



Application and System Diagnostic Framework on CIP

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Technical Track

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- ▶ **System overview**
- ▶ **Device heartbeat**
- ▶ **Aggregators**
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Introduction

- ▶ Longstanding topic at the EtherNet/IP Workshops
 - Troubleshooting
 - Diagnose Ethernet and TCP
- ▶ The European series looked at a different type of diagnostics
 - Application
 - Device diagnostics
 - A working group was started

Introduction

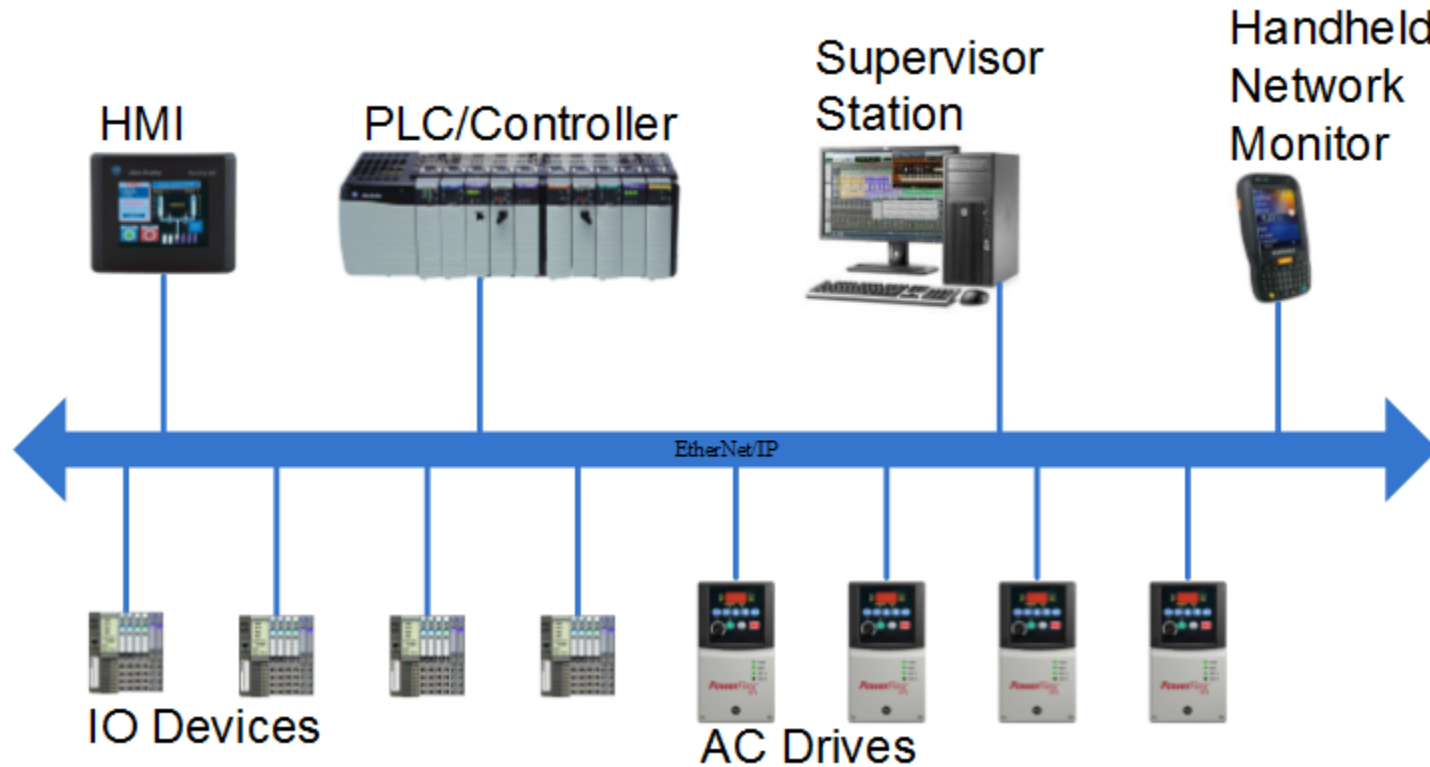
- ▶ Diagnostics and event logging as an integrated part of the functionality of devices
- ▶ Minimize the overall downtime
- ▶ Increase flexibility of the manufacturing system
- ▶ Maximize investment turnover

Introduction

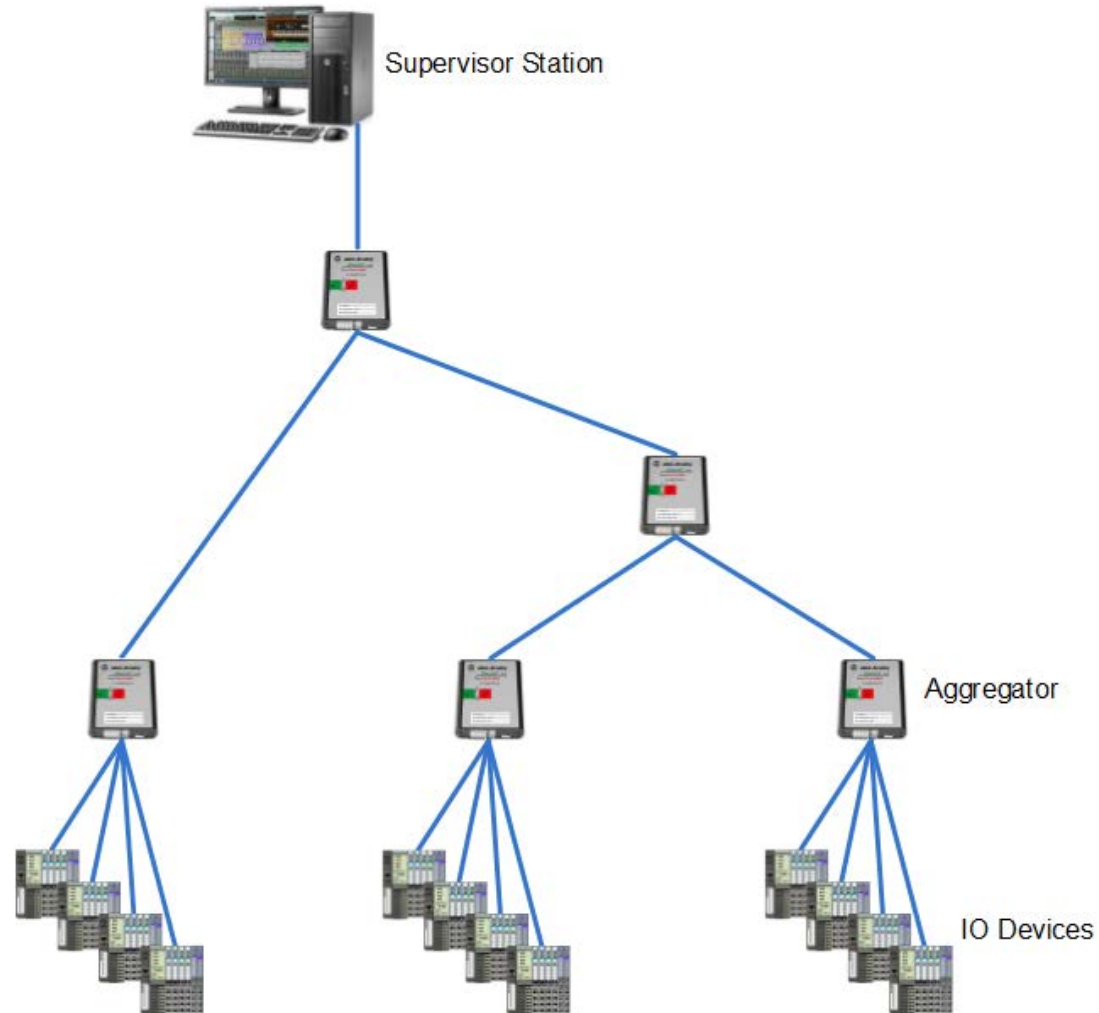
- ▶ Detect misaligned photo-eye
 - Log an high priority event
 - Service technician gets notified
 - Production stopped or run at a lower speed
- ▶ A motor has been used under a certain load for a certain number of hours
 - A low priority event is logged
 - Service for the motor gets scheduled to the next downtime period

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System overview

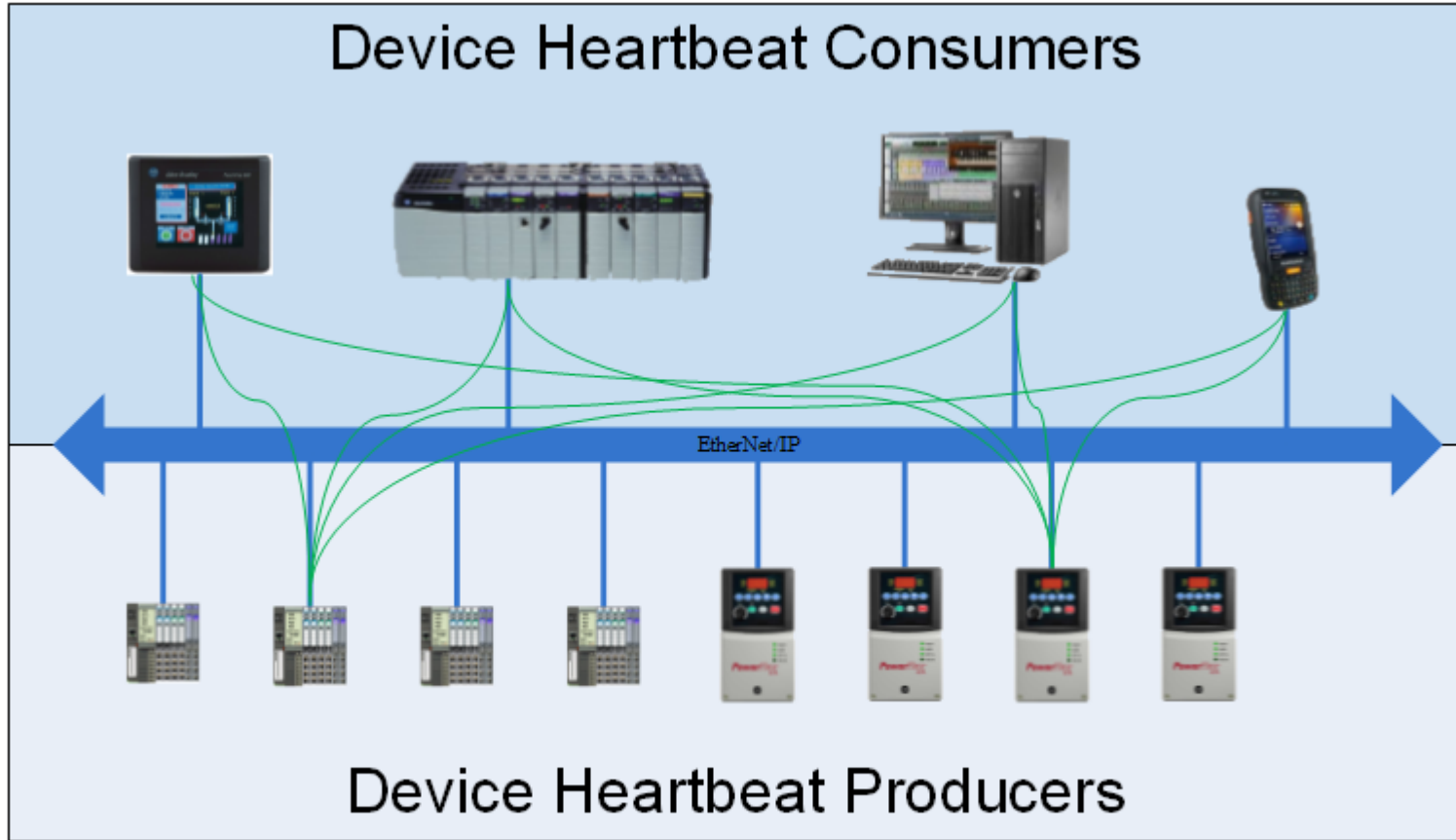


System overview



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Device heartbeat



— = Device Heartbeat

Device heartbeat

- ▶ Diagnostic Heartbeat delivery method
 - Unicast
 - Broadcast
 - Multicast
- ▶ All have their pros and cons
- ▶ Preferable method
 - Multicast
 - Can be filtered
 - Using IGMP Snooping
 - Already used on EtherNet/IP

Device heartbeat

Structure	Field Name	Data Type	Field Value
Encapsulation header	Command	UINT	Device Heartbeat
	Length	UINT	Length of the command specific data
	Session handle	UDINT	Any value (ignored by receiver).
	Status	UDINT	0
	Sender Context	ARRAY of octet	Value from request. Length of 8.
	Options	UDINT	0
Command specific data	Item Count	UINT	Number of target items to follow
	Target Items	STRUCT of	Device Heartbeat Information
		UINT	Item ID
		UINT	Item Length
		ARRAY of octet	Item Data

Device heartbeat

- ▶ Time To Live (TTL)
 - Part of the IP header
 - Defines how “far” an IP datagram can “travel”
- ▶ By default set to one
 - Limits Device Heartbeats to the local network
- ▶ Would have to be configurable
 - A new attribute in the TCP/IP Interface Object

Device heartbeat

- ▶ IP Multicast Address
 - Can not use the same address as for Class 0 and Class 1
 - Different IP Multicast Addresses per device
- ▶ A new IP multicast address needs to be allocated from the IPv4 Organizational Local Scope
- ▶ Would have to be configurable
 - A new attribute in the TCP/IP Interface Object

Device heartbeat

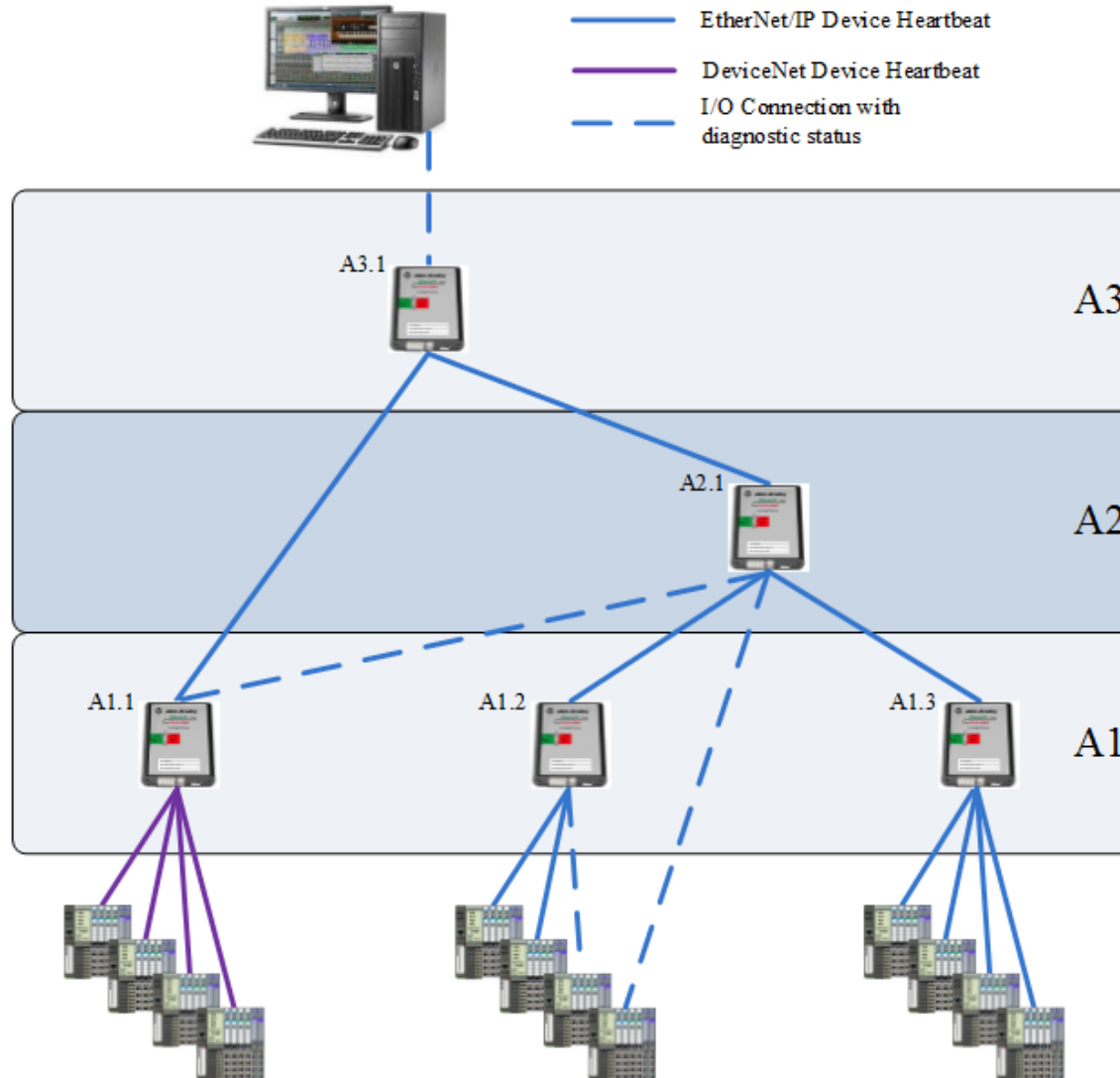
- ▶ Sent as Change-of-State
 - Speed up the delivery
 - The cyclic production interval is in seconds
 - An inhibit time is required
 - Defaults to $\frac{1}{4}$ of the heartbeat interval

Device heartbeat

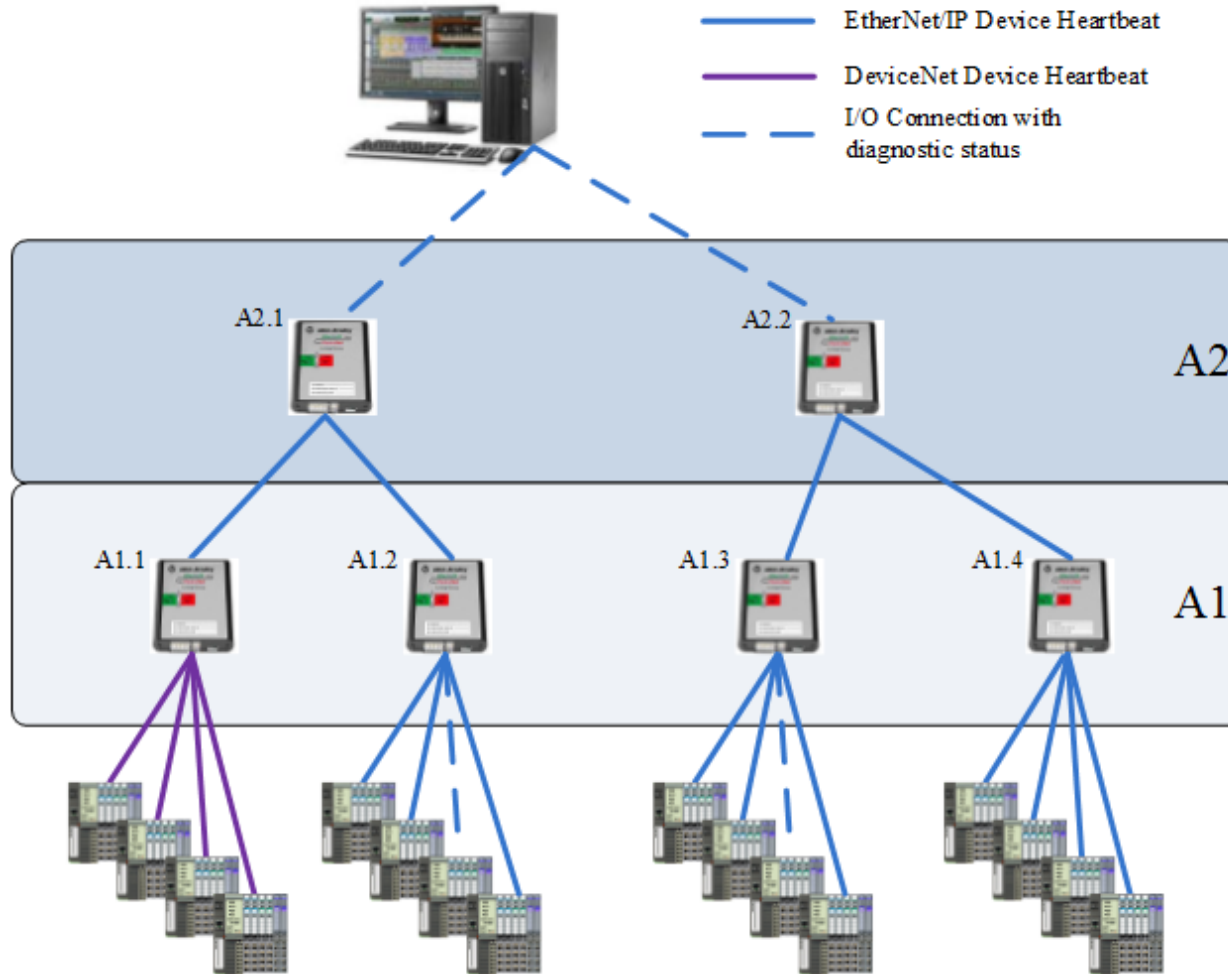
	7	6	5	4	3	2	1	0
0	Heartbeat Sequence Count							
1								
2	Identity Object Instance ID							
3								
4	Device State							
5	Severity Level							
6	AH	Reserved	Reserved	Reserved	VS3	VS2	VS1	VS0
7	Reserved	Reserved	Reserved	MA	EV	SF	UF	DF
8	Configuration Consistency Value							
9								
10	Device Heartbeat Instance ID (included if AH flag is set)							
11								
12	Path Size (included if AH flag is set)							
13								
14	Padded EPATH (included if AH flag is set)							
N								

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Aggregators



Aggregators



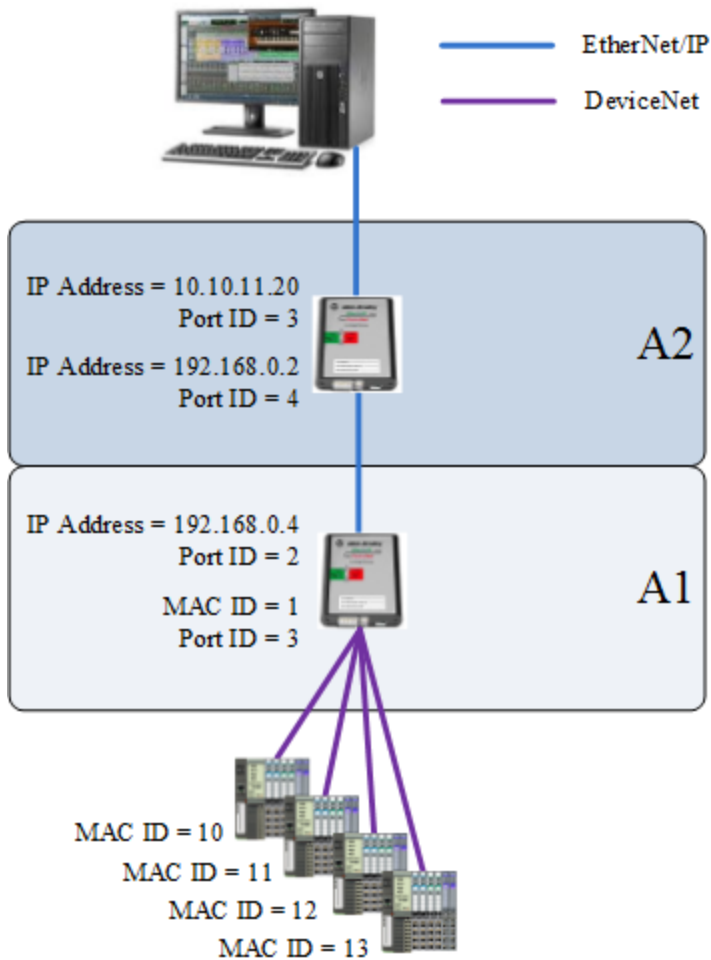
▶ Aggregator Object

- The Aggregator collects and store Device Heartbeat messages here in
- One instance per Device Heartbeat
 - Only new Device Heartbeat messages is stored
- The object either add or prepend the EPATH to the original producer with the address of the previous producer and the entry port
- Once the Device Heartbeat messages is stored it's produced "upstream"

Aggregators

- ▶ Upper layer tools making use of the Device Heartbeat messages are responsible for deleting consumed Device Heartbeat messages from the Aggregator Object
- ▶ The upper layer tools uses the Original Device Heartbeat Producer Path to drill down through the network hierarchy

Aggregators



- ▶ Path in A1
 - Path Size: 01 00
 - Path: 03 0B
- ▶ Path in A2
 - Path Size: 08 00
 - Path: 14 0B 31 39 32
2E 31 36 38 2E
30 2E 34 00 03
0B

- ▶ Filtering options in Aggregator Object
 - An acceptance mask of the Flags in the Diagnostic Heartbeat message
 - Applies as a logical AND
 - Defaults to all ones

Attr ID	Need In Implem	Access Rule	NV	Name	Data Type	Description of Attribute	Semantics of Values
<snip>							
8	Required	Set	NV	Diagnostic Flag Mask	WORD	Filter mask applied to Diagnostic Flags on received Device Heartbeat messages	See semantics section

- ▶ Filtering options in Aggregator Object
 - Severity level acceptance
 - Only events with a severity level equal to or higher than the configured will be accepted

Attr ID	Need In Implem	Access Rule	NV	Name	Data Type	Description of Attribute	Semantics of Values
<snip>							
9	Required	Set	NV	Severity Level Filter	USINT	Sets the minimum Severity Level of events that shall be accepted	See semantics section

- ▶ Filtering options in Aggregator Object
 - Device Heartbeat IP Address Mask
 - Filters on the destination IP Address
 - Default the defined IP Multicast address used for Device Heartbeat messages

Attr ID	Need In Implem	Access Rule	NV	Name	Data Type	Description of Attribute	Semantics of Values
<snip>							
10	Required	Set	NV	Device Heartbeat IP Address Mask	STRUCT of:	List of IP addresses that shall be masked	See semantics section
					UINT	Number of filtered addresses	
					UDINT	Device Heartbeat IP Address	

- ▶ Storage policy in Aggregator Object
 - It's possible to define when new instances are created
 - One instance per Device Heartbeat producer
 - Keep creating new and overwrite old instances
 - Keep creating new until out of memory

Attr ID	Need In Implem	Access Rule	NV	Name	Data Type	Description of Attribute	Semantics of Values
<snip>							
11	Required	Set	NV	Device Heartbeat Storage Policy	USINT	Defines how instances will be used to store Device Heartbeat	See semantics section

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Diagnostic object

- ▶ Event Log Object
 - Already exists and is defined
 - Seems logical to use because of the above
 - Contain some issues
 - Loosely defined
 - Defined in a generic way to support any kind of logging
 - Suggests defining a new object
 - The Diagnostic Object

Diagnostic object

- ▶ Device implementing the Device Heartbeat shall also implement the Diagnostic Object
- ▶ A small and light weight object
 - Yet flexible enough
 - Can be implemented in devices with limited resources

Diagnostic object

- ▶ One instance per bit in the Flag field of the Device Heartbeat
 - Bit 15 excluded
 - Bit 0 corresponds to 1
 - Bit 1 corresponds to 2
 - And so on...

Diagnostic object

- ▶ Event list attribute
 - Where all information about the logged events are stored
 - Comprise of a size member and an array of logged events
 - Grow as new events are logged
 - New events are added to the end of the list

Diagnostic object

Attr ID	Need In Implem	Access Rule	NV	Name	Data Type	Description of Attribute	Semantics of Values
<snip>							
6	Required	Get	V	Event List	STRUCT of:	List of all logged events	See semantics section
				List Size	UINT	Number of entries diagnostic entries	
				Event Information	ARRAY of STRUCT of:	Array of diagnostic entries	
				Event Code	UINT	Identifier uniquely identifying this diagnostic event	
				Severity Type	USINT	The severity of the event	
				Event Code Description	SHORT_STRING	Textual representation of the diagnostic event	
				Time	DATE_AND_TIME	Data and time when the event was logged	

Diagnostic object

- ▶ Severity levels
 - Discrete levels identifying the importance
 - Loosely based on the Syslog severity levels

Code	Description
0	Emergency
1	Alert
2	Critical
3	Error
4	Warning
5	Information

Diagnostic object

- ▶ The behavior of new events can be controlled
 - What to do with a full list
 - How duplicates are handled

Attr ID	Need In Implem	Access Rule	NV	Name	Data Type	Description of Attribute	Semantics of Values
<snip>							
3	Required	Set	NV	List Full Action	USINT	Configures the action to take when a new event is detected and the log is full.	See semantics section
4	Required	Set	NV	Duplicate Action	USINT	Configures the action to take when a duplicate event is detected.	See semantics section
<snip>							

Diagnostic object

- ▶ A new object specific service
 - Used to read logged events
 - Return the last unread event logged

Service Code	Need in Implementation		Service name	Description of Service
	Class	Instance		
4Bhex	n/a	Required	Get_Next_Unread_Member	Returns the next member in the Event List Attribute that has not been read yet.

Diagnostic object

► EDS construct

- Make it possible to provide textual strings for the events in the EDS file

Field Name	Field Number	Data Type	Required/Optional
First Event Code	1	UINT	Required
First Event Code String	2	STRING	Required
Nth Event Code	3,5,7,...	UINT	Optional
Nth Event Code String	4,6,8,...	STRING	Conditional ¹

Table Footnotes

1 Required if preceding field is specified, not allowed if preceding field is not specified.

```
[Diags]
Diag =
0x3000, "Over temperature",
0x3001, "Under temperature",
0x3002, "Delta temperature error",
0x4000, "Sensor misaligned",
0x4001, "Sensor disconnected";
```

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- ▶ **Summary**

- ▶ A generic framework for diagnostic reporting and event logging
 - Can be used for almost any type of application and device diagnostics and events
 - Functionality to report diagnostics
 - Store and publish diagnostics
 - Aggregate diagnostics through a network hierarchy
 - All based on standardized CIP functionality



Thank you for your attention!