New Data Objects & New Protocols

Supporting new TSN features in decentralized and centralized organized Industrial Networks

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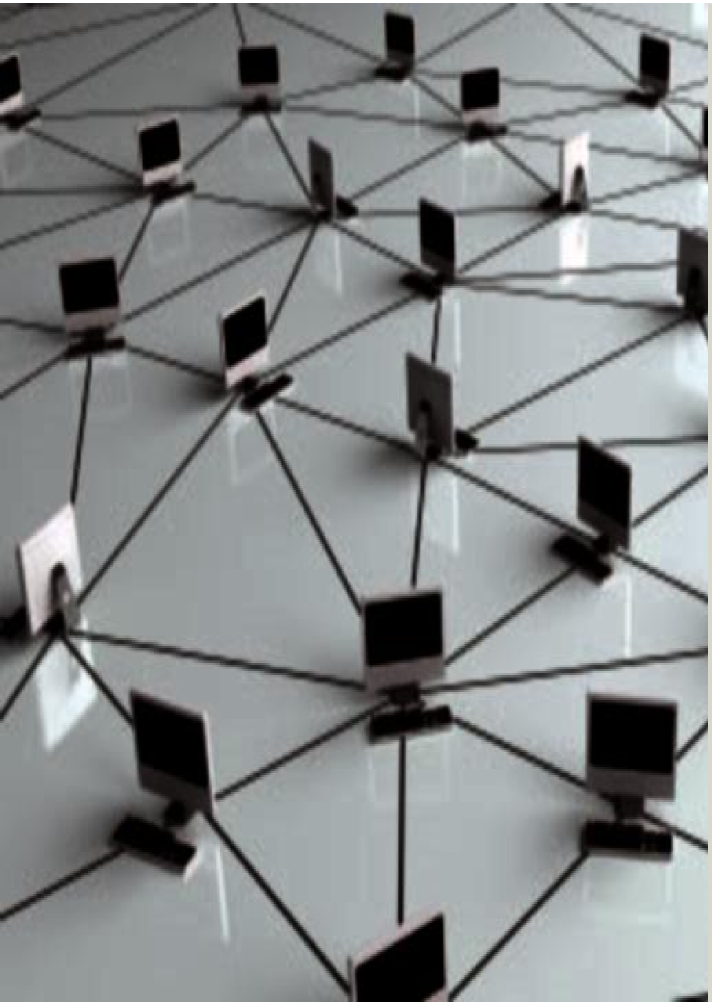

- De-/centralized organized Networks
  - Without Scheduled Traffic
  - With Scheduled Traffic
- Future of Industrial Networks
- Registration & Reservation
- Next Steps

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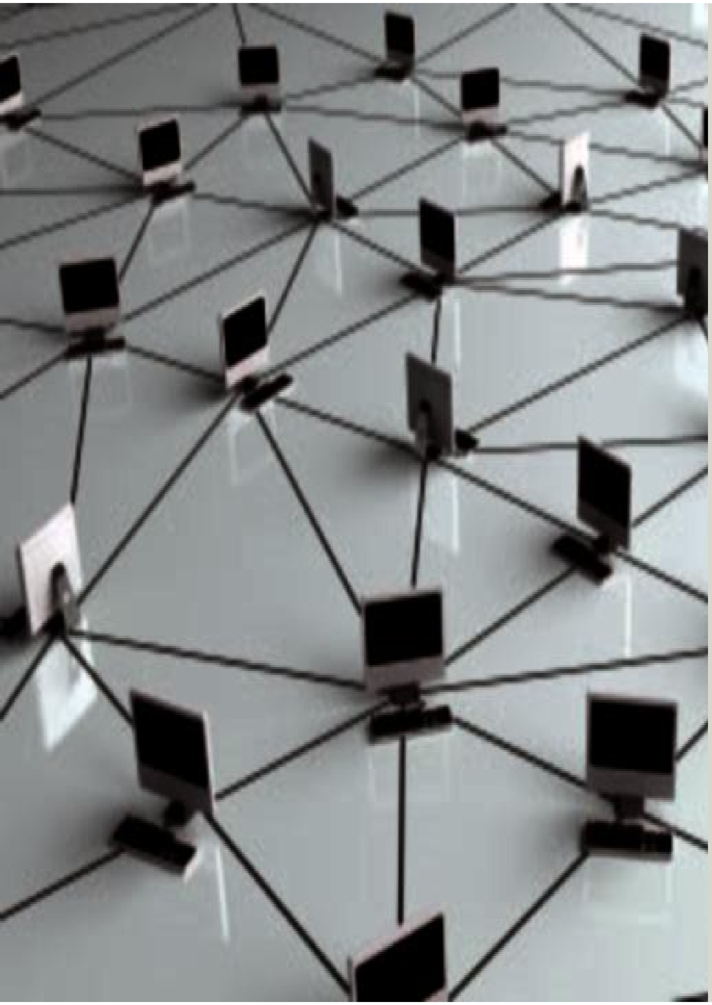

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- **Next Steps**

Thoughts about de-/centralized organized Industrial Networks

1. Centralized Organized Networks
   - Within industrial automation there are a lot of established centralized organized systems (e.g. EtherCat, PROFInet, VARAN, …).

2. Decentralized Organized Networks
   - Ethernet and Internet are well known decentralized organized Systems.
   - AVB is also a decentralized organized system.

When talking about industrial automation we have to differentiate between administration, applications and communication.

With introducing TSN in industrial automation, vendors are also requesting for a decentralized organized communication system.
One example is the ongoing discussion about OPC_UA over TSN.
See: http://www.ieee802.org/1/files/public/docs2015/tsn-munz-requirements-for-tsn-in-manufacturing-0515-v01.pdf

ONE Solution for Centralized and Decentralized organized industrial networks

General:

- TSN is talking about how to implement deterministic Ethernet
- Deterministic Ethernet can be implemented "all traffic is scheduled" **but** TSN has also specified other mechanism (e.g. traffic classes, reservation in combination with strict priority and pre-emption)
- Industrial networks can be organized centralized and decentralized
- Diagnostic / double check is very important for industrial communication

Assumptions:

- IEEE 802.1 has already standardized a lot of building blocks for a centralized or decentralized organized networks, **TSN builds upon them**.
- TSN has to take care not to overload existing protocols
- If the existing building blocks have too much functionality, specifying a "profile" for an industrial TSN network reduce complexity ***by restricting*** the functionality
- If the existing building blocks do not cover the required functionality TSN has to fill the gap

Objective:

=> Standardize ONE and only ONE solution within IEEE 802.1 to support centralized or decentralized organized TSN networks.

=> This is essential for TSN to succeed in the industrial market!

Motivation

IEEE 802.1 has standardized a lot of mechanism and building blocks
(e.g. .1Qai, .1Qak, .1Qal, .1AS, .1Qat, .1Qav, .1Qbu, .1Qbh, .1Qca, .1CB, …)-

The following slides shows how these buildings blocks can be used for TSN to support centralized or decentralized organized TSN networks!

The following slides shows

- **gaps**, which must be filled and
- **interfaces** for which the TSN group has to specify **data objects**

Motivation

The success of Ethernet was a decentralized organized Network.

This is the reason why this presentation will concentrate on 2 models!

1. Decentralized organized Ethernet network
2. Centralized organized Ethernet network

The 2 models can be also used for networks with “SCHEDULED TRAFFIC”!

- *This presentation also assumes a fully distributed user mode because a fully centralized user model is not in scope of the IEEE 802.1*

- *This presentation shows a interim result of the ongoing discussion with the TSN task group* *http://www.ieee802.org/1/files/public/docs2015/cc-goetz-MRPv2-MSP-v13.pdf*

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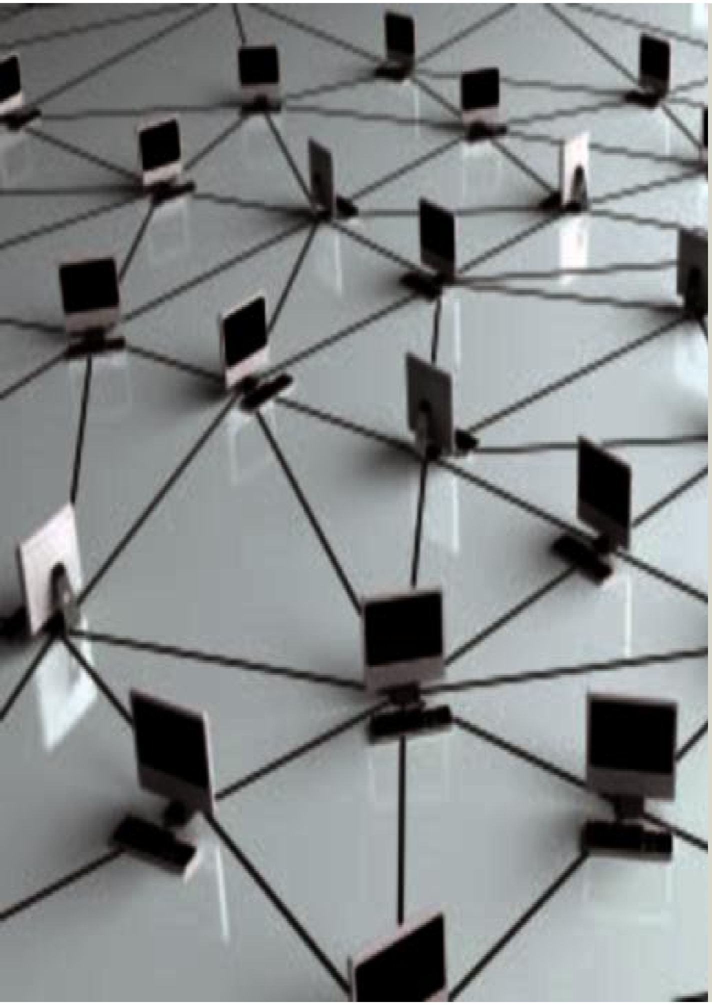

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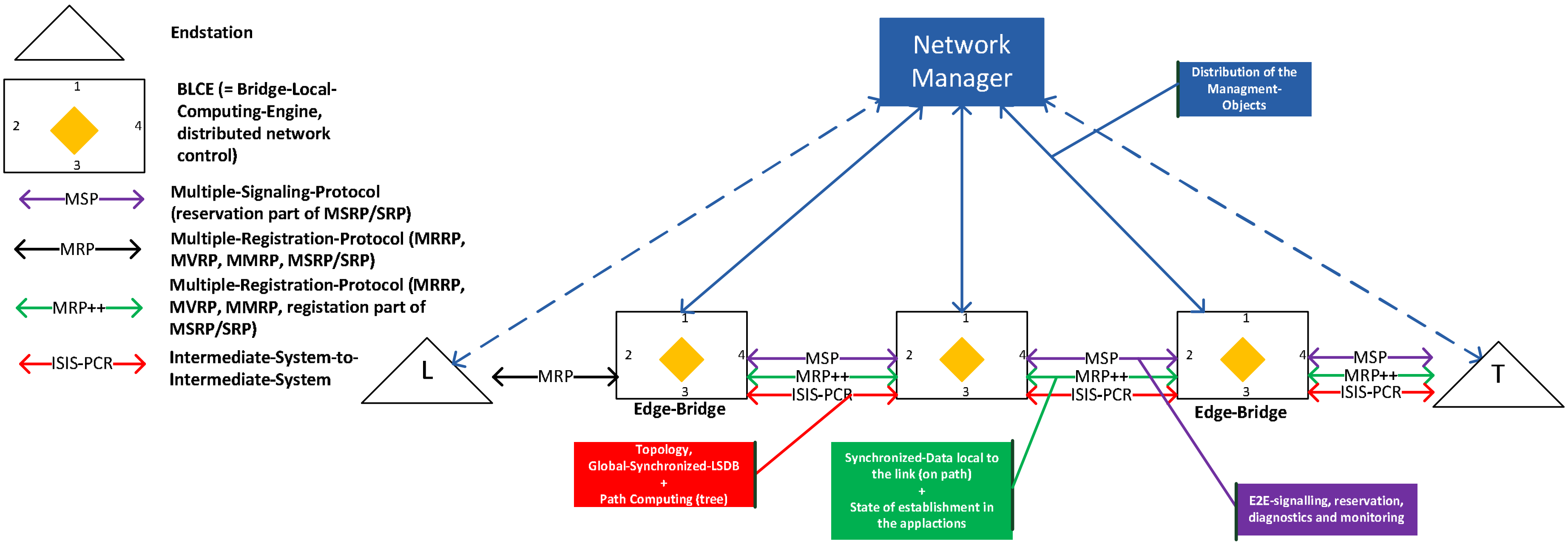
Path Computation, Registration & Reservation for decentralized organized Ethernet Networks without “Scheduled Traffic”



Endstation

BLCE (= Bridge-Local-Computing-Engine, distributed network control)

MSP: Multiple-Signaling-Protocol (reservation part of MSRP/SRP)

MRP: Multiple-Registration-Protocol (MRRP, MVRP, MMRP, MSRP/SRP)

MRP++: Multiple-Registration-Protocol (MRRP, MVRP, MMRP, registation part of MSRP/SRP)

ISIS-PCR: Intermediate-System-to-Intermediate-System

Distribution of the Managment-Objects

Topology, Global-Synchronized-LSDB + Path Computing (tree)

Synchronized-Data local to the link (on path) + State of establishment in the applactions

E2E-signalling, reservation, diagnostics and monitoring

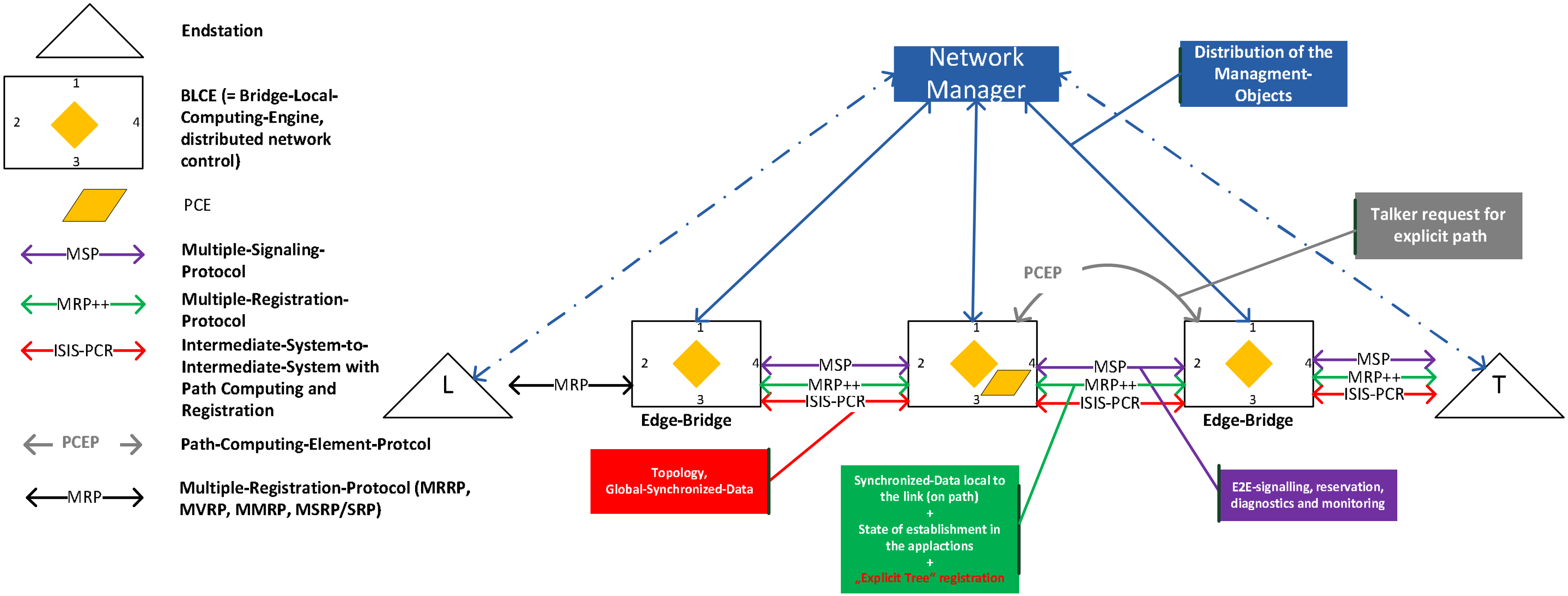
Network:

- *ISIS-PCR is used for topology discovery*
- *BLCE’s are used for decentralized path computing*
- *MRP++ to register data objects for network control, stream specification, …*
- *MSP is used for E2E signaling e.g. stream reservation*

End Station:

- Using existing MRP (including MRRP, MVRP, MMRP, MSRP/SRP) for registration & reservation between end station and edge bridge (part of an UNI-Interface)
- Adding to existing MRP data objects for control (TLV’s) to support new TSN features like redundancy

Path Computation, Registration & Reservation for centralized organized Ethernet Networks without “Scheduled Traffic”



Endstation

BLCE (= Bridge-Local-Computing-Engine, distributed network control)

PCE

Multiple-Signaling-Protocol

Multiple-Registration-Protocol

Intermediate-System-to-Intermediate-System with Path Computing and Registration

Path-Computing-Element-Protcol

Multiple-Registration-Protocol (MRRP, MVRP, MMRP, MSRP/SRP)

Network Manager

Distribution of the Managment-Objects

Talker request for explicit path

Edge-Bridge

Edge-Bridge

Topology, Global-Synchronized-Data

Synchronized-Data local to the link (on path)
+
State of establishment in the applactions
+
„Explicit Tree“ registration

E2E-signalling, reservation, diagnostics and monitoring

Network:

- *PCE for centralized path computing*
- *ISIS-PCR is used for topology discovery*
- *PCEP is used to request / response path computing (“Explicit Tree”) for streams / relations*
- *MRP++ to register data objects for network control, stream specification, distributing also the data object for “Explicit Tree” and all the others*
- *MSP is used for stream reservation and also E2E signaling*

End Station:

- Using existing MRP (including MRRP, MVRP, MMRP, MSRP/SRP) for registration & reservation between end station and edge bridge (part of an UNI-Interface)
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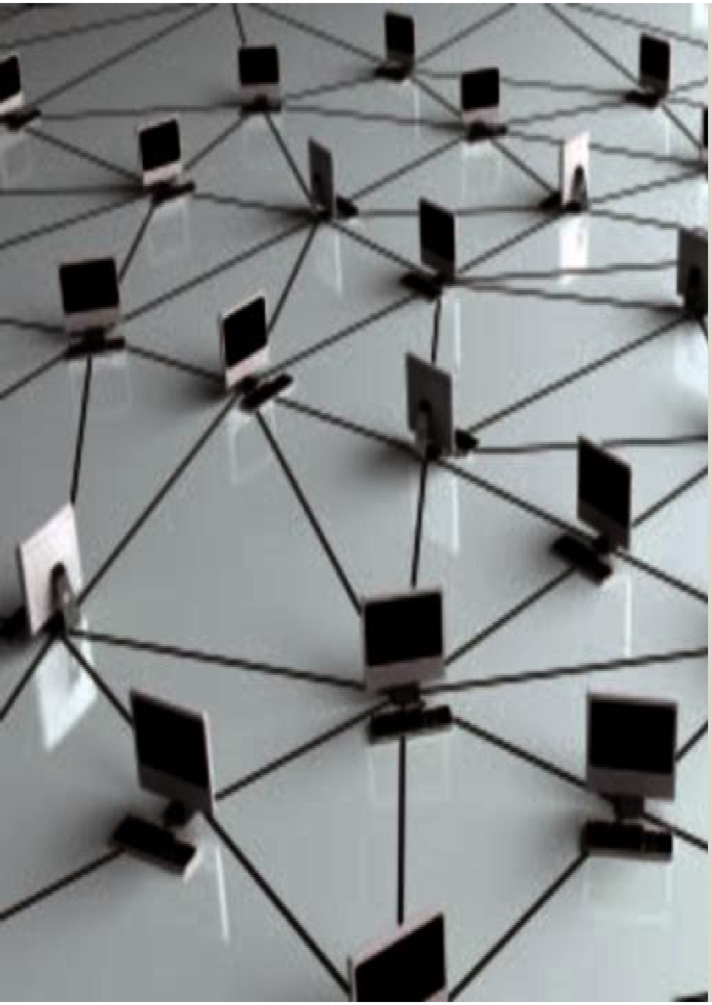

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Path Computation, Scheduling, Registration & Reservation for de- and centralized organized Ethernet Networks with “Scheduled Traffic”

A systems using the TAS scheduler requires configuration of gate open and gate close times for each scheduled traffic class on each port. How can we configure these?

Proposal:

A new version of a stream reservation protocol shall distribute additional parameters to configure the gate open and gate close times. Three additional parameter sets for reservation are proposed:

- ***Downstream (talker -> bridges- > listener)***
  - Best-Case-Min-Latency (physical minimum latency means accumulated min forwarding bridge delay, min path delay, …)
  - Worst-Case-Min-Latency (max. interference for a steam within a time window means accumulated max. interference, max forwarding bridge delay, max path delay, …)

- ***Upstream (listener -> bridges -> talker)***
  - Min-Listener-Allowed-Latency (listener minimum stream arrival time – related to schedule start time)
  - Max-Listener-Allowed-Latency (listener maximum stream arrival time – related to schedule start time)

- ***Reservation (talker -> bridges listener)***
  - Min-Reservation-Delay (reserved min transmission delay – “like gate open time for a stream”)
  - Max-Reservation-Delay (reserved max transmission delay – “like gate close time for a stream””)

⇒ Dependent form stream reservation and hardware capabilities each bridge can calculate for each scheduled traffic class on each port the gate open and gate close times.

Advantages:

- Each network component can configure the window size for each scheduled traffic class on each port itself.
- NO bridge specific parameter (e.g. forwarding delay, CT, …) must be distributed.
- The reservation mechanism can be used in combination with different time based shapers.
- The reservation mechanism can be used for a decentralized an centralized organized time aware networks.

Proposal:
Supporting distributed Scheduling
by Stream Reservation for “Scheduled Traffic”

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Usage of the additional reservation parameters supporting “Scheduled Traffic”

- ***Downstream (talker -> bridges- > listener)***
  - Best-Case-Min-Latency (physical minimum latency means accumulated min forwarding bridge delay, min path delay, …)
  - Worst-Case-Min-Latency (max. interference for a steam within a time window means accumulated max. interference, max forwarding bridge delay, max path delay, …)
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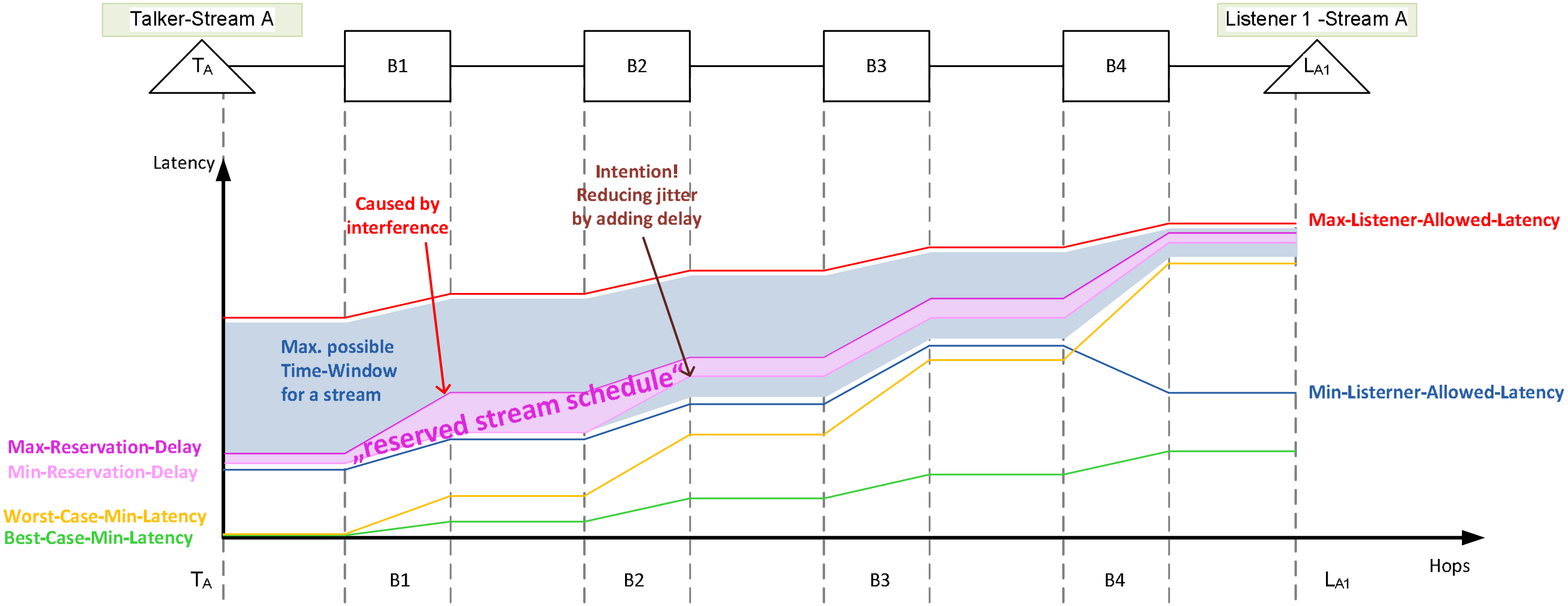
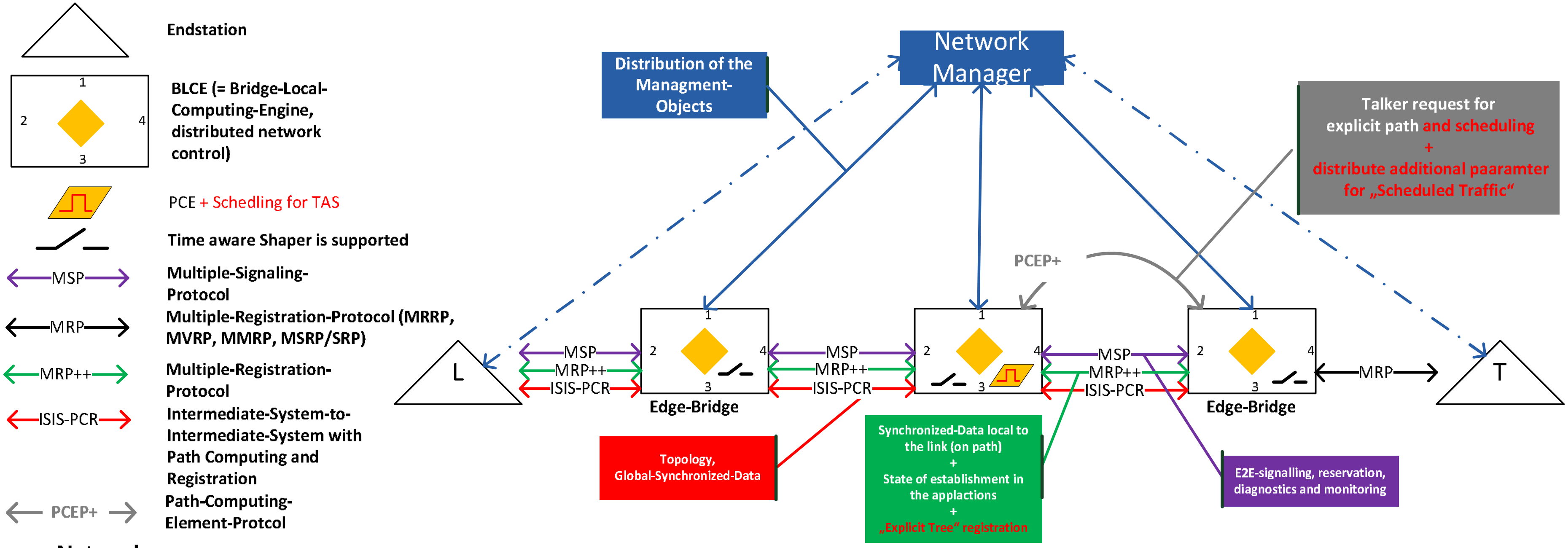


Path Computation, Scheduling, Registration & Reservation for centralized organized Ethernet Networks with “Scheduled Traffic”



Endstation

BLCE (= Bridge-Local-Computing-Engine, distributed network control)

PCE + Schedling for TAS

Time aware Shaper is supported

MSP: Multiple-Signaling-Protocol

MRP: Multiple-Registration-Protocol (MRRP, MVRP, MMRP, MSRP/SRP)

MRP++: Multiple-Registration-Protocol

ISIS-PCR: Intermediate-System-to-Intermediate-System with Path Computing and Registration

PCEP+: Path-Computing-Element-Protcol

Network Manager

Distribution of the Managment-Objects

Talker request for explicit path and scheduling + distribute additional paaramter for „Scheduled Traffic“

Topology, Global-Synchronized-Data

Synchronized-Data local to the link (on path) + State of establishment in the applactions + „Explicit Tree“ registration

E2E-signalling, reservation, diagnostics and monitoring

Network:

- *PCE for centralized path computing + Scheduling for “Scheduled Traffic”*
- *ISIS-PCR is used for topology discovery*
- *PCEP is used to request / response for path computing (“Explicit Tree”) for streams / relations and also to request / response for scheduling of “Scheduled Traffic” (with calculation of* Best-Case-Min-Latency, Worst-Case-Min-Latency, Min-Listener-Allowed-Latency, Max-Listener-Allowed-Latency)
- *MRP++ to register data objects for network control, stream specification, distributing also the data object for “Explicit Tree” and all the others parameter (also for Scheduled Traffic – optional* Min-Listener-Allowed-Latency and Max-Listener-Allowed-Latency)
- *MSP is used for stream reservation and also E2E signaling and also to synchronize the parameter set supporting scheduling*

End Station:

- Using existing MRP (including MRRP, MVRP, MMRP, MSRP/SRP) for registration & reservation between end station and edge bridge (part of an UNI-Interface)
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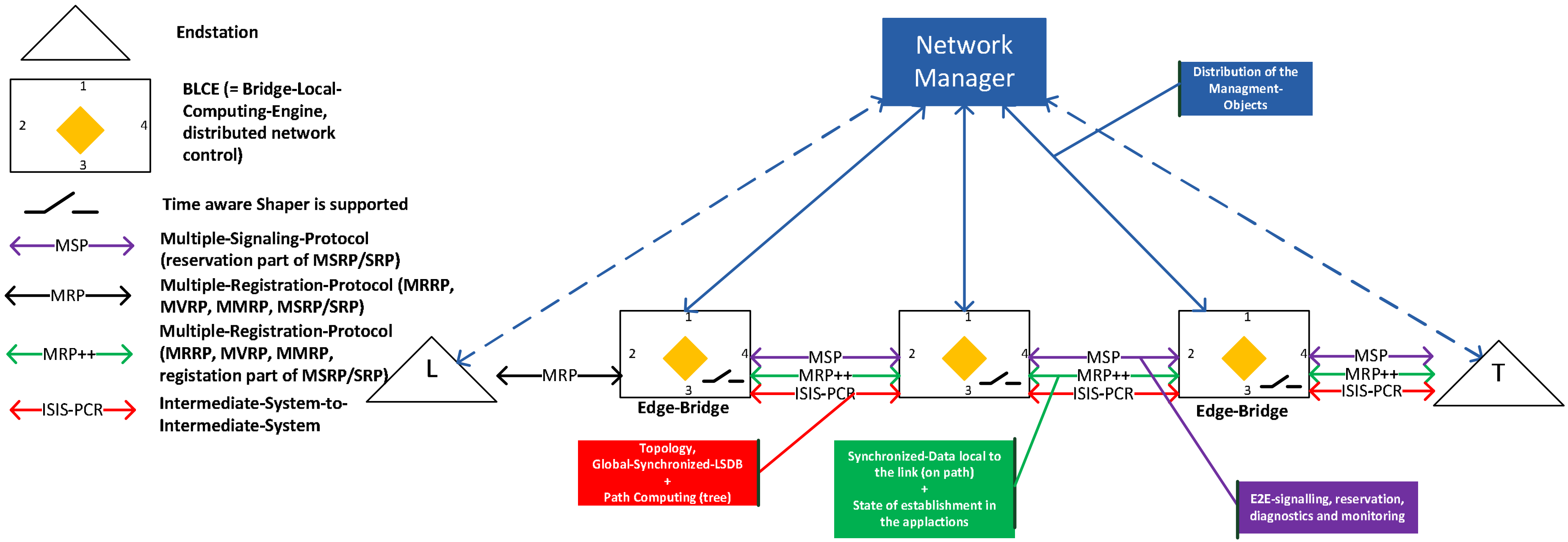
Path Computation, Scheduling, Registration & Reservation for decentralized organized Ethernet Networks with “Scheduled Traffic”


Endstation
1
2
4
3
BLCE (= Bridge-Local-Computing-Engine, distributed network control)
Time aware Shaper is supported
MSP
Multiple-Signaling-Protocol (reservation part of MSRP/SRP)
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Network:

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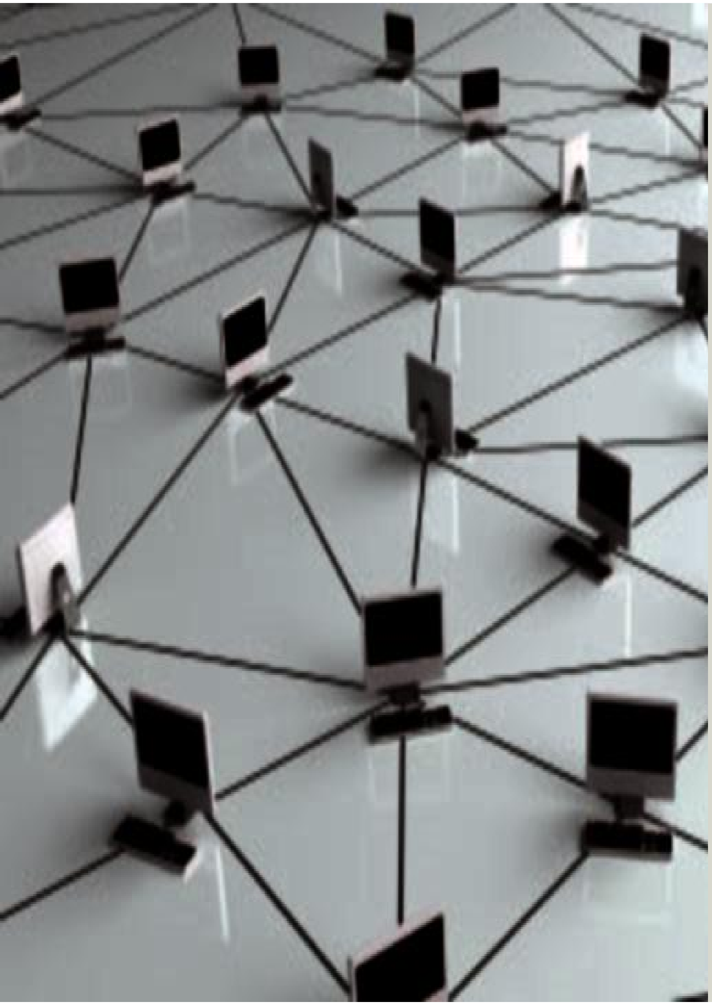

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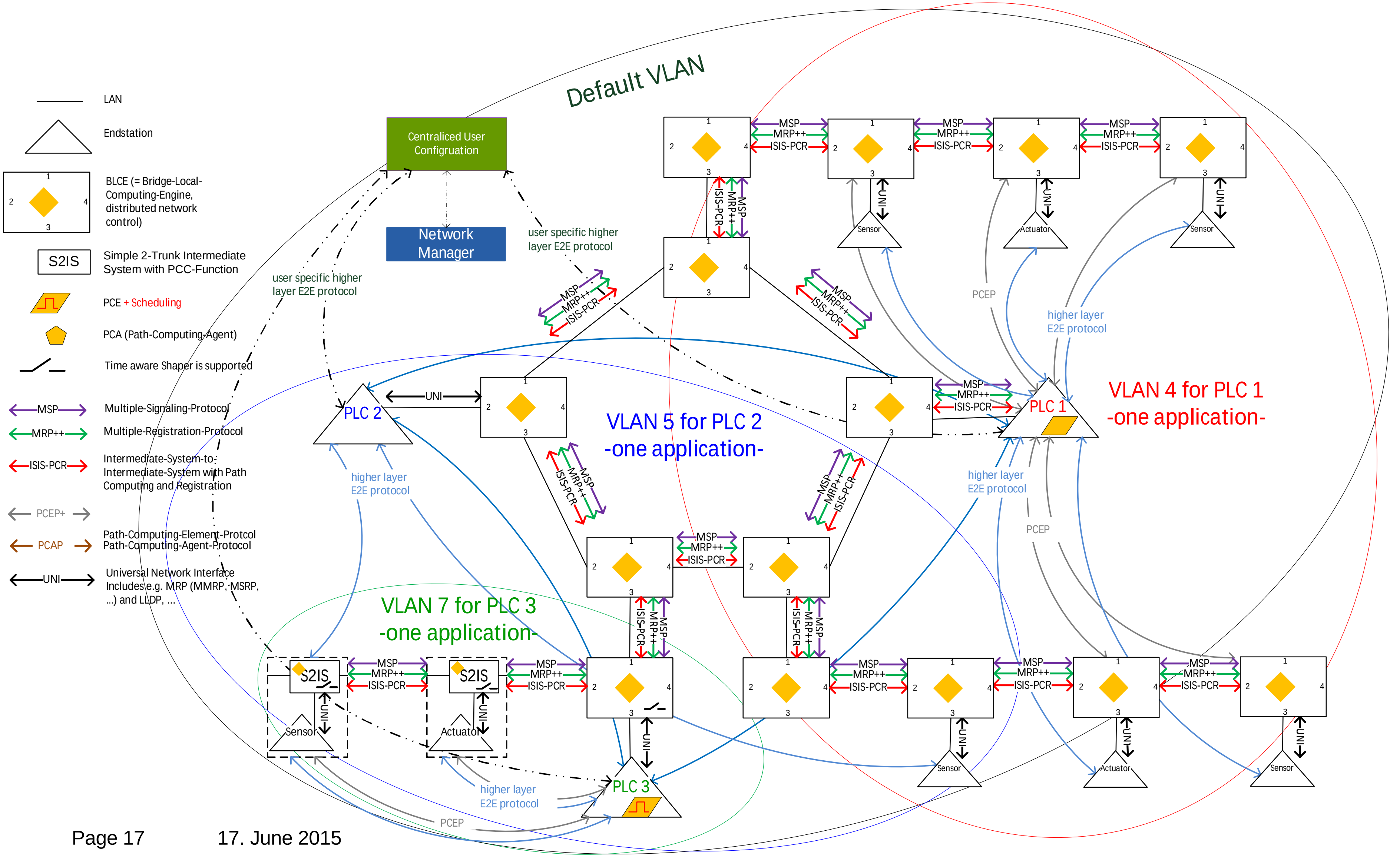
The Future of de-/centralized organized Industrial Networks based on the existing IEEE 802.1 Building Blocks



LAN

Endstation

BLCE (= Bridge-Local-Computing-Engine, distributed network control)

S2IS — Simple 2-Trunk Intermediate System with PCC-Function

PCE + Scheduling

PCA (Path-Computing-Agent)

Time aware Shaper is supported

←MSP→ Multiple-Signaling-Protocol

←MRP++→ Multiple-Registration-Protocol

←ISIS-PCR→ Intermediate-System-to-Intermediate-System with Path Computing and Registration

←PCEP+→

←PCAP→ Path-Computing-Element-Protcol Path-Computing-Agent-Protocol

←UNI→ Universal Network Interface Includes e.g. MRP (MMRP, MSRP, ...) and LLDP, ...

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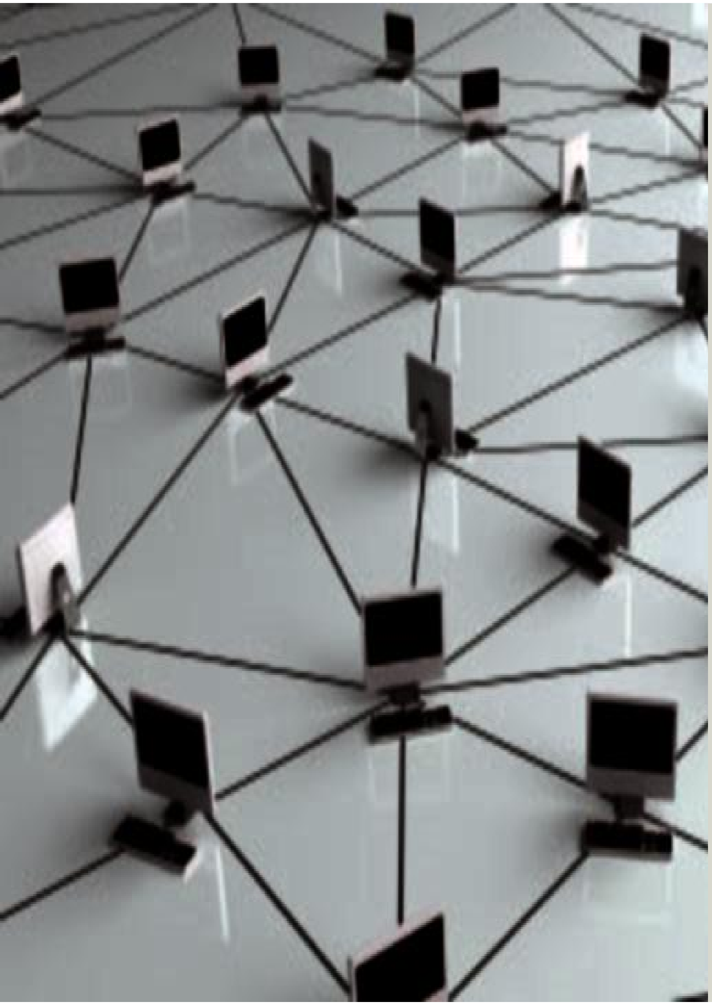

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MRP++ and MSP
Reasons for splitting Registration and Reservation

At the moment within the TSN group there is a discussion

- How to “support for more streams. The current worst case limit is less than 500 streams; there are use cases that require two orders of magnitude greater than this.”
- How to get “deterministic stream reservation convergence.”
- …

(excerpt from the .1Qcc PAR)

The following slides

- explain registration
- explain reservation
- and show the difference also in the architecture between both

Registration:

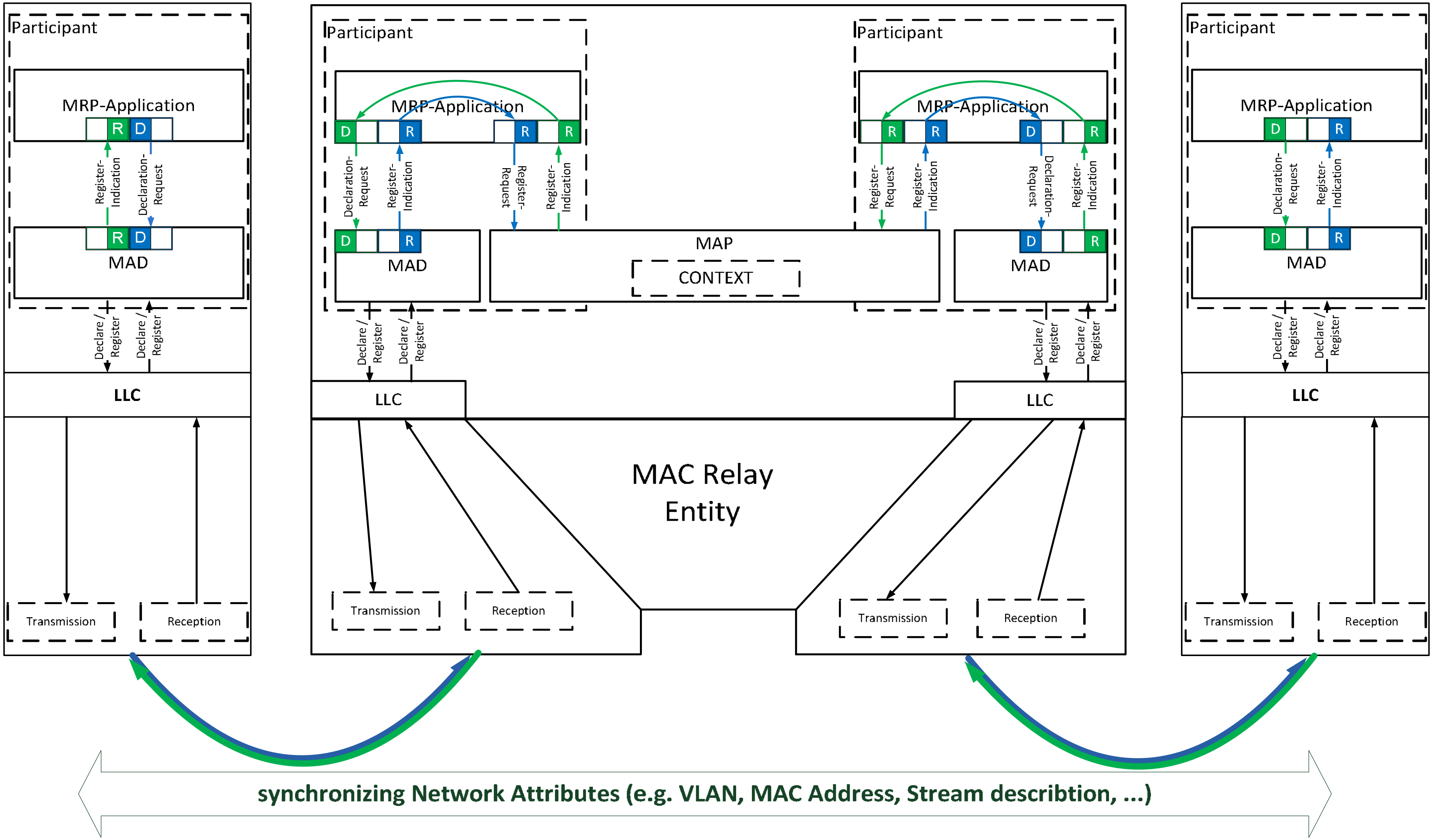
Properties:

- Attributes get synchronized between links *(ISIS-like on link)*
- Synchronized data is constant (no modification within a Bridge)
- No creation of new Attributes
- Has to scale to larger amount of data (🡐 Fragmentation of PDU is necessary)
- Performance of attribute propagation is not the main focus

Main focus:

- Reliable synchronization of network attributes within an active topology given by a context. (In contrast to ISIS where Attributes are flooded all over the network to everybody)

MRP++ Architecture



synchronizing Network Attributes (e.g. VLAN, MAC Address, Stream describtion, ...)

One Registration Application (out of others) is MSRP (Multiple Stream Registration Protocol)

Used to propagate the static properties of a stream along the path.

Such properties are for example:

- VID
- Max. frame size
- Frame priority
- Rank
- Stream-ID
- Tree-ID (for path)
- Stream destination MAC
- …

Signaling

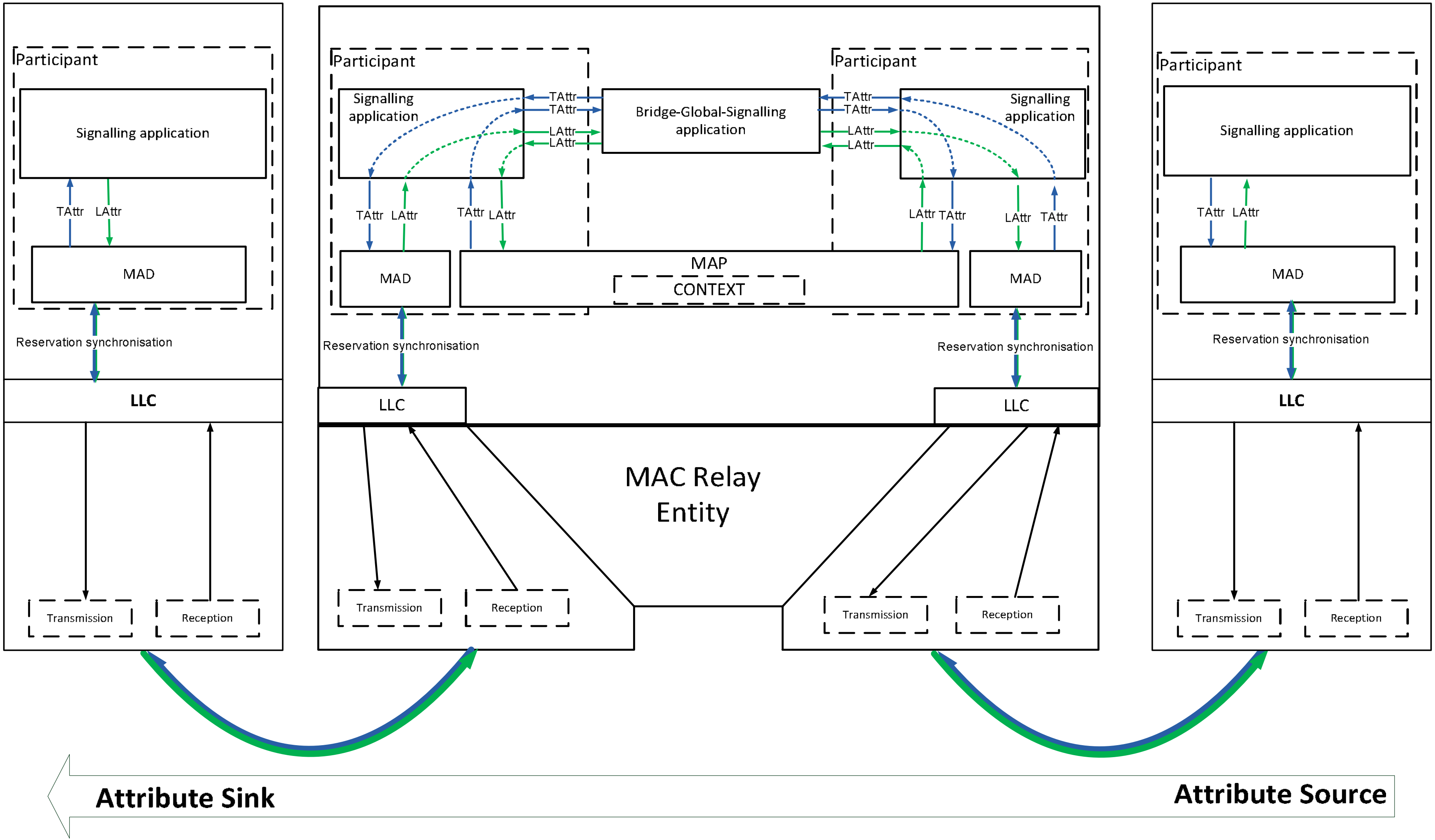
Properties:

- Directed from source to sink
- Attributes can get modified at every Hop
- Changes along the Path between source and sink has to be signaled very fast
- Attribute disappears if source withdraws or times-out
- Beside cyclic Link-To-Link synchronization, event based PDUs are necessary

Main focus:

- End-to-End signaling
- Monitoring the route between source and sink
- Fast signaling of changes along the road to source and sink
- Signal the source and the sink what they get if they go along the route

Basic MSP Architecture



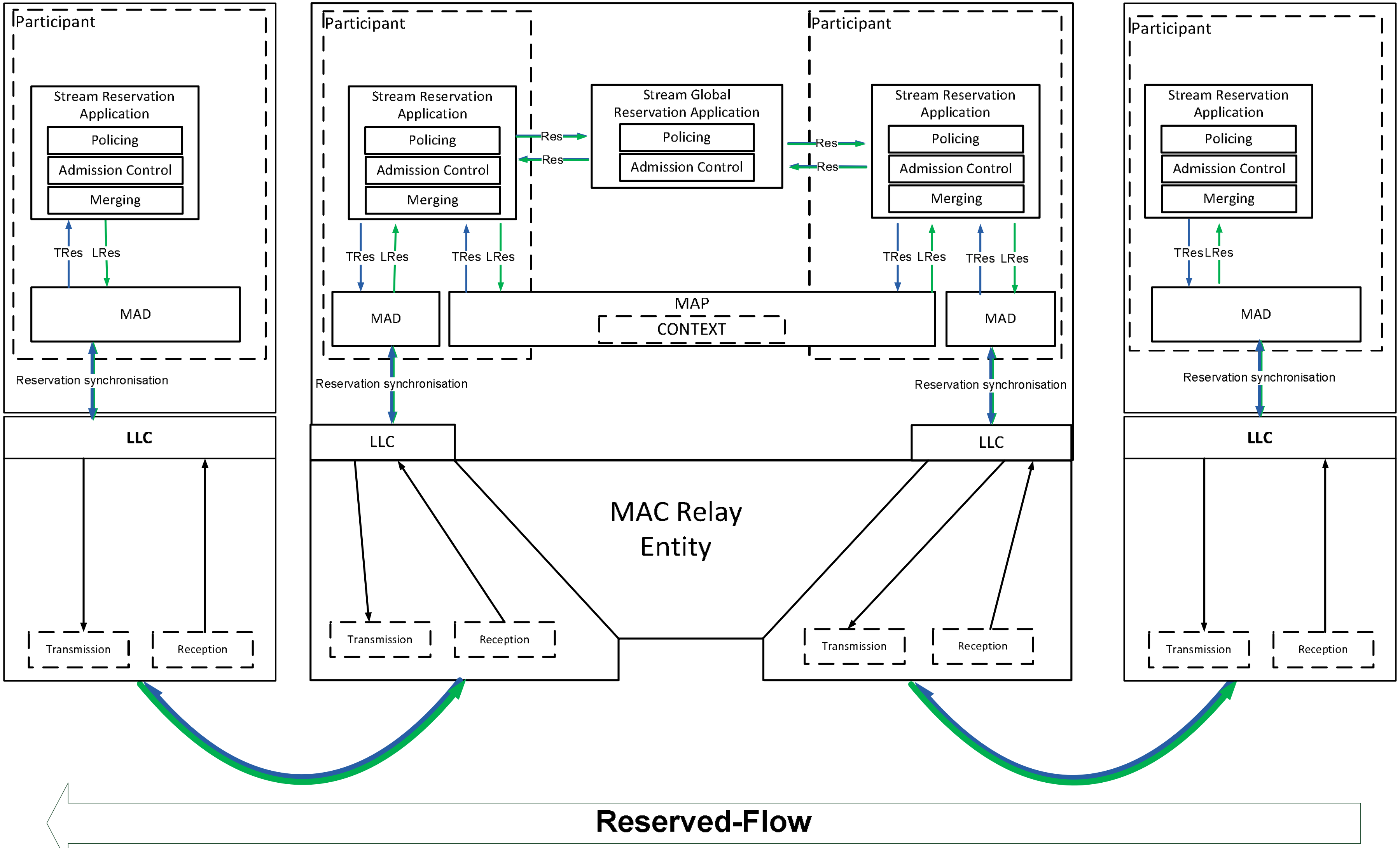
One Signaling Application (out of others) is MSSP (Multiple Stream Signaling Protocol)

Used to:

- propagate the dynamic properties of a stream along the path (Upstream AND Downstream).
  E.g.:
  - Accumulated Latency (Downstream)
  - Required Latency (Upstream)
  - Min. receive Interval (Upstream)
  - Effective receive Interval (Downstream)
  - Stream send state (Ready/Failed) (Downstream)
  - Stream receive state (Ready/Failed/ReadyFailed) (Upstream)

- Use the event based messages to by-pass the slow cyclic Link-To-Link synchronization to signal disruptive events on the path (e.g. Link-Down due to wire break)

MSSP Architecture
(Multiple Stream Signaling based on the MSP-Architecture)



Conclusion for decentralized and centralized Approaches

General

- *Ongoing task in .1Qcc*
  - *Adding to existing MRP data objects for control (TLV's) to support new TSN features like redundancy*
  - *Specifying new Managed Objects which required to configure traffic classes*
- *New work item:*
  - Splitting Registration and Reservation into MRP++ for registration and MSP for reservation

For the "Centralized Network / Distributed User Model" and also for the Fully Centralized Model" there are 4 proposals:

- *Proposal 1 - Using ISIS-PCR also for registration -> will overload ISIS-PCR (scaling issue)!*
- *Proposal 2 - Introducing PCEP for path computing request / response and using MRP++ for "Explicit Tree" registration*
- *Proposal 3 - Supporting "SCHEDULING"*
- *Proposal 4 - Network-Controller with PCE functionality*
- *Proposal 5 - Implementation proposal for the "Fully Centralized Model"*

New Work item for Proposal 2,3,4,5:

- *Standardizing PCEP and its data objects for Ethernet (supporting also optional "Scheduled Traffic") within IEEE 802.1*
- *Splitting MRP and its applications in registration (MRP++) and reservation (MSP)*

=> Discussion: How to proceed?

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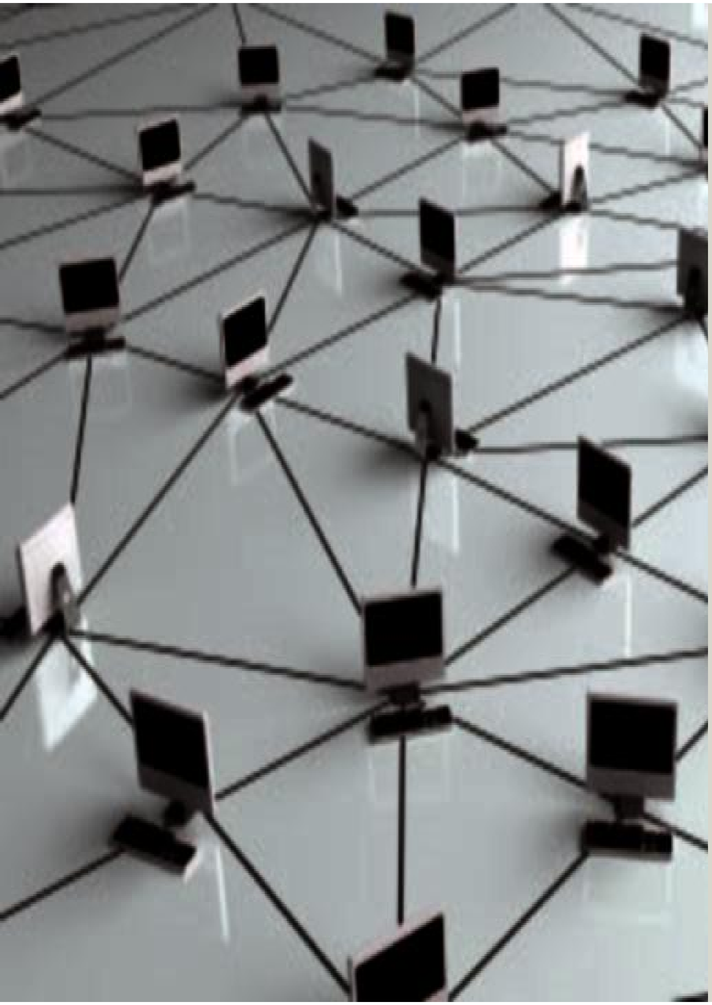

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Next Steps!

ToDo:

- The TSN WG has to look for the best way to support “Scheduled Traffic” by reservation!
- Deliver lower layer interfaces for the relevant IETF protocols!

The TSN WG has to look for the best way to bring the relevant IETF protocols in IEEE 802.1:

relevant IETF protocols			IEEE 802.1 protocol
PCEP	Path Computation Element (PCE) Communication Protocol	RFC 5440	
	Encoding of Objective Functions in the Path Computation Element Communication Protocol	RFC 5541	
	Extensions to the Path Computation Element Communication Protocol (PCEP) for Route Exclusions	RFC 5521	next: PCEP communication between PCE, PCC and PCA
	A Set of Monitoring Tools for Path Computation Element (PCE)-Based Architecture	RFC 5886	
RSVP	Resource ReSerVation Protocol	RFC 2205	today: MRP (MVRP, MMRP, MSRP)
	The Use of RSVP with IETF Integrated Services	RFC 2210	
	Specification of the Controlled-Load Network Element Service	RFC 2211	next: MRP++ (MVRP, MMRP, MSRP, MRRP?)
	Specification of Guaranteed Quality of Service	RFC 2212	next: MSP? (MSSP, ...)

Conclusion:

- The already in IEEE 802.1 defined building blocks include support for decentralized and decentralized organized Ethernet networks.
- There is no need to introduce further models.
- The current .1Qcc draft includes a “Fully Centralized Model”.
  The “Fully Centralized Model” is implicitly already included within the existing IEEE 802.1 building blocks.
- Other organizations are still free to specify further application specific network organization models.

Thank you for your attention!

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Backup

The following slides contain further details!

Motivation splitting Registration and Reservation in MRP++ (MRPv2) and MSP

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Motivation for V2 MRP (Multiple Registation Protocol) and V1 MSP (Multiple Signaling Protocol)

MRP v1		**MRP v2** "transport-protocol" for applications like MVRP, MMRP, MSRP, ...
Pro (also Supported by new Version)	**Cons**	**Features**
Distribution of network attributes over context	No fragmentation - limits the number of attributes. This problem is partly solved by spending one seperate frame for each application or application instance. The disadvantige of the current solution that high computing power is required for serialization and dserialization.	+' Support Fragmentation '+' One MRP frame for all applications (including all attribute lists and states) '+' Sperate checksum for each attribute list
One basic machnism for different applications (MVRP, MMRP,...)	Very complex and intransparent state machines -> difficult to synchronize implementations from different vendors	+' Simplified state machine and synchronization mechanism
Common architecture (aplication-->instance-->attribute)		
	MSRP combines registration and reservation, the attribute size (advertise) is very large and extended the MAP mechanism and introduced four packed events exclusiv for MSRP	+' MSRPv2 is only a registration protocol to register stream attributes (e.g. TSpec, TC, SR-DA, SR-ID, VID, ...)
	The pack mechanism form MRP is not practical (only for special use cases)	+' By introducing fragmentation the packed mechnism is no longer necessary
		+' Extending existing apllications (MVRP, MMRP, MSRP) to support redundancy and seamless redundancy on precalculated trees '+' If necessary add a new application like MRRP
		+' Optional suport for higher layers like IP (e.g. transport higher layer addresses, QoS specifier, ..) by e.g. using TLV's
		+' Managed Objects
		+' TLV's are used to specify the MRP attributes
		+' The mechanism to synchronize the attribute list on a link is compareable to the synchronziation mechanism used by ISIS (ISIS-like)
		MSP ("RSVP like") ("MSP is a seperate transport-protocol" for e.g. stream reservation)
	MSRP combines registration and reservation, the attribute size (advertise) is very large and extended the MAP mechanism and introduced four packed events exclusiv for MSRP	+' MSSP (Multiple Stream Signaling Protocol) is a applicaiton for MSP which is used for stream reservation, e2e signalling and diagnostic. The context, which is required for forwarding the signal / reservation, is either built by MRP or ISIS-PCR
		+' Optional suport for higher layers like IP (e.g. transport higher layer addresses, QoS specifier, ..) by e.g. using TLV's
		+' Managed Objects

Support for more streams. The current worst case limit is less than 500 streams; there are use cases that require two orders of magnitude greater than this.

Support for higher layer streaming sessions, such as Real-Time Protocol (RTP)-based sessions

Deterministic stream reservation convergence -> request for performance

Data model for splitting the existing MSRP to MSRP on MRP++ and MSSP on MSP

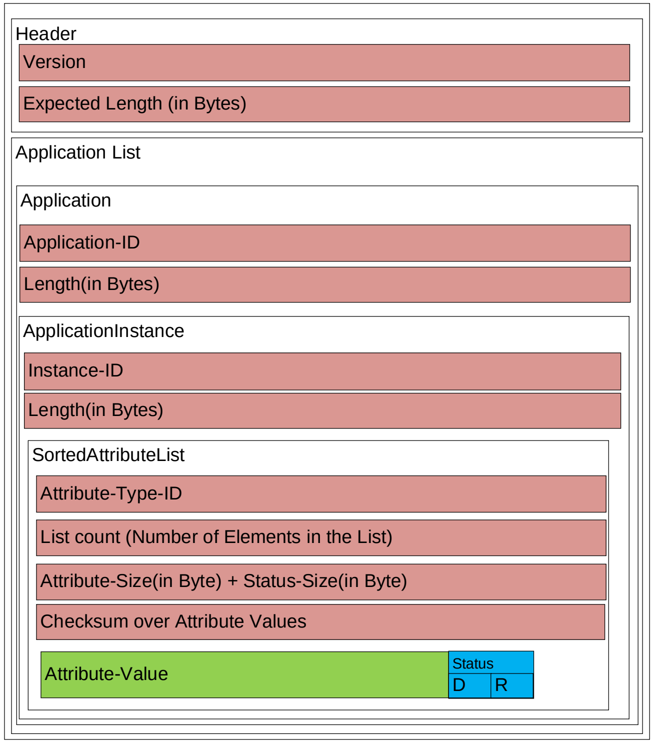
New
Static Information
Dynamic Information

	Talker Advertise		Talker Failed		Listener		Domain
MSRP on MRP	**StreamID**	Talker Sys-ID	**StreamID**	Talker Sys-ID	**StreamID**	Talker Sys-ID	**StreamClassID**
		Unique-ID		Unique-ID		Unique-ID	**StreamClassPriority**
	DataFrameParameters	Dest-Address	**DataFrameParameters**	Dest-Address	**FourPackedEvent**	Ready / ReadyFailed / AskingFailed / Ignore	**StreamClassVid**
		VID		VID			
	Tspec	MaxFrameSize	**Tspec**	MaxFrameSize			
		MaxInterval		MaxInterval			
	PriorityAndRank	DataFramePriority	**PriorityAndRank**	DataFramePriority			
		Rank		Rank			
	AccumulatedLatency	portTxMaxLatency	**AccumulatedLatency**	portTxMaxLatency			
			FailureInformation	BridgeID			
				FailureCode			

	Talker Advertise		Listener		Domain
MSRPv2 on MRP++	**StreamID**	Talker Sys-ID	**StreamID**	Talker Sys-ID	**StreamClassID**
		Unique-ID		Unique-ID	**StreamClassPriority**
	DataFrameParameters	Dest-Address	**Rspec**	MinRecvInterval	**StreamClassVid**
		VID	**Listener ID**	Listener Sys-ID	
	Tspec	MaxFrameSize			
		MaxInterval			
	PriorityAndRank	DataFramePriority			
		Rank			
MSSP on MSP	**StreamID**	Talker Sys-ID	**StreamID**	Talker Sys-ID	
		Unique-ID		Unique-ID	
	AccumulatedLatency (Calculated downstream)	portTxMinLatency	**RequiredLatency (Calculated upstream)**	portRxMinLatency	
		portTxMaxLatency		portRxMaxLatency	
	State	ok?	**AccumulatedRspec**	AccMinRecvInterval	
	List<FailureInformation>	BridgeID	**State**	Ready / ReadyFailed / Failed	
		FailureCode	**List<FailureInformation>**	BridgeID	
				FailureCode	

MRP++ Frame Format

Frame:



Header

Version

Expected Length (in Bytes)

Application List

Application

Application-ID

Length(in Bytes)

ApplicationInstance

Instance-ID

Length(in Bytes)

SortedAttributeList

Attribute-Type-ID

List count (Number of Elements in the List)

Attribute-Size(in Byte) + Status-Size(in Byte)

Checksum over Attribute Values

Attribute-Value

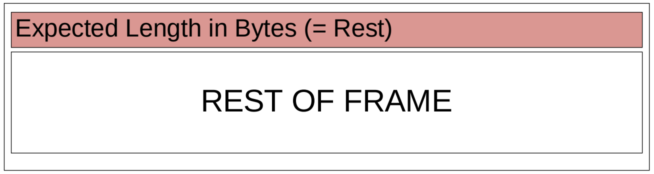
Status

D R

MRP-PDU	→ Header, ApplicationList
Header	→ Version, ExpectedLength
Version	→ UINT8
ExpectedLength	→ Length
Length	→ UINT16
ApplicationList	→ Application*
Application	→ ***ApplicationId***,Length,ApplicationInstance*
ApplicationId	→ ID
ID	-> UINT8
ApplicationInstance	→ InstanceID,Length,SortedAttributeList*
InstanceID	→ UINT16
SortedAttributeList	→ ListHeader,ListBody
ListHeader	→ ***AttTypeId***,ListCount,***AttributeSize,***Checksum
AttTypeId	→ ID
ListCount	→ UINT8
AttributeSize	→ UINT8
Checksum	→ Fletcher-16
ListBody	→ Attribute*
Attribute	→ Value,State
Value	→ ***Attribute value defined by Application***
State	→ Declarator, Registrar
Declarator	→ BIT
Registrar	→ BIT

Red: TBD(unsure)
Green: Defined By Application
**** := 0 - N***

Fragment:



Expected Length in Bytes (= Rest)

REST OF FRAME