic control, emergency shutdown, paper quality control, advanced control and compressor control etc. from different suppliers. As long as all of them use HSE, information can effortlessly be accessed without patching with drivers and mapping of addresses, variable files and registers, and renaming. Users can combine the most suitable of each subsystem and keeping cost at a minimum, while at the same time reducing the configuration effort. In large plants users often have basic control systems from more than one supplier, most of

FOUNDATION™ HSE for high availability at the host-level the time these systems cannot talk to each other. Because of HSE new systems can in the future be connected together and easily exchange information.

The integrity checking diagnostics mechanism and redundancy management is also part of the upper layers of the HSE protocol and therefore works seamlessly between devices from different manufacturers.

#### **2.4. Intra-area control**

HSE has peer-to-peer communication capability, meaning that nodes on the network are able to communicate with each other directly without having to go through any central computer. This makes it possible to build advanced control strategies involving variables throughout the plant and benefit from the combined power of all system components. At the same time the system becomes more reliable as weak computer links are eliminated. Many existing network types do not have this capability, e.g. it is common that one controller cannot talk directly to another controller and therefore relying on PC software to mirror the information from one to the other. One benefit of this HSE capability is the ability to bridge information between devices on different H1 networks in different ends of the plant. Control can span between process cells and even areas.

#### **2.5. Easy to use**

Just like for H1, in HSE several features have been designed in to make it plug-'n'-play. Because HSE is built on IP technology, each HSE device needs to have an IP address. However, users need not worry about the rules for IP address assignment, and avoid duplication because it is all automatically handled by a DHCP (Dynamic Host Configuration Protocol) server in the system, essentially a piece of software running in one of the nodes on the HSE network. As devices are added they are automatically detected and assigned an address.

Typically shielded twisted-pair cable is used for wiring the HSE devices and hubs together, no special tools or skills are therefore required. Installation is simple and very fast. Ethernet and IP are technologies already understood by many and therefore the learning curve is not steep.

#### **2.6. Homogenous system configuration**

HSE devices use the same function block programming language as H1 devices. The same standard FOUNDATION™ function blocks that are used in H1 field instruments are used for control strategy building in HSE devices such as shared central controllers too. I.e. HSE does away with proprietary programming languages. Transducer blocks and a resource block are used for device configuration. The same control strategy programming language can be used throughout the entire system making it more homogenous than a system using the FOUNDATION™ language in the instruments and another language in the central controller that generally required two different software applications for configuration. Using the FOUNDATION™ language it is possible to independent of control being done in a shared central controller or distributed in the field configure the entire system from the same single software (figure 5).

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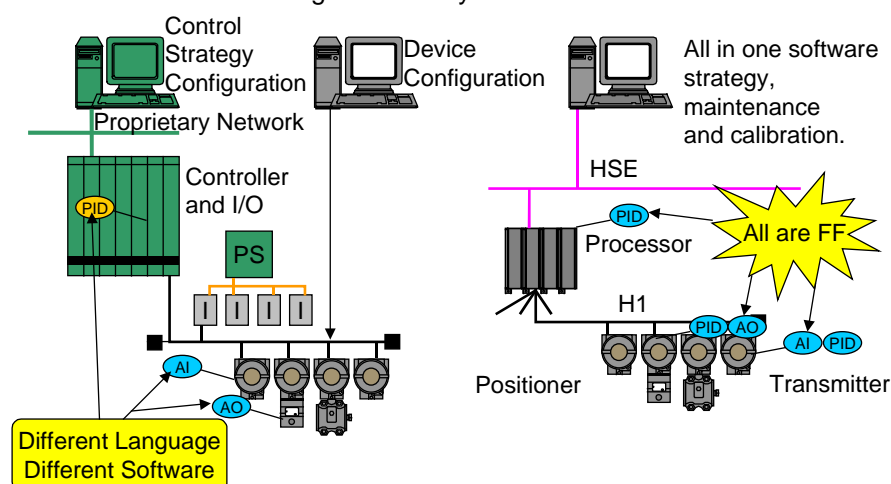


Figure 5 Homogenous control strategy building

The status associated with function block links is primarily generated by field instruments based on failed sensors and stuck valves etc. and is used for loop shutdowns, windup protection and bumpless transfer. This status is lost in proprietary control strategy languages when Fieldbus devices are connected to old centralized controllers. Systems that adopt HSE for the host-level network and devices and use the FOUNDATION™ blocks from sensor to actuator avoid this problem and are able to let users fully benefit from the many features of Fieldbus because field instruments and processor modules integrate completely.

### 2.7. Low-cost and full featured

Because HSE is built on standard Ethernet for which components are made in extremely high volume the cable, interface cards and other networking hardware are extremely low cost compared to the proprietary networks of legacy systems. Because Ethernet is a widespread technology, there is a wealth of options for media available including twisted pair, fiber optics and wireless. Networking hardware is available in both commercial and industrial grades from many suppliers.

### 3 HSE fault-tolerance

HSE is built on Ethernet that originally is a technology for the office environment. However, industrial grade hardware is available and HSE has a number of functions built in to make it fault tolerant. The modern form of Ethernet uses UTP (Unshielded Twisted Pair) wiring using a hub-based star topology in which there is only one device per wire segment. Therefore devices can be disconnected and connected without disrupting other devices and any wire fault also only affects a single device (figure 6). I.e. the impact of a fault is reduced somewhat.

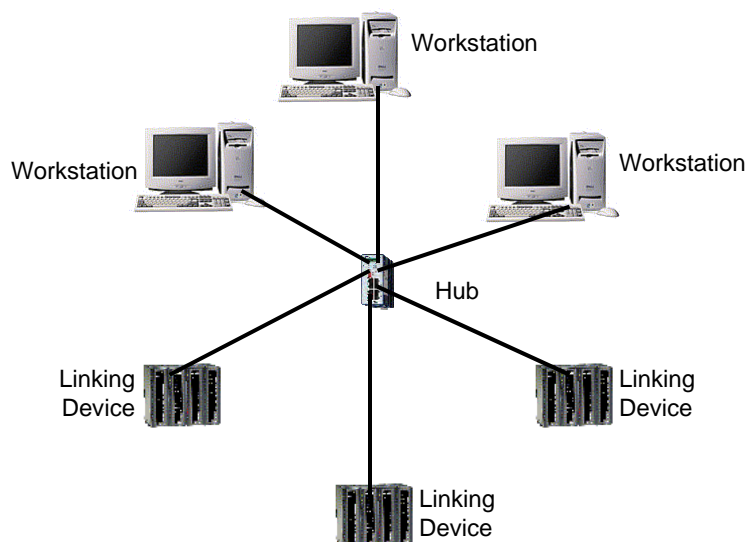


Figure 6 in a star topology only a single device is affected by a wire fault

A shared hub is a multiple port repeater that joins several segments into a single network. A switched hub is a multiple port bridge that joins several networks together. Fiber optic media can be employed to increase tolerance towards electrical noise and ground potential differences further increasing the robustness of the system. Industrial grade hubs with redundant power supply, wide temperature range, rugged enclosure etc. are available for use in a tough plant environment.

### **3.1. Need for host-level redundancy**

A shutdown of a plant is extremely disruptive and downtime means heavy losses. At the host-level the network and devices are shared between many loops making these parts very critical to the operation of the plant. If the host-level network is not functioning the operators would be unable to monitor and supervise the plant and therefore many loops would have to be shut down. The host-level network is also used for intra-area control loops that would have to be shut down. Unlike the field-level where high availability is achieved by distributing functionality thereby isolating faults to a small sector, at the rather centralized host-level redundancy is instead used to achieve high availability. Any Ethernet network can use media redundancy to achieve some measure of increased availability but HSE also supports complete device and networking redundancy.

### **3.2. Media redundancy**

Any Ethernet device even with just a single port can have simple media redundancy using some form of port "splitter". Splitters are implemented in different way but all work in the same basic way. A single port is split into two connecting devices together in a circle providing alternate communication paths. If communication in one direction is not possible, communication is routed the other way. I.e. the network is "self-healing". The switchover time is very short, recovery is much faster than for the traditional spanning tree algorithm, operation will continue without any loss of data. A splitter can either be a transceiver handling a single port requiring one at every node or be implemented between hubs in a ring topology (figure 7). Media redundancy works only on the physical layer and is therefore independent of protocol used.

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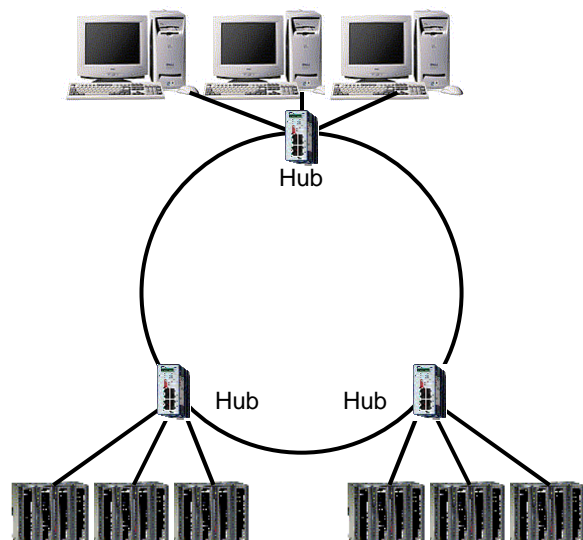


Figure 7 Ring-topology provides two communication paths

Some solutions require a central redundancy management device that may be an Achilles heel whereas other solutions have the redundancy management built into the hubs. Very often the media redundancy ring is implemented using fiber optics. The ring is not a standard Ethernet topology and the special splitting hubs and transceivers usually use standard media but employ proprietary mechanisms to manage the switchover and therefore all the splitters in the ring have to come from the same manufacturer (figure 8).



Figure 8 Redundant linking devices and hubs for media redundancy

Simple media redundancy may be sufficient for some applications but not all. For example, Petrobras on their Namorado-I platform combined media redundancy with fully duplicated networks and linking devices (figure 9).

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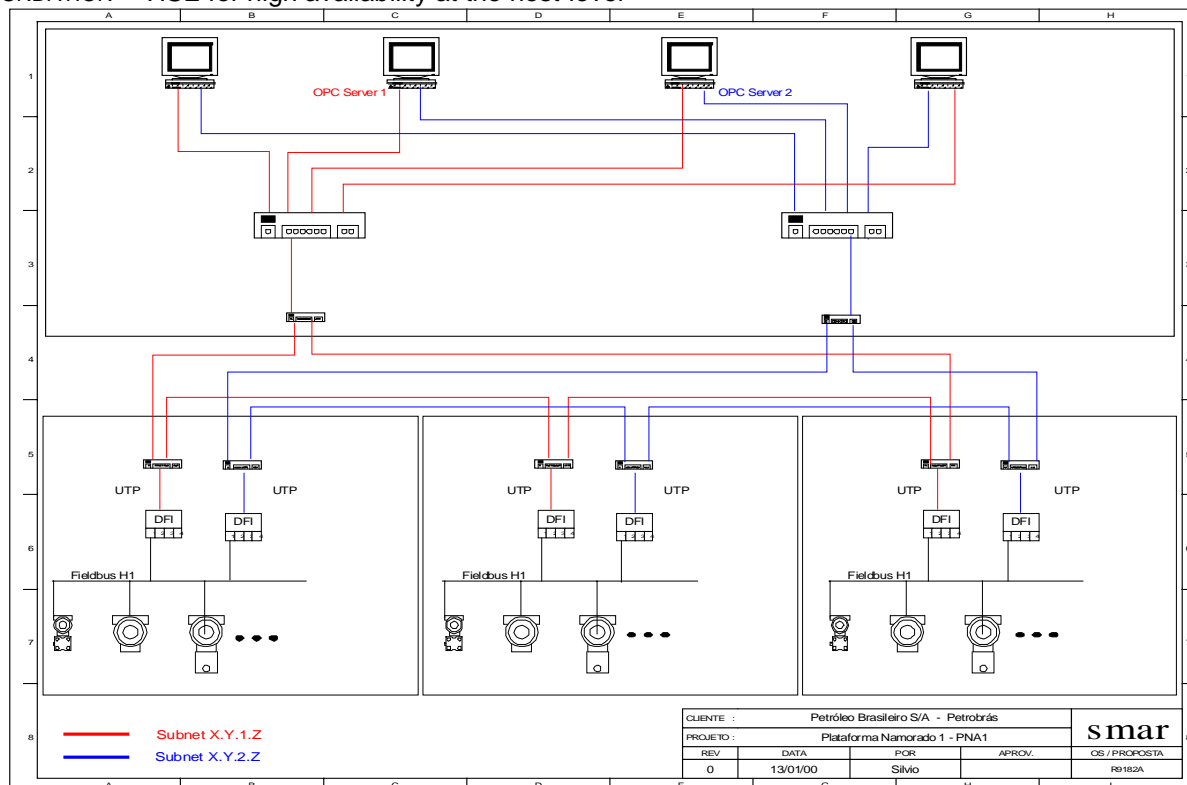


Figure 9 Device redundancy and media redundancy

### 3.3. Complete network redundancy

The HSE protocol goes further than simple media redundancy. Special integrity checking diagnostics and redundancy management part of the HSE protocol in each device enables use of two completely independent networks, redundant communication ports and also redundant device pairs. All redundant Ethernet device pairs and the workstations are connected to both Ethernet buses. When a single unit has two ports these are named "A" and "B". The switchover is totally bumpless and transparent. The redundancy scheme leaves several device options open (figure 10), but they are all compatible with each other, e.g.:

- Redundant device pair where primary and secondary have one port each
- Redundant device pair where primary and secondary have two ports each
- Single device that has two ports

All parts of the network have redundancy, including the hubs, i.e. two independent networks ensuring that communication can continue even if one network fails. This means that the network can sustain multiple faults but still continue to function. Thus the networking is extremely reliable minimizing loss of data and unnecessary shutdowns.

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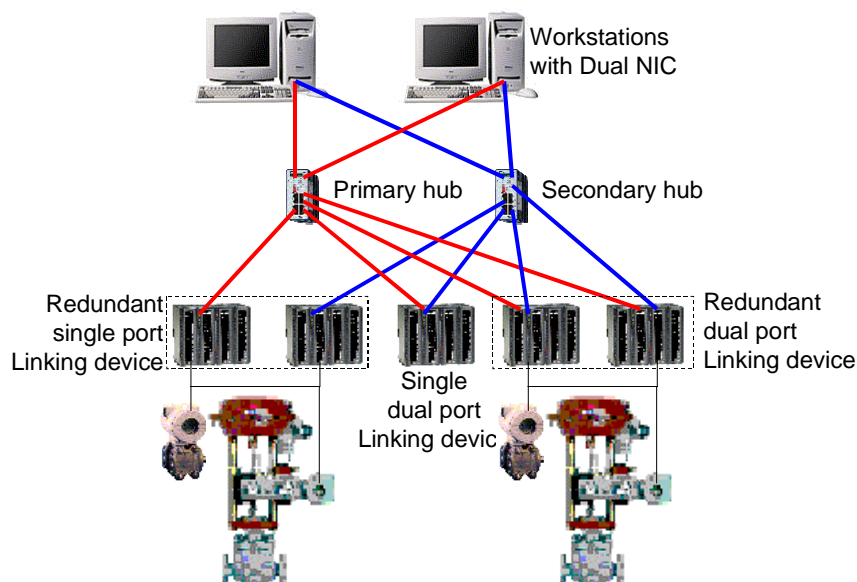


Figure 10 Three types of redundancy

The philosophy of the HSE redundancy is that of "operational transparency and diagnostic visibility". This means that the control application only sees either the primary or the secondary Ethernet device depending on which one is active, whereas the system diagnostics sees both. Thus the diagnostics can make sure that even the inactive devices are fully functional and ready to take over at any moment. A wide diagnostic coverage is an integral part of the HSE protocol going far beyond mere hardware duplication. Every HSE device, including the host or any "redundancy manager", independently keeps track of the status of the networks and all the devices on it. Because HSE is not only Ethernet media but also has a standard application layer, devices from different manufacturers periodically exchange their view of the network with each other using diagnostic messages through all ports on both networks which also serve as sign of life indication. Every device has a complete picture of the network to intelligently select which network, device and port to communicate with. Failure detection includes late and lost messages and duplication. Through exhaustive network diagnostics every device knows the health of the primary and secondary as well as communication port A and B of every other device on the network. Diagnostics in each device detect failure allowing the device to respond to and circumvent these faults as well as notifying the operator. No other standard protocol has this level of redundancy capability. Because the redundancy management is distributed to each device, no centralized "redundancy manager" is required. This way the Achilles heel of centralized architectures are again avoided.

Every communication port has a unique IP address. The IP address does not change when the primary switches over to the secondary. Depending on the health of the network segments, communication ports and device pairs the redundancy management in each device will pick the most suitable route to communicate with another device using the appropriate IP address. Therefore the system can sustain multiple faults and still continue to operate.

The network, device and port redundancy work independently of the physical media. Therefore it is possible to use a ring-topology media redundancy at the same time (figure 11).

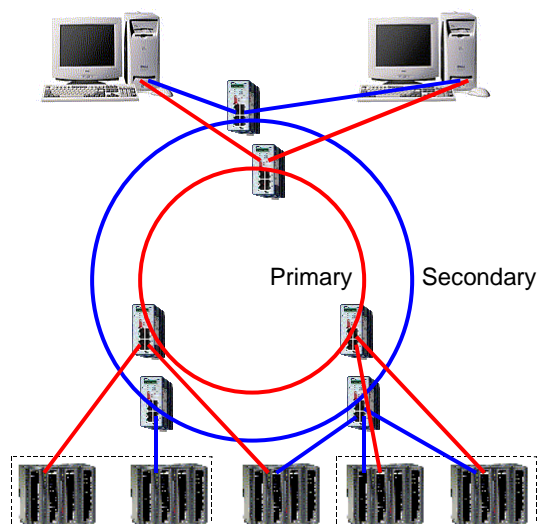


Figure 11 Redundancy and ring-topology

### 3.4. Device redundancy

True device redundancy is implemented using two identical devices, one primary and one secondary. The HSE protocol specifies how these devices communicate with others and how the communication is switched over. However, HSE does not specify how the functionality is switchover or how device configuration and data is synchronized.

For example, a primary and secondary linking device are connected to the same H1 field-level network and the two redundant host-level networks providing two interfaces and two completely separate communication paths from the H1 Fieldbus to the host. In case of any fault along the primary path, data can still pass through on the secondary path. This ensures that the plant floor data reaches the operator even if one interface fails always providing a window to the process. This compares favorably to a solution with only a single field-level interface.

The primary and secondary devices need to have an identical configuration in order to allow for a quick switchover in case of failure. When a primary device fails the secondary takes over the role of the primary. Primary to secondary configuration data synchronization is typically done over the Ethernet. The HSE technology allows the primary and secondary units in the device pair to be physically separated i.e. mounted some distance apart. To eliminates chances of common failures like faulty backplane or faults due to exposure to the same stresses.

## 4 Conclusion

HSE is required at the host-level to benefit fully from H1 at the field-level. HSE simplifies the system architecture and add functionality on top of Ethernet and IP to make the system open at all levels. The emergence of HSE at the host-level means an even greater change to systems than what was brought about by H1 Fieldbus. HSE places open networking above the controllers thereby making controllers standard interoperable devices using the standard function block language to build control strategies. The shared and centric nature of the host-level network and the devices at the host-level necessitates redundancy to achieve adequate availability. This fault tolerance is provided by the HSE scheme for standard interoperable redundancy above and beyond just the media.

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