Cut-Through Forwarding (CTF): Towards an IEEE 802.1 Standard

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Introduction

Proposed Activities

1) IEEE 802 Nendica: Already ongoing

- Discuss administrative and detailed technical aspects of potential lower layer modelling across IEEE 802.3 and IEEE 802.1 with support for CTF.
- Requires sufficient need/interest in IEEE WG 802.1 and IEEE WG 802.3 to work on such a modelling.

2) IEEE WG 802.1: Proposed

- Motion to develop PAR&CSD for an IEEE 802.1 project to standardize CTF as standalone IEEE 802.1 standard (not amendments to 802.1 Standards). Proposed items included in a scope:
  - Support for IEEE Std 802.3-2018 compatible ***real implementations***.
  - Incorporate/standardize IEEE 802.1 aspects of a joint model across IEEE WG 802.1 and 802.3 with support for CTF, if such a ***model*** becomes available during the proposed IEEE 802.1 Stds development project.

3) IEEE 802 Nendica/IEEE WG 802.1: Now … before the proposed motion in item 2)

- Discuss individual contributions that may support the aforementioned motion, and may be considered during development of the PAR&CSD [item 2)] by IEEE WG 802.1.

Note: IEEE 802 Nendica appears to be a good place for item 3), but this may be discussed due ongoing discussion on the processes between IEEE 802 Nendica and IEEE WG 802.1.

A closer Look

Proposal to IEEE WG 802.1

- Motion to develop PAR&CSD for an IEEE 802.1 project to standardize CTF as standalone IEEE 802.1 standard (not amendments to 802.1 Standards).

- Proposed items included in a PAR scope:
  1. Support for IEEE Std 802.3-2018 compatible ***real implementations***.
  2. Incorporate/standardize IEEE 802.1 aspects of a joint model across IEEE WG 802.1 and 802.3 with support for CTF, if such a ***model*** becomes available during the proposed IEEE 802.1 Stds development project.

A clear specification of CTF in the scope of IEEE WG 802.1 appears technically feasible.

- Of course not the entire proposed scope…
- **Options** allowed by scope, although **not** pre-conditions/requirements for the suggested 802.1 Stds development project.

Difference may be small, but worth to talk about (figuratively):

"A MAC …"

v.s.

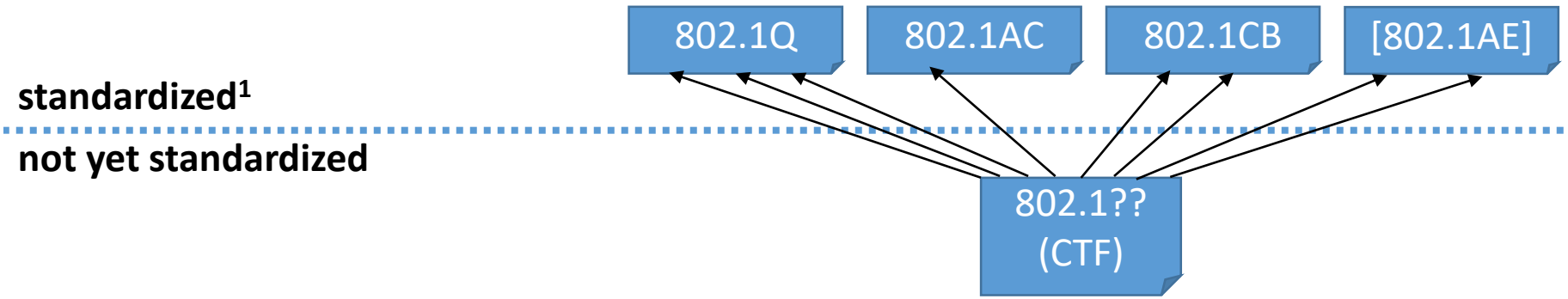
"A MAC with the externally visible behavior specified in IEEE Std 802.3-2018…"

- If both WGs see the technical need to drive this, the model should become part of a running IEEE WG 802.1 project!
- The other way around, decisions documented in associated IEEE 802.1 Stds drafts could be helpful input for development of such a model.
- **IEEE 802 Nendica – contributions are welcome!**

CTF as a standalone 802.1 Standard, not amendments to existing 802.1 standards

See also https://mentor.ieee.org/802.1/dcn/21/1-21-0037-00-ICne-ieee-802-tutorial-cut-through-forwarding-ctf-among-ethernet-networks.pdf

Recap: Proposed Location in IEEE 802.1 Standards

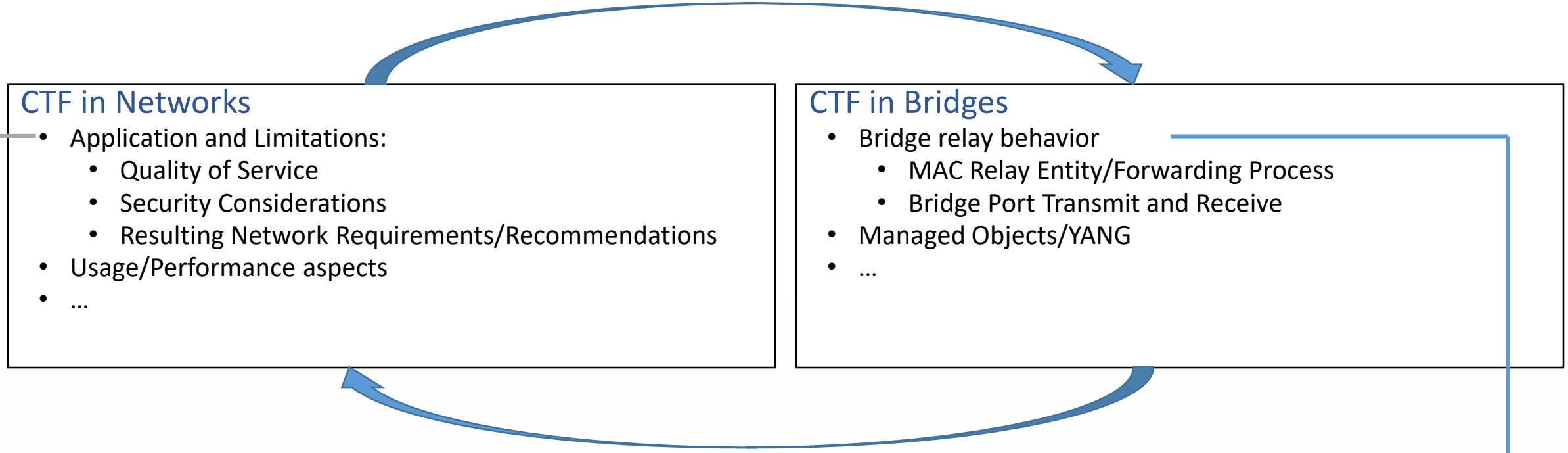


Separate stand alone IEEE 802.1 base standard for CTF

- **Single document**
  Avoids distribution of CTF across existing standards (compared to multiple amendment projects).
- **Exclusion, inclusion/re-use and adjustment of existing protocols**
  - Existing protocols not referred to are basically beyond specification.
  - <u>If no adjustments for CTF are needed:</u>
    Inclusion by reference (e.g., *"as specified in x.y.z of IEEE Std 802.1Xxx-20XX"*) can be sufficient.
  - <u>If adjustments for CTF are needed:</u>
    - Additional description of the differences can be sufficient.
    - Adjustments apply for CTF only; no side effects on existing protocols in absence of CTF support.

1) The latest published base standards, corrigenda, and a subset of the published amendments.

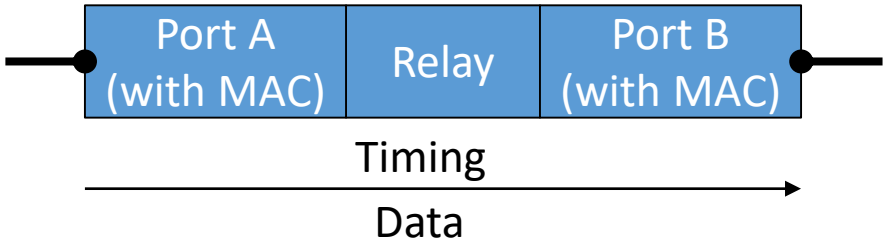
Recap: Proposed Content Categories and (some) Contents



See https://mentor.ieee.org/802.1/dcn/21/1-21-0037-00-ICne-ieee-802-tutorial-cut-through-forwarding-ctf-among-ethernet-networks.pdf

On the next slides

Aspects of externally visible Behavior
(on the relevant path from frame reception to frame transmission)



Two types of aspects define the externally visible behavior of a bridge

1. Data

- What data goes into a bridge, and comes out of the bridge?
  - Ports: What data in frames is transmitted by a Port B, as a result of data in frames received on a Port A?
  - Management: What are the management interfaces, and how can management parameters change/be set?

2. Timing

- When are frames transmitted at a Port B as a result of frame reception at a Port A?

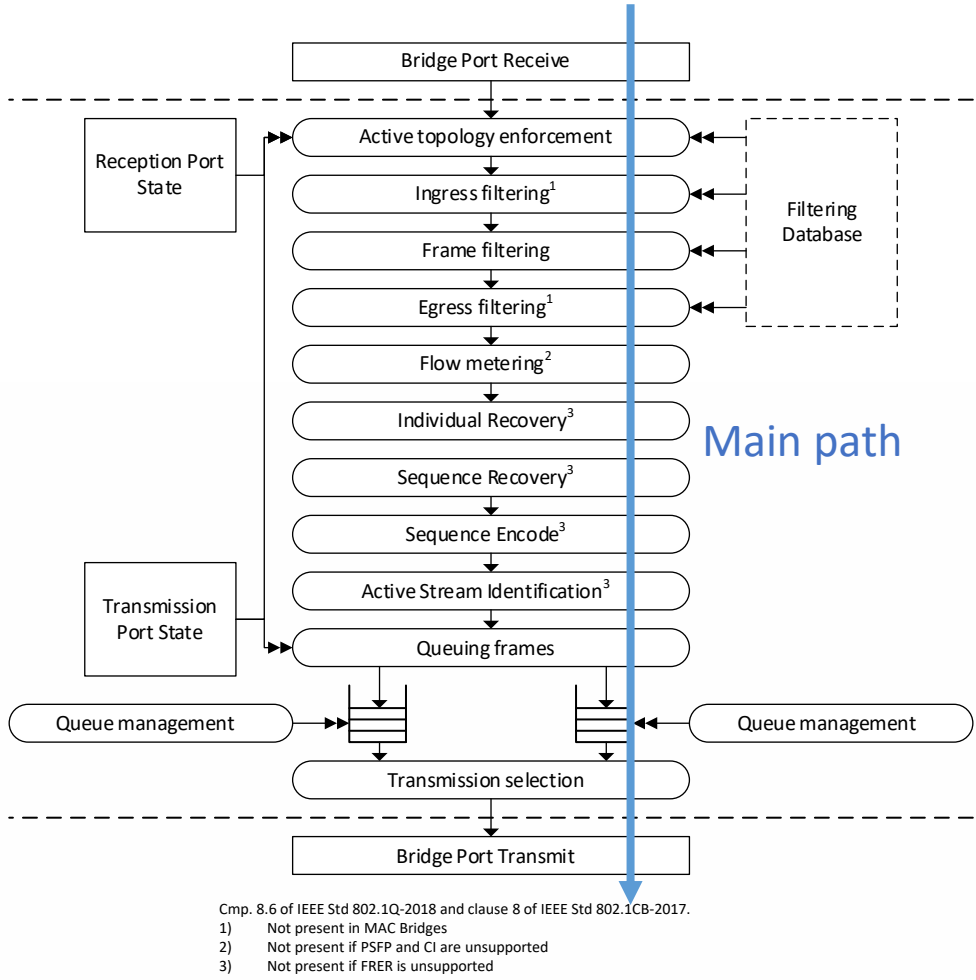
Recap: CTF in Bridges - Relay with CTF Support

Coexistence of CTF & S&F

- **Traffic separation**
  - Decoded priority (VLAN-Tags, IPV assignment)
  - Ports/traffic classes (FDB & decoded priority)
- **Enabling/disabling CTF**
  - Per reception port (the entire port)
  - Per transmission port per traffic class

The standardized model extended

- **Flow**
  (Incomplete) frames pass through processing stages, remain visible to earlier stages.
- **Stalls (incomplete frames)**
  Waiting for more data of an incomplete frame before passing it to the next stage.
- **Stall until completed (incomplete frames)**
  Stalling incomplete frames until completed before passing it to the next stage → Fallback to S&F
- **Late errors (incomplete frames)**
  - Causes (earlier stage)
  - Handling (same or later stage)



Cmp. 8.6 of IEEE Std 802.1Q-2018 and clause 8 of IEEE Std 802.1CB-2017.
1) Not present in MAC Bridges
2) Not present if PSFP and CI are unsupported
3) Not present if FRER is unsupported

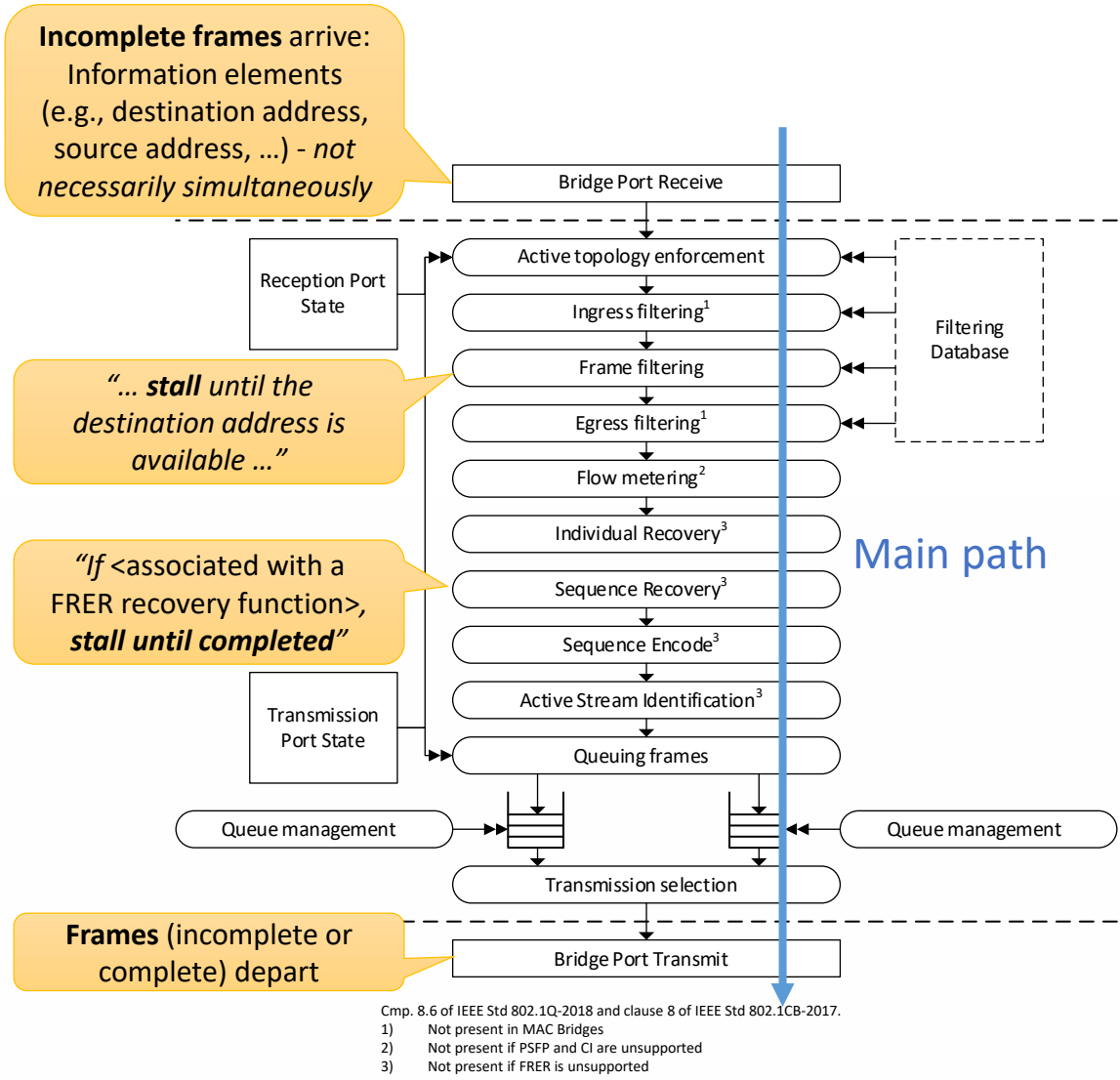
CTF in Bridges: Data and Flow of the Model Illustrated

Upfront: Relevant implications of an IEEE 802.1 standalone Standard for CTF

- **No** (***full***) conformance with IEEE Stds 802.1Q, 802.1AC, etc. required.
- ***Partial*** re-use of elements from existing IEEE 802.1 Stds is reasonable (e.g., individual data transformations), omitting others is possible (e.g., MAC service definition without ISO/IEC 10731 service primitives, handle information elements in frames individually, both)

Resolution of Information Elements

- Information elements of (incomplete) frames at the resolution necessary for the behavior in stages.
  → Keep definitions at a minimum.
- It may be discussed in detail if higher resolution (e.g., octets) are helpful/needed …
- … it likewise appears that such detailed discussions can/should happen during a potential IEEE 802.1 Stds development project according to the defined process.



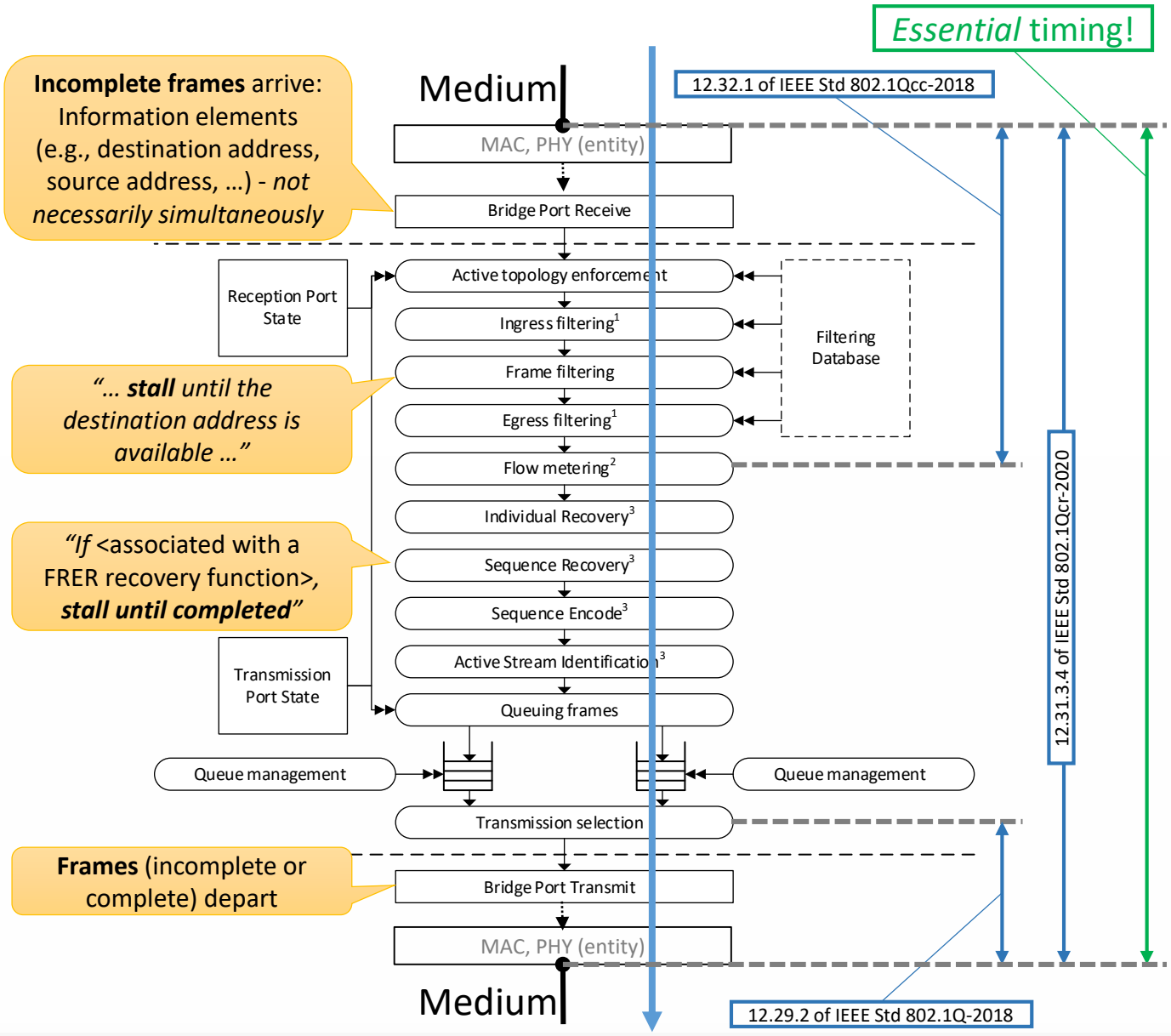
Timing

Essential Timing

- Required for clear specification of the externally visible behavior on the path *medium → bridge → medium* with CTF.

Can it be specified in an IEEE 802.1 Std?

- An IEEE 802.1 Std is the right place to do this:
  - A perception of this timing only exists if there is "*something*" (i.e., bridge) between the network media.
  - ➢ For S&F Bridges, the essential timing (and more) is found in existing 802.1 standards.



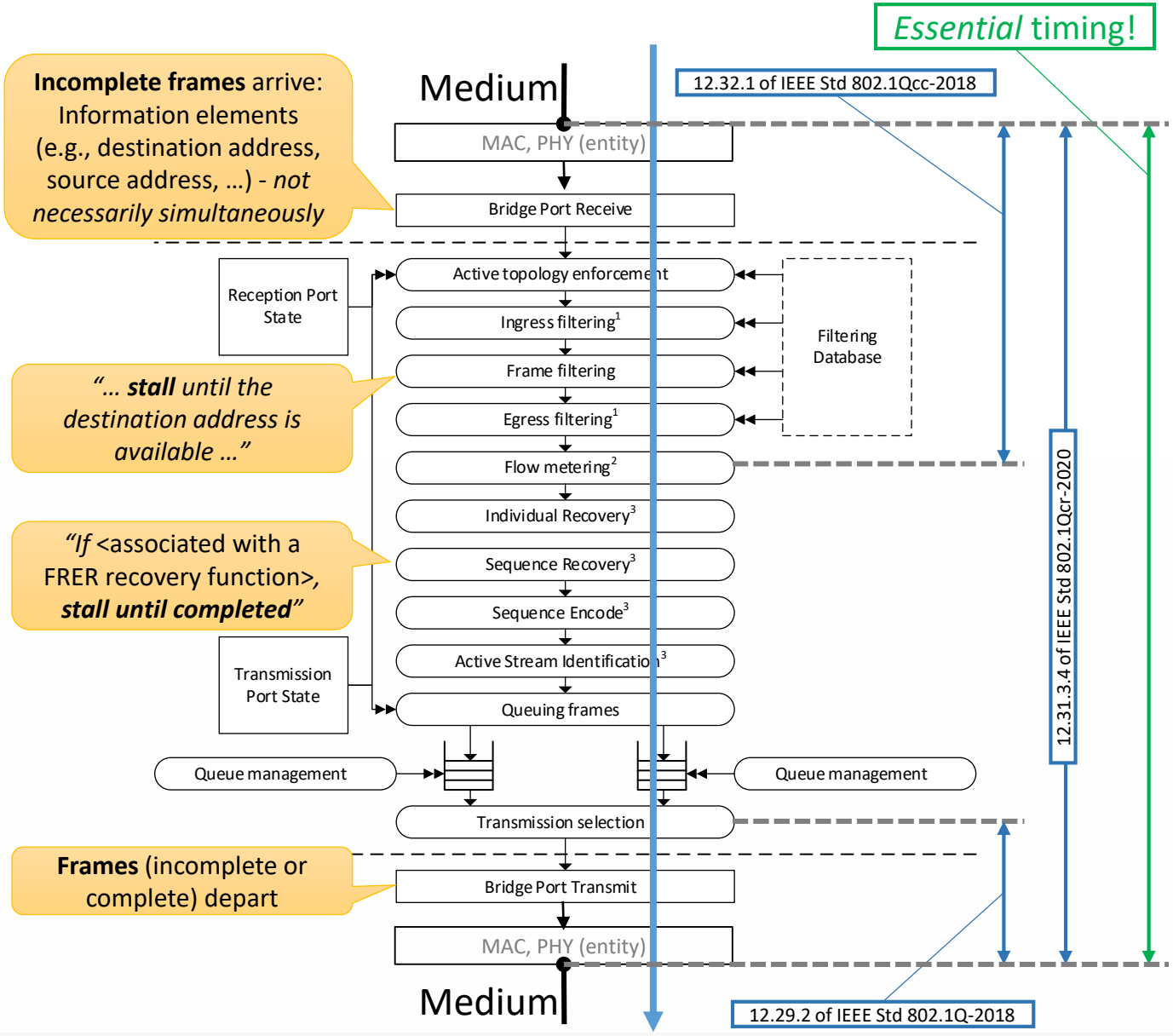
Intermediate Discussion

Technical questions

- Fundamentally missing elements that prevent clear specification of the behavior of a bridge with support for CTF?
- Items beyond the scope of IEEE WG 802.1?

Non-technical questions

- Comments for getting a better impression about the “for and against” of standardizing CTF?
- Other non-technical aspects?



How could core elements of PAR&CSD look like?

Important:

This slide set is an individual contribution, not an official statement of IEEE 802 or IEEE 802.1. At the date of this slide set, IEEE WG 802.1 is not authorized to develop PAR&CSD for the proposed project. In the case such authorization becomes available, IEEE WG 802.1 may or may not consider individual contributions for development.

Individually contributed PAR&CSD proposals (1)

PAR/Approximate number of people expected to be actively involved in the development of this project [5.1]

30

PAR/Scope [5.2]

This standard specifies usage and operation of Bridges with support for Cut-Through Forwarding (CTF) that interconnect individual Local Area Networks (LANs) connected by different or identical media access control methods.

The project allows for integration of a detailed model for internal interaction between Bridges with support for CTF and future 802 MAC standards, although completion of this project does not depend on such a model.

Individually contributed PAR&CSD proposals (2)

PAR/Is the completion of this standard dependent upon the completion of another standard? [5.3]

No.

PAR/Purpose [5.4]

Bridges with support for CTF, as specified by this standard, allow the compatible interconnection of information technology equipment attached to separate individual LANs.

PAR/Need [5.5]

Support for CTF is found in real Bridge implementations, but is not standardized by an IEEE 802.1 Standard. The existing IEEE 802.1 Standards do not permit support for CTF. This project complements the existing IEEE 802.1 Standards and allows interoperability of CTF Bridge implementations.

Individually contributed PAR&CSD proposals (3)

CSD/Managed objects [1.1.1]

This project will use method a).

CSD/Coexistence [1.1.2]

This project is not a wireless project; therefore, the CA document is not applicable.

Individually contributed PAR&CSD proposals (4)

CSD/Broad Market Potential/Broad sets of applicability [item a) in 1.2.1]

CTF is already widely used in Industrial Automation installations and Data Center Networks. Standardizing CTF can be an enabling technology for a wide range of Pro A/V applications.

CSD/Broad Market Potential/Multiple vendors and numerous users [item b) in 1.2.1]

Existing products of multiple Bridge vendors support CTF, but interoperability is limited. Standardizing CTF is an opportunity for existing and new use cases of this technology in Industrial Automation systems high performance computing data center applications, Pro A/V applications such as concert venues, theatres, conference centers, corporate buildings, casinos, hotels, theme parks, cruise ships, sport venues and beyond.

Additional material: https://mentor.ieee.org/802.1/dcn/21/1-21-0037-00-ICne-ieee-802-tutorial-cut-through-forwarding-ctf-among-ethernet-networks.pdf.

Individually contributed PAR&CSD proposals (5)

CSD/Compatibility/Will the proposed standard comply with IEEE Std 802, IEEE Std 802.1AC and IEEE Std 802.1Q? [item a) in 1.2.2]

No, there will be variances in conformance, as disclosed in https://mentor.ieee.org/802.1/dcn/21/1-21-0051-02-ICne-ctf-discussing-next-steps.pdf for reviewing with IEEE 802.1 WG.

This project will not modify the definitions of IEEE Std 802.1AC, as used by various IEEE 802 MAC standards. Conformance of existing implementations complying to IEEE Std 802, IEEE Std 802.1AC and IEEE Std 802.1Q remains unaffected.

Individually contributed PAR&CSD proposals (5)

CSD/Compatibility/ If the answer to a) is no, supply the response from the IEEE 802.1 WG [item a) in 1.2.2].

<TBD: Response from IEEE WG 802.1>

CSD/Distinct Identity [1.2.3]

No other IEEE 802 standard or project defines support for CTF in Bridges and Bridged Networks.

CSD/Technical Feasibility/Demonstrated system feasibility.[item a) in 1.2.4]

System feasibility is demonstrated by existing Industrial Automation Installations and Data Center Networks.

CSD/Technical Feasibility/Proven similar technology via testing, modeling, simulation, etc.[item b) in 1.2.4]

CTF in Bridges is proven by existence of products implementing similar technology.

Support for real implementations of IEEE Std 802.3-2018 possible?

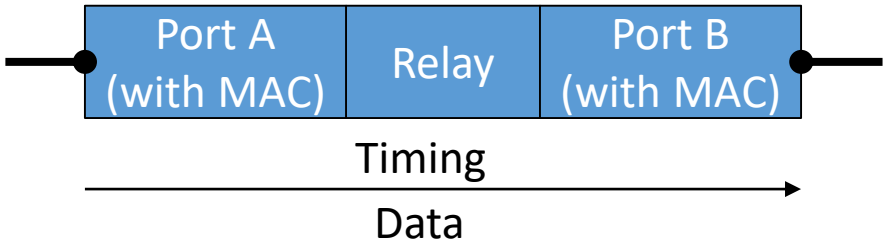
Considerations with the focus on externally visible behavior

Model v.s. Implementations (1)

It is important to distinguish, however, between the model and a real implementation. The ***model*** *is* ***optimized for simplicity and clarity*** *of presentation, while any realistic* ***implementation*** *shall place heavier* ***emphasis on*** *such constraints as* ***efficiency and suitability*** *to a particular implementation technology or computer architecture.* [4A.2.2 of IEEE Std 802.3-2018, "Overview of the Procedural Model"]

… ***it is the behavior of any MAC sublayer implementations that shall match the standard****, not their internal structure. The internal details of the procedural model are useful only to the extent that they help specify that behavior clearly and precisely.* [item b) in 4A.2.2.1 of IEEE Std 802.3-2018, "Ground rules for the procedural model"]

Model v.s. Implementations (2)



Model

The handling of incoming and outgoing frames is rather stylized in the procedural model, in the sense that ***frames are handled as single entities*** *by most of the MAC sublayer and are only serialized for presentation to the Physical Layer.* [item c) in 4A.2.2.1 of IEEE Std 802.3-2018, "Ground rules for the procedural model"]

Implementations

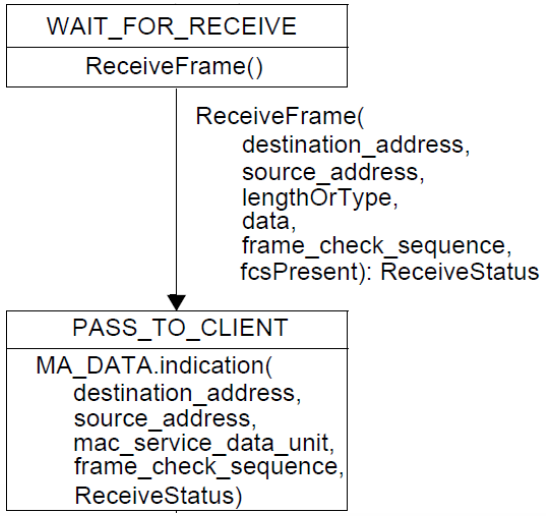
In reality, ***many implementations will instead handle frames serially on a bit, octet or word basis****. This approach has not been reflected in the procedural model, since this only complicates the description of the functions without changing them in any way.* [item c) in 4A.2.2.1 of IEEE Std 802.3-2018, "Ground rules for the procedural model"]

Observations & Considerations

- MAC *implementations* that handle frames serially appear conformant to IEEE Std 802.3-2018.
- Serial handling fits well to the concept around "incomplete frames" proposed on earlier slides.
- Aspects of the data behavioral that appear important to look at (only "fast path" in a bridge):
  1. Port A: Is it possible to access frame contents in the relay in presence FCS errors?
  2. Port B: Is it possible to send FCS errors forwarded by the relay (i.e., no unintended "repair")?

Note: Less than minFrameSize octets appears likewise important, but is not in focus of this slide set (see also https://mentor.ieee.org/802.1/dcn/21/1-21-0058-01-ICne-ctf-forwarding-timing-in-industrial-automation.pdf).

Data: Receive Path



Source: Figure 4A-4 of IEEE Std 802.1-2018

From 4A.2.9 of IEEE Std 802.3-2018

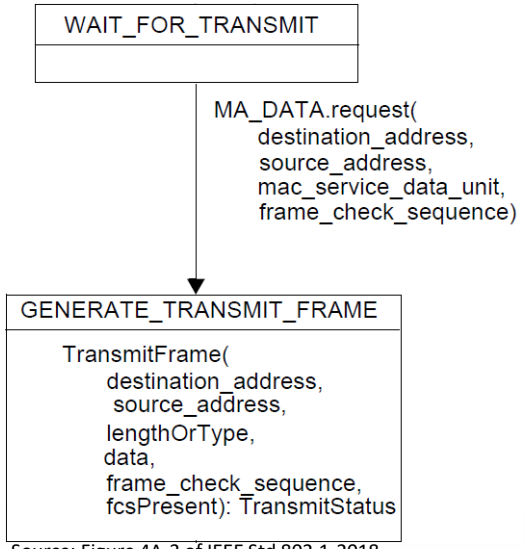
procedure ReceiveLinkMgmt;
begin
  repeat
    StartReceive;
    ***while* receiving *do* nothing; {Wait for frame to finish arriving}**
    excessBits := frameSize *mod* 8;
    frameSize := frameSize – excessBits; {Truncate to octet boundary}
    receiveSucceeding := (frameSize ≥ minFrameSize) {Reject frames too small}
  until receiveSucceeding
end; {ReceiveLinkMgmt}

From 4A.2.9 of IEEE Std 802.3-2018

function **ReceiveFrame** (
  ...
  function ReceiveDataDecap: ReceiveStatus; {Nested function; see body below}
...
function ReceiveDataDecap: ReceiveStatus;
…
  receiveSucceeding := LayerMgmtRecognizeAddress(destinationField);
  if* receiveSucceeding *then
  begin {Disassemble MAC frame}
    destinationParam := destinationField;
    sourceParam := sourceField;
    lengthOrTypeParam := lengthOrTypeField;
    dataParam := RemovePad(lengthOrTypeField, dataField);
    fcsParamValue := fcsField;
    fcsParamPresent := passReceiveFCSMode;
    …
    if exceedsMaxLength *then* status := frameTooLong
    else if fcsField = CRC32(incomingFrame) *then*
    if validLength *then* status := receiveOK *else* status := lengthError
    else if excessBits = 0 *then* status := **frameCheckError**
    else status **:= alignmentError**;
  …
  ReceiveDataDecap := status
end; {ReceiveDataDecap}

→ It seems that contents of valid and **several types of invalid frames <u>including frames with invalid FCS</u>,** are transferred to MAC clients (e.g., Relay) other than MAC control and LLC (see also 3.4 of IEEE Std 802.3-2018).

Data: Transmit Path



Source: Figure 4A-3 of IEEE Std 802.1-2018

From 4A.2.8 of IEEE Std 802.3-2018

```
process BitTransmitter;
begin {Inner loop}
...
  while transmitting do
  begin
    TransmitBit(outgoingFrame[currentTransmitBit]);
    currentTransmitBit := currentTransmitBit + 1;
    transmitting := (currentTransmitBit ≤ lastTransmitBit)
  end
...
```

From 4A.2.8 of IEEE Std 802.3-2018

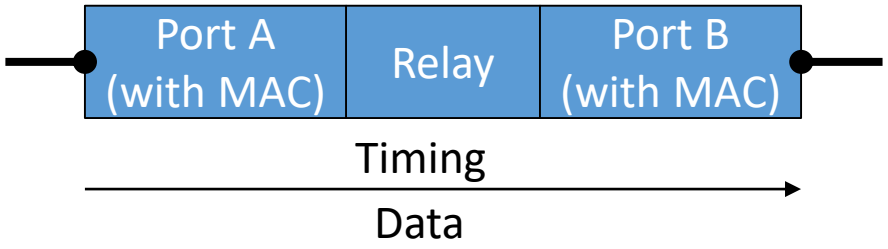
```
function TransmitFrame (
  destinationParam: AddressValue;
  sourceParam: AddressValue;
  lengthOrTypeParam: LengthOrTypeValue;
  dataParam: DataValue;
  fcsParamValue: CRCValue;
  fcsParamPresent: Bit): TransmitStatus;
  procedure TransmitDataEncap; {Nested procedure; see body below}
  begin
    if transmitEnabled then
    begin
      TransmitDataEncap;
      TransmitFrame := TransmitLinkMgmt
...
```

From 4A.2.8 of IEEE Std 802.3-2018

```
procedure TransmitDataEncap;
begin
  with outgoingFrame do
  ...
  destinationField := destinationParam;
  sourceField := sourceParam;
  lengthOrTypeField := lengthOrTypeParam;
  if fcsParamPresent then
  begin
    dataField := dataParam; {No need to generate pad if the FCS is passed from MAC client}
    fcsField := fcsParamValue {Use the FCS passed from MAC client}
...
```

→ It seems that contents of **frames from a MAC client, including frames with invalid FCS,** are transmitted.

Intermediate Discussion



Discussion

- It seems both, the transmit and the receive path of IEEE 802.3 Std conformant MAC implementations allow exchange of frames with invalid FCS between a MAC client (relay) and a PHY entity.
- The simplified MAC (clause 4A of IEEE Std 802.3-2018) has been considered, but the same observation appears valid for the CSMA/CD MAC (clause 4 of IEEE Std 802.3-2018).
- Not mentioned in the slides before were error counters on the receive path (this is nothing new) …
- … but there may be other implications, for example, during transmission.
- Should IEEE WG 802.3 be asked for having a look at invalid FCS'?

Summary & Conclusions

Summary & Conclusion

Proposed to IEEE WG 802.1

- Motion to develop PAR&CSD for an IEEE 802.1 project to standardize CTF as standalone IEEE 802.1 standard (not amendments to existing 802.1 Standards).

Technical Contents in this Slide Set

- An approach for clear specification of bridge behavior with support for CTF appears feasible and in scope of IEEE WG 802.1.
- Considerations on the option to refer to implementations of IEEE Std 802.3-2018 in a potential IEEE 802.1 standard for CTF.

Contributions related to PAR&CSD

- If appropriate, the author is happy to prepare and present individual contributions, independent of whether IEEE 802.1 would consider such contributions during a potential future PAR&CSD development or not.

Thank you for your Attention!

Questions, Opinions, Ideas?

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