HSR NOTES

CHAPTER 21

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Hardware suffix:	L & M
Software version:	B0 and later

CONTENTS

TABLES

FIGURES

Notes:

1 INTRODUCTION TO HSR

1.1 Introduction to High-availability Seamless Redundancy (HSR)

This section gives an introduction to the High-availability Seamless Redundancy (HSR); and how it is implemented on MiCOM-based products manufactured by Schneider Electric.

1.2 Protocols

Industrial real-time Ethernets typically need much better levels of availability and uninterrupted operation than normal office-type Ethernet solutions. For power networks, even a short loss of connectivity may result in a significant loss of functionality or impaired safety. To recover from a network failure, various redundancy schemes have been considered, including: Rapid Spanning Tree Protocol (RSTP), Media Redundancy Protocol (MRP), High-availability Seamless Redundancy (HSR). The key properties of these are as follows:

RSTP This uses mesh-based topologies and computes a tree, based on path costs and priorities. In case of network failure, a typical reset time for RSTP-based system is normally a few seconds.

MRP this uses ring-based topologies. In case of network failure, the network is broken into two separate lines, which are reconnected by de-blocking the previously blocked part. The guaranteed reset time for MRP protocol-based systems is typically around 100ms.

HSR HSR is typically used in a ring topology, This Clause describes the application of the HSR principles (Clause 5) to implement a High-availability Seamless Redundancy (HSR), retaining the PRP property of zero recovery time, applicable to any topology, in particular rings and rings of rings. With respect to PRP, HSR allows to roughly halve the network infrastructure. With respect to rings based on IEEE 802.1D (RSTP), IEC 62439-2 (MRP), IEC 62439-6 (DRP) or IEC 62439-7 (RRP), the available network bandwidth for network traffic is somewhat reduced depending on the type of traffic. Nodes within the ring are restricted to be HSR-capable bridging nodes, thus avoiding the use of dedicated bridges. Singly Attached Nodes (SANs) such as laptops or printers cannot be attached directly to the ring, but need attachment through a RedBox (redundancy box).

Power networks need to be able to respond to problems very quickly (typically in less than 10ms), and HSR is available protocol which is quick enough to achieve this. The HSR protocol used in the MiCOM relay/IED is defined in the IEC62439-3 (2012) standard and is configured using the existing redundant Ethernet card(s).

1.3   HSR Summary (IEC 62439-3 Clause 5)

A summary of the main HSR features is given below:

- HSR Ethernet redundancy method independent of any industrial Ethernet protocol and typically used in a ring topology

- Seamless switchover and recovery in case of failure, which supports real-time communication

- Supervises redundancy continuously for better management of network devices

- Suitable for hot swap, 24 hour/365 day operation in substations

- Allows laptops and workstations to be connected to the network with HSR Redbox

- Particularly suited for substation automation, high-speed drives and transportation

1.4   Example of an HSR Network

Essentially a HSR network is a ring topology. An example of a HSR network is shown in Figure 1:
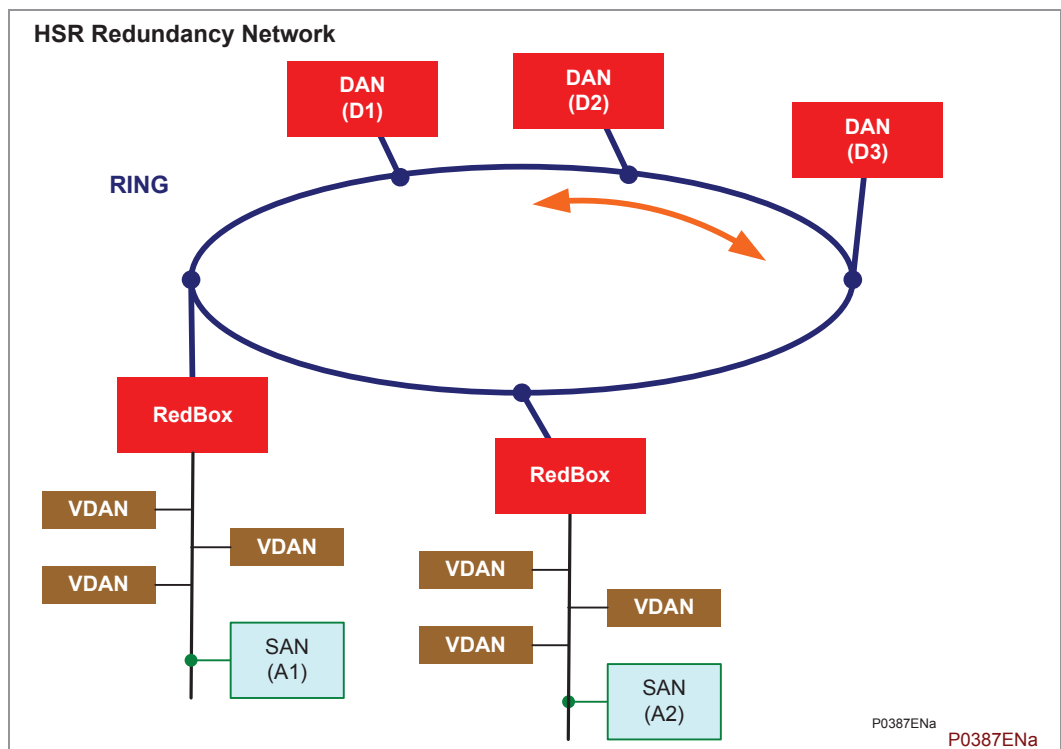
Figure 1 - HSR Redundancy Network

Figure 1 shows typical ring networks that have various Nodes in common. The key features of the network include:

- Nodes within the ring are restricted to be HSR-capable bridging nodes, thus avoiding the use of dedicated bridges

- Singly Attached Nodes (SANs) such as laptops or printers cannot be attached directly to the ring, but need attachment through a RedBox (redundancy box)

- A simple HSR network consists of doubly attached bridging nodes, each having two ring ports, interconnected by full-duplex link

- A source DANH sends a frame passed from its upper layers, prefixes it by an HSR tag to identify frame duplicates and sends the frame over each port

- A destination DANH receives, in the fault-free state, two identical frames from each port within a certain interval, removes the HSR tag of the first frame before passing it to its upper layers and discards any duplicate.

- In particular, the node will not forward a frame that it injected into the ring.

- A destination node of a unicast frame does not forward a frame for which it is the only destination, except for testing.

1.5 Structure of a DAN

Each DAN has two ports that operate in parallel. As in Figure 2, The two HSR ports A and B and the device port C are connected by the LRE, which includes a switching matrix allowing to forward frames from one port to the other. The switching matrix allows cut-through bridging. The LRE presents to the higher layers the same interface as a standard Ethernet transceiver would do.
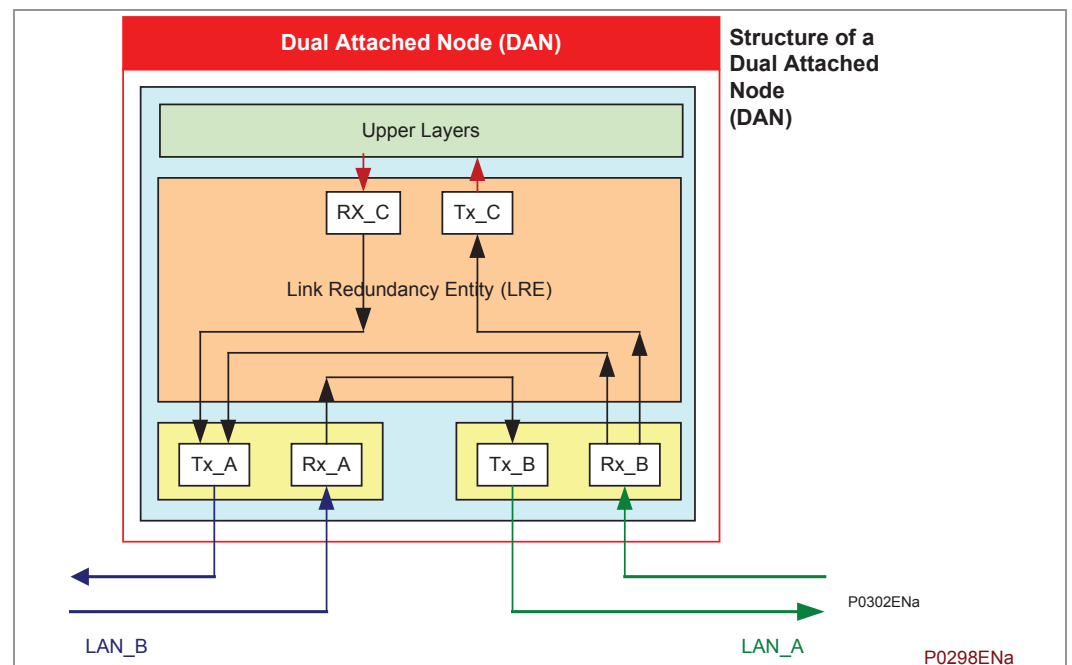

Figure 2 - DAN communication between two paths

DAN node is operable in HSR-tagged forwarding mode, the DANH shall inserts the HSR tag on behalf of its host and forwards the ring traffic, except for frames sent by the node itself. Duplicate frames and frames where the node is the unicast destination shall not be forwarded.

1.6	**Structure of a RedBox**

The RedBox has a LRE that performs the duties of the HSR protocol, in particular:

- forwards the frames received from one HSR port to the other HSR port, unless the frame

- receives frames addressed to its own upper protocols

- prefixes the frames sent by its own upper layers with the corresponding HSR tag before sending two copies over its HSR ports

The switching logic can be incorporated into the RedBox, so interlink becomes an internal connection.

A simple RedBox is present in every node, since the LRE makes a transition to a single non-HSR host. In addition, it is usual to have more than one host in a node, since a port for maintenance often exists.

A node shall not send over a port a frame that is a duplicate of a frame previously sent over that port in that same direction. A node shall not send over a port a frame that is a duplicate of a frame previously sent over that port in that same direction.

For the purpose of Duplicate Discard, a frame shall be identified by:

- its source MAC address;

- its sequence number.

For the purpose of Duplicate Discard, a frame shall be identified by:

Any Duplicate Discard method shall be able to forget an entry identified by <Source MAC Address><Sequence number> after a time EntryForgetTime.

1.7	**Communication between SANs and DANs and RedBoxs**

Singly attached nodes (SAN), for instance maintenance laptops or printers cannot be inserted directly into the ring since they have only one port and cannot interpret the HSR tag in the frames. SANs communicate with ring devices through a RedBox (redundancy box) that acts as a proxy for the SANs attached to it.

A source DANH sends a frame passed from its upper layers, and prefixes it by an HSR tag to identify frame duplicates and sends the frame over each port.

A destination DANH receives, in the fault-free state, two identical frames from each port within a certain interval, removes the HSR tag of the first frame before passing it to its upper layers ("D"-frame) and discards any duplicate.

A typical frame contains these parameters:

- dest_addr   Destination Address

- src_addr   Source Address

- type   Type

- data

- fcs   Frame Check Sequence (i.e. extra checksum characters added to allow error detection and correction)

HSR frames are identified uniquely by their HSR tag

The HSR tag consists of these parameters:

- 16-bit Ethertype (HSR_EtherType = 0x892F)

- 4-bit path identifier (PathId), 0000-0001 for a HSR node(A/B) and 0010-1111 for one of 7 PRP networks (A/B).

- 12-bit frame size (LSDUsize)

- 16-bit Sequence Number (SeqNr)

> *Note*   *The 4-bit PathId field prevents reinjection of frames coming from one PRP network to another PRP network.*

Accordingly, a typical HSR frame then contains these parameters:

- dest_addr   Destination Address

- src_addr   Source Address

- HSR tag data:
    - 16-bit Ethertype (HSR_EtherType = 0x892F)
    - 4-bit path identifier
    - 12-bit frame size
    - 16-bit sequence number:

- type   Type

- payload   Payload

- Padding   if needed

- fcs   Frame Check Sequence

Padding	After the payload data, there may be some data padding. This is added to frames which would otherwise be too short for conventional network traffic (minimum frame size is 70 octets).
Size	The frame size will vary depending on the contents of the frame and how it has been tagged by the various SANs and DANs. In VLANs, frame tags may be added or removed during transit through a switch. To make the length field independent of tagging, only the original LPDU and the HSR tag are considered in the size.

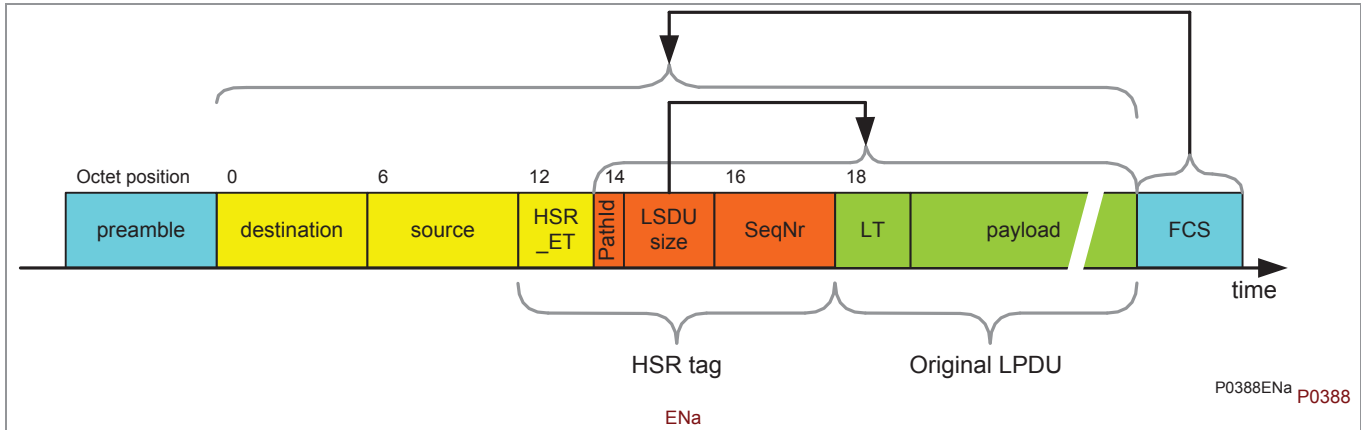Figure 3 and Figure 4 shows the frame types with different types of data.

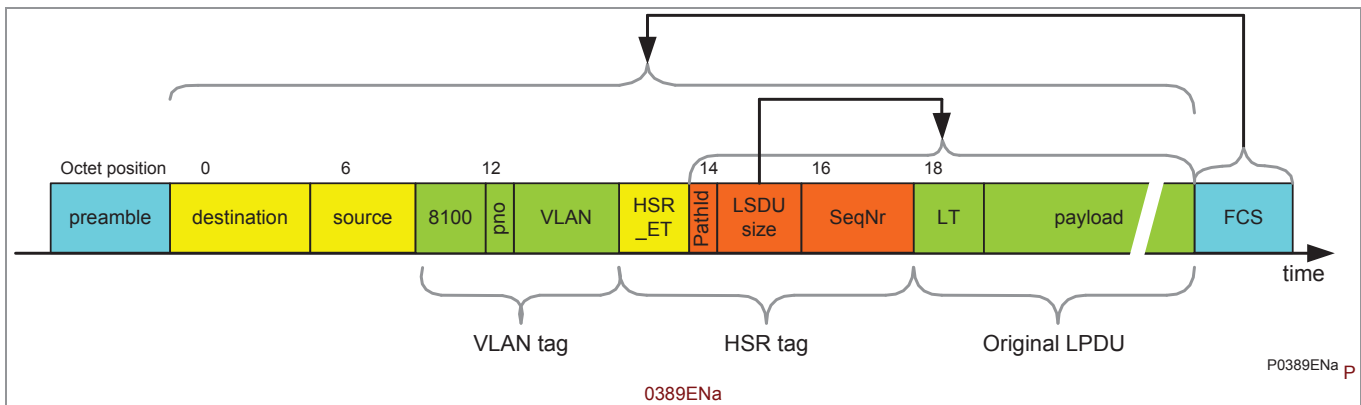**Figure 3 - HSR frame without a VLAN tag**

Figure 4 - HSR frame with VLAN tag

The key points about these differing frame structures are that:

- Unlike PRP, SANs cannot be attached directly to such a duplicated network unless they are able to interpret the HSR tag.

- In particular, the node will not forward a frame that it injected into the ring.

- A destination node of a unicast frame does not forward a frame for which it is the only destination, except for testing.

- DANH receiving from an HSR port, if this frame is not HSR-tagged and is a link local traffic, consume the frame and do not forward it.

- DANH receiving from an HSR port, if this frame is HSR-tagged and this node is not a destination, do not pass the frame to the link layer interface.

- A node accepts an HSR tagged frame also if the LanId does not correspond to the PortId and if the LSDUsize does not match the frame size.

Rejection Algorithm

A Nodes table maintains a list of all the Nodes (SANs and DANs) on each network. This table is used by the rejection algorithm, which is to assess the possibility of duplicated frames and for network integrity monitoring. The table maintains a list of all the sequence numbers so it can keep track of the frames that have been sent.

For every node on BOTH networks, the table also maintains:

- The expected next sequence number (so it can establish whether messages are not being received or are being received in an incorrect order)

- Message counts to show how many messages have been received

- Error counts to show whether frames were received out-of-order or were not received or were sent/received on the incorrect LAN

- A time field to keep track of when a frame was last received from the node

- An indicator to track whether the node is a SAN or not

The receiver scans the frames starting from the end and uses the algorithm to analyze the frames it has already received and the various data included in the current frame. The algorithm then combines the frame data with the information in the Nodes table to decide whether the frame is the first one it has received, or whether it is a candidate for rejection.

1.8 HSR Technical Data

- One VLAN tag supported

- 128 VDANs supported

- Up to 100Mbit/s full duplex Ethernet

- Dynamic frame memory allocation (page manager)

- Configurable duplicate detection

- Wishbone interface for configuration and status registers

- CPU port interface - Wishbone

- Support for link-local protocols - CPU may send to specific ports only - CPU knows receive port

- Configurable frame memory and queue length

- Duplicate detection with configurable size and aging time

- MAC address filtering (8 filter masks for interlink port, 6 for CPU port)

- Support for interfaces with or without Ethernet preamble

2   HSR AND MICOM FUNCTIONS

2.1   MiCOM Products and HSR

The HSR functions being introduced as part of the overall MiCOM product range provide additional functionality, which is backwards compatible with existing Schneider Electric MiCOM equipment. This means that existing MiCOM relays/IEDS can be used on networks, which use HSR functions, with no changes being made to those relays/IEDs.

The new MiCOM products that use the HSR, will interrogate other equipment to determine the equipment model number, and then use the model number to decide (at runtime), whether that particular item of equipment can support HSR or not.

The model number with the follow Ethernet board assembled ((Digit 7 Hardware option is Q or R) provided the possibility for HSR function support. This is shown in Table :

Hardware Option	Type	Example Model Number
"Q" at digit number 7	2LC + 1 RJ45 ports redundant Ethernet board	P64521**Q**A6M0B00M
"R" at digit number 7	3 RJ45 ports redundant Ethernet board	P64521**R**A6M0B00M

Table 1 - MiCOM model numbers for HSR options

The MiCOM relay/IED firmware has been modified to allow the HSR options to be accepted for the power-up tests in addition to the implementation of the supervision frame transmission.

2.2   MiCOM S1 Studio Software

The addition of the HSR feature has no impact of the MiCOM S1 Studio support files so there is no need to upgrade any MiCOM S1 Studio software.

2.3   MiCOM Relay Configuration

There is no need to change the configuration of any relay (as relays that include support for HSR will be able to recognize other devices that support HSR).

2.4   Hardware Changes

The HSR protocol is implemented using the redundant Ethernet card as a starting point. The HSR Frame management is achieved by programming the Field-Programmable Gate Array (FPGA).

The low-level management of the redundant frames is performed within the FPGA; this being defined as the Link Redundancy Entity (LRE). This will involve the addition of the HSR tag to a frame to be transmitted. The FPGA is also responsible for the stripping of the HSR tag from received frames and discarding the duplicated messages such that only a single application frame is received by the Ethernet processor.

The LRE functionality of the supervision frame transmission is performed by the NIOS II.

The new version of the redundant Ethernet card is based on the 2072069A01 and 2072071A01 (both have modulated and un-modulated IRIG-B).

2.5 HSR Parameters

The Redundant Ethernet standard (IEC 62439-3:2012/FDIS) defines several parameters for the HSR protocol; these being fixed at a default value within this release. The following values are set:

Parameter	Value	Description
Supervision Frame Multicast Address	01-15-4E-00-01-00	Target MAC Address for multicast supervision frame
Life Check Interval	2 seconds	Period between transmission of supervision frames
HSR Mode	Duplicate Discard	This is normal HSR mode, Duplicate address will not be supported.
Node Forget Time	60 s	
Entry Forget Time	400 ms	Duration that the received message Sequence number will be held to discard a duplicate message.
Node Reboot Interval	500ms	Duration following reboot for which no HSR frames should be transmitted.
MulticastFilterSize	16	Number of multicast addresses to be filtered

Table 2 - HSR parameter values

2.6   Product Requirements

Here is a list of the main Product Requirements for MiCOM products that support HSR:

- The MiCOM relay/IED provides two redundant Ethernet ports using HSR.

- The MiCOM relay/IED must be connected to the redundant Ethernet network as a Double Attached Node (DAN) using HSR (DAN using HSR is known as DANH)

- The redundant Ethernet interface can be made using an RJ45 or an optical fibre connection with an LC connector type.

- The management of the HSR redundancy is transparent to the application data provided via the Ethernet interface.

- The HSR option is available with any of the existing protocol options via the Ethernet Interface (IEC61850)

- Loss of one of the Node connections to the device does not cause any loss or degradation to the Application data over the Ethernet interface.

- The link fail alarm within the MiCOM relay/IED firmware can be detected the failure of the link on the redundant Ethernet interface.

- The MiCOM relay/IED supports the transmission of the HSR Supervision frame at a fixed time period (LifeCheckInterval) of 2s (+/- 100ms)

- Each supervision frame includes a sequence number as defined in the IEC 62439-3:2012/FDIS specification. This will be incremented for each supervision message and the value will start from zero following a system restart.

- The MiCOM relay/IED support SNMP.

- The MiCOM relay/IED does not provide for the HSR management to be configured (via either the MiCOM relay/IED HMI or the Ethernet interface). Accordingly, the default values (as defined within this document) are used for all HSR parameters.

- The performance of the Ethernet Interface is not degraded by using the HSR interface.

- We are stating that the HSR interface of the Px40 relay will support up to 128 connected DANH nodes.

2.6.1   Abbreviations and Acronyms

Abbreviations / Acronyms	Meaning
CRC	Cyclic Redundancy Check
DAN	Dual Attached Nodes
DANH	Double Attached Node implementing HSR
FPGA	Field-Programmable Gate Array
HMI	Human Machine Interface
HSR	High-availability Seamless Redundancy
IED	Intelligent Electronic Devices
IP	Internet Protocol
LAN	Local Area Network
LRE	Link Redundancy Entity
MAC	Media Access Control
MRP	Media Redundancy Protocol
PRP	Parallel Redundancy Protocol
HSR	High-availability Seamless Redundancy
RedBox	Redundancy Box
RSTP	Rapid Spanning Tree Protocol
SAN	Singly Attached Node
TCP	Transmission Control Protocol
VDAN	Virtual Doubly Attached Node