Cut-Through Forwarding (CTF) in Bridges and Bridged Network – Considerations on Modelling, Compatibility and Locations

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Introduction

- The discussion on April 27, 2022 based on contribution https://www.ieee802.org/3/ad_hoc/ngrates/public/calls/22_0427/jones_nea_01_220427.pdf provided several insights on understanding different concerns on CTF/the proposed project P802.1DU.
- This slide set
  - summarizes the author's interpretation of the concerns, and thoughts/options on addressing these,
  - is on further discussing and analyzing concerns,
  - is an individual contribution (not a WG statement), and
  - limits on the first topics listed in the following.

Topics and Aspects from April 27

- Topics
  - Main CTF operation – frame transmission start before reception completed
  - Frames with inconsistent FCS
    - Processing by the 802.3 MAC
    - Passing between 802.3 MAC ⇔ MAC Client (bridges in the context of this slide set)
    - “FCS stomp” variations
  - Management counters
  - Options for locating CTF in IEEE 802 WGs and projects
- Aspects
  - Modelling
    - In existing 802 Stds
    - In new 802 Stds for CTF (P802.1DU)
  - Conformance/Compatibility
    - Of existing S&F implementations – related to 1.2.2 of the P802.1DU CSD draft
    - Of existing CTF implementations – no strong relationship to existing 802 Stds

Aspects over Topics

Topic \ Aspect	Modelling: Existing 802 Stds	Modelling: New 802 Stds on CTF	Conformance/Compat.: Existing S&F Impl.	Conformance/Compat.: Existing CTF Impl.
Main CTF operation	X	X	X	[X]
Frames with inconsistent FCS: Processing by 802.3 MACs	X		X	
Frames with inconsistent FCS: Passing between 802.3 MACs ⇔ MAC clients (bridge)	X		X	
Frames with inconsistent FCS: "FCS stomp" variations		X		X
Management counters		X		X
Locating CTF in IEEE 802 WGs/projects		X		

Stds 802, 802.1Q, 802.1AC and MAC Stds (802.3)

-"New Features" for CTF
-No existing 802 Stds
-Only for diagnosis

P802.1DU, MAC WGs?

Main CTF Operation

Main CTF Operation: Introduction

- Author's recollection and interpretation of related concerns discussed:
  1. Changing the 802.3 MAC model could be a huge Stds development task.
     1. The 802.3 MAC, as it is right now, passes frames to higher layers (i.e., Std 802.1AC) as atomic unit after the end of serial reception by the MAC sublayer.
     2. CTF could require serial transfer from MAC sublayer to higher layers.
  2. Existing S&F implementations conformant to IEEE Stds 802, 802.1AC and 802.1Q could be non-conformant/incompatible with P802.1DU.
- Related items presented on April 27 (https://www.ieee802.org/3/ad_hoc/ngrates/public/calls/22_0427/jones_nea_01_220427.pdf)
  - Slide 5
  - Slide 7
  - Slides 8 (except "without error")
  - Slides 9
  - Slide 10 (except "properly formed")
  - Slide 11 (except "without error")
  - Slides 12 and 13

Main CTF Operation: Modelling (1)

- At least two approaches for **modelling** the main CTF operation were presented
  - Modelling limited “as much as possible” to externally visible behavior (e.g., https://www.ieee802.org/1/files/public/docs2021/new-specht-ctf-802-1-1121-v01.pdf)
  - Modelling by look-ahead of frame reception service primitive invocations (https://mentor.ieee.org/802.1/dcn/22/1-22-0015-01-ICne-idealistic-model-for-p802-1du.pdf)
- The second approach, modelling by look-ahead of frame reception service primitive invocations, is considered in the following:
  - Appears good for progressing discussions in the joint NEA/Nendica ad hoc meetings
  - Along the idea of showing potential approaches to address concerns for discussion

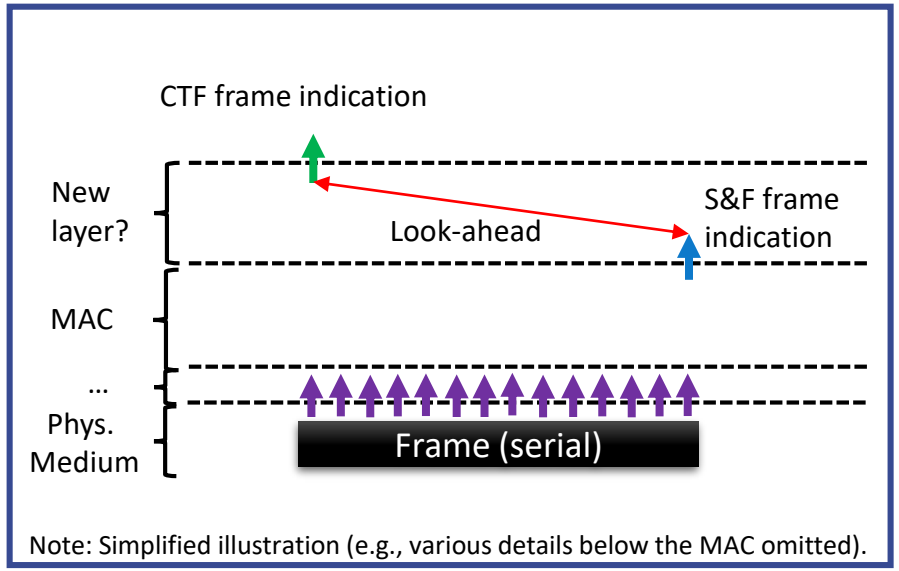
Main CTF Operation: Modelling (2)

- Modelling by look-ahead of frame reception service primitive invocations (https://mentor.ieee.org/802.1/dcn/22/1-22-0015-01-ICne-idealistic-model-for-p802-1du.pdf)
- Summary of the approach
  - Look-ahead of S&F frame indication primitive invocations (i.e., on RX), resulting in new CTF frame indication primitive invocations a frame duration earlier. I.e.:

    → **Atomic (and instantaneous)** invocations on per-frame resolution.

    → **No need for serial transfers from MAC to MAC client at a resolution below frames (e.g., octets)!**
  - Similar look-ahead approaches are found in the models of lower sublayers in IEEE Std 802.3-2018 ["prescient" functions in some PCS clauses, Reconciliation Layer (65.2.3.4.5) and MAC Merge Sublayer (99.4.7.4)]
  - Could be done in P802.1DU (e.g., located on top of where the ISS is in 802.1AC)

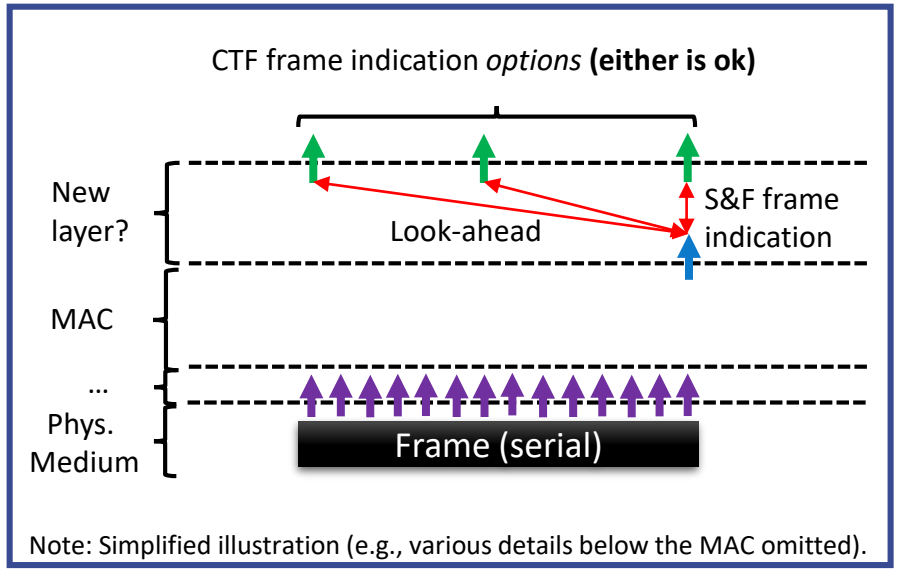
    → **No need for changing the 802.3 MAC!**



Main CTF Operation: Conformance (1)

- <u>Author's Interpretation of the Concern</u>
  As soon as P802.1DU would require bridge implementations to start frame transmission (TX port) prior to completed frame reception (other RX port), existing S&F implementations conformant to IEEE Std 802, IEEE Std 802.1AC and IEEE Std 802.1Q could turn out non-conformant to P802.1DU.
- A technical approach
  - Extend the look-ahead based modelling approach by permitting CTF frame indication primitive invocations within an implementation-dependent range
    - Earliest: The frame duration earlier than the (non-CTF) indication primitive invocation
    - Latest: At the same time as (non-CTF) indication primitive invocation

  → **Conformance of existing S&F implementations**
  (even if frame transmission start prior to compete frame reception is not supported by an existing S&F implementation)

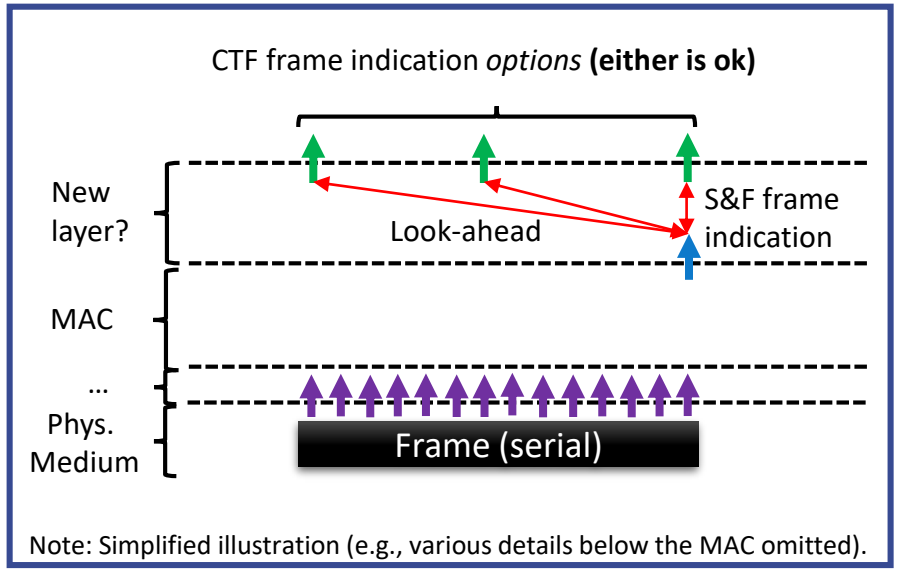


Main CTF Operation: Conformance (2)

- Thoughts on compatibility with IEEE Stds 802, 802.1AC and 802.1Q
  - CTF frame indications earlier than the associated S&F frame indication are like an optional feature of bridge implementations
  - Similar, several amendments to 802.1AC and 802.1Q introduced optional features (e.g., new traffic shapers)

  →**It may be acceptable if WG 802.1 would answer "Yes" in "1.2.2 Compatibility"** of the P802.1DU CSD draft (similar to past amendment projects)

  →**WG 802.1 would be responsible for maintaining compatibility** during development of P802.1DU
- Necessary but not sufficient …
  - The main CTF operation may be the most important topic to with regard to "1.2.2 Compatibility" in CSD drafts of P802.1DU, but not the only one.
  - Achieving "1.2.2 compatibility" = "Yes" by retaining elements as optional features may apply for elements from topics other than the main CTF operation (next slides).



FCS: Processing by 802.3 MACs

FCS: Processing by 802.3 MACs: Introduction

- Author's recollection and interpretation of related concerns discussed:
  - CTF would require the 802.3 full-duplex MAC in to:
    - Accept frames with inconsistent FCS during reception for subsequent processing by MAC clients.
    - Transmit frames from mac clients with passed inconsistent FCS.
  - The processing full-duplex MAC is clearly specified in A4 of 802.3, and does not allow for this.
- Related items presented on April 27
  (https://www.ieee802.org/3/ad_hoc/ngrates/public/calls/22_0427/jones_nea_01_220427.pdf)
  - Slide 10 ("properly formed")
  - Slide 11 ("without error")

FCS: Processing by 802.3 MACs: 4A of 802.3

- References in IEEE Std 802.3
  - 802.3, 4A.2 (precise specification of the full-duplex MAC/Pascal model)
    - 802.3, 4A.2.9 (Frame reception)
      - Received frames with inconsistent FCS result in properly set output variables of function ReceiveFrame(…) with return value/*ReceiveStatus* = *frameCheckError* or *alignmentError* in function ReceiveDataDecap(…)
        The precise specification of the 802.3 full-duplex MAC does not require changes for receiving frames with inconsistent FCS
    - 802.3, 4A.2.8 (Frame transmission)
      - rame transmissions by function TransmitFrame(…) with input variable *frame_check_sequence* set by the MAC client (and *fcsPresent* = *true*) are without further checking whether or not *frame_check_sequence* is consistent

      →**The precise specification of the 802.3 full-duplex MAC does not require changes for transmitting frames with inconsistent FCS**
    - *S*ee also:
      - Slide 61 of https://mentor.ieee.org/802.1/dcn/21/1-21-0037-00-ICne-ieee-802-tutorial-cut-through-forwarding-ctf-among-ethernet-networks.pdf
      - Slide 23ff. of https://mentor.ieee.org/802.1/dcn/21/1-21-0051-07-ICne-ctf-discussing-next-steps.pdf

→No change of the 802.3 full-duplex MAC precise specification required for processing frames with inconsistent FCS.

FCS: Passing between 802.3 MACs ⇔ MAC clients (bridge)

FCS: Passing between MAC ⇔ MAC clients: Introduction

- Author's recollection and interpretation of related concerns discussed:
  - 802.1 AC, 11.1 Only frames with consistent FCS cause MUNITDATA indications.
  - 802.3, 2.3.2.3: MA_DATA indications are only reported to MAC clients with consistent FCS ("received without error") according to 2.3.2.3:

    Such frames are reported only if they are validly formed, received without error, and their destination address designates the local MAC entity.
  - 802.3, 4A.2.9 is defining frame errors (recap).
- Related items presented on April 27
  (https://www.ieee802.org/3/ad_hoc/ngrates/public/calls/22_0427/jones_nea_01_220427.pdf)
  - Slide 6
  - Slide 10 ("properly formed")
  - Slide 11 ("without error")
  - Slide 12
  - Slide 13

FCS: Passing between MAC ⇔ MAC clients: 802.1AC

- P802.1DU (new base standard) could deviate from 802.1AC with regard to the definition frames with error, but it seems this is not needed.
- 802.1AC, 11.1
  - *Each M_UNITDATA indication corresponds to the receipt of an **error-free** MAC frame from a LAN*

  → No M_UNITDATA indication for frames in error
- … 802.1AC, 2nd paragraph in clause 13
  - *All **error-free received user data frames** give rise to M_UNITDATA indication primitives. A **frame that is in error, as defined by the relevant MAC specification**, is discarded by the MAC entity without giving rise to any M_UNITDATA indication.*

  →Definition of "frame in error"/"error free frame" per MAC standard (e.g., 802.3), <u>not</u> 802.1AC

FCS: Passing between 802.3 MACs ⇔ MAC clients: 802.3

From 2.3.2.3 of 802.3: *Such frames are reported only if they are validly formed, received without error, and their destination address designates the local MAC entity.*

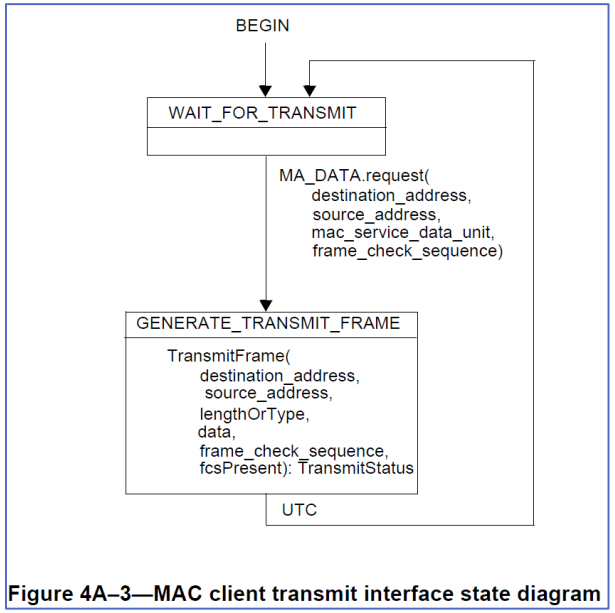


Figure 4A–3—MAC client transmit interface state diagram

Source: IEEE Std 802.3-2018

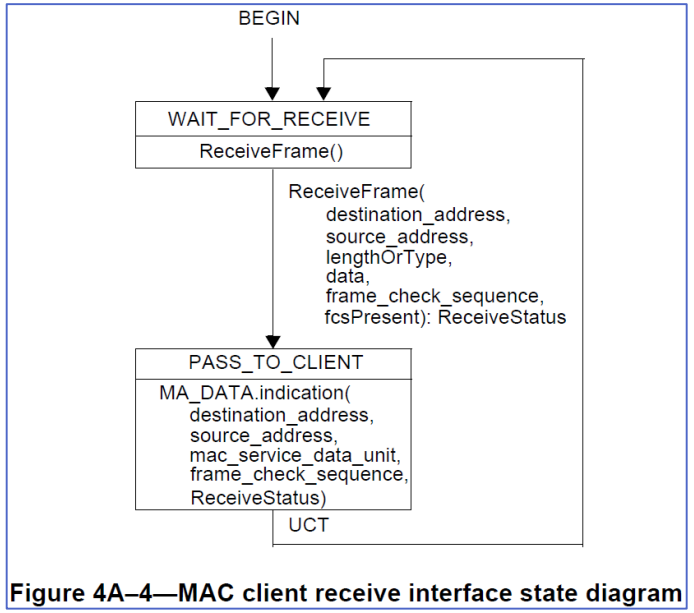


Figure 4A–4—MAC client receive interface state diagram

Source: IEEE Std 802.3-2018

- Recap (prev. slides):
  - *Allowing 0-time between M_UNITDATA indication and CTF frame indication would allow conformance of P802.1DU and existing S&F implementations*
  - *No change of the 802.3 full-duplex MAC precise specification required for processing frames with inconsistent FCS.*

→ **Clarification desirable (802.3WG):**

- Is 4A.2.9 defining “received without error” (i.e., excludes frames with inconsistent FCS)or is there another definition meant in 2.3.2.3 of 802.3?
- Is the statement from 2.3.2.3 in conflict with the precise specification of the 802.3 full-duplex MAC/what is the relationship between both?
- Does 2.3.2.3 apply for Bridges at all (due to “destination address designates the local MAC entity”)?
- Are there other statements in 802.3 (outside of 4A) similar to the one in 2.3.2.3?

→ **Does not matter at all for case 0-time between M_UNITDATA indication and CTF frame indication:**

→ Even if frames with inconsistent FCS would be included in “frames in error”, CTF frame indication and M_UNITDATA indication **could be 100% identical**

Summary, Conclusion & Proposals for WG 802.1

Topic \ Aspect	Modelling: Existing 802 Stds	Modelling: New 802 Stds on CTF	Conformance/Compat.: Existing S&F Impl.	Conformance/Compat.: Existing CTF Impl.	
Main CTF operation	X	X	X	[X]	Stds 802, 802.1Q, 802.1AC and MAC Stds (802.3)
Frames with inconsistent FCS: Processing by 802.3 MACs	X		X		
Frames with inconsistent FCS: Passing between 802.3 MACs ⇔ MAC clients (bridge)	X		X		
Frames with inconsistent FCS: "FCS stomp" variations		X		X	-"New Features" for CTF -No existing 802 Stds -Only for diagnosis
Management counters		X		X	
Locating CTF in IEEE 802 WGs/projects		X			P802.1DU, MAC WGs?

Summary & Conclusion

- Modelling a new CTF frame indication by look-ahead,
  at the time of M_UNITDATA.indication or earlier,
  is an approach to realize the main CTF operation in P802.1DU
  - Treats frames as atomic unit
  - Allows CTF, but does not enforce it (allows compatibility of existing S&F implementations with P802.1DU)
  - CTF main operation would be a new optional feature in P802.1DU, but not mandatory
    (like new shapers in 802.1Q)

  →**No change of MAC Stds (802.3) would be mandatory for compatibility to P802.1DU**
- Processing frames with inconsistent FCS
  - The 802.3 full-duplex MAC precise specification does this already

  →**No change of the 802.3 full-duplex MAC precise specification would be required**
- Passing frames with inconsistent FCS between 802.3 full-duplex MAC and MAC client (bridge)
  - The 802.3 full-duplex MAC precise specification does this already
  - Other statements in Std 802.3 (at least 2.3.2.3) require clarification, however, …
  - … the outcome does not matter for case CTF frame indications at the time of the associated M_UNITDATA.indications.

  → **No change of MAC Stds (802.3) would be required**

Proposals for WG 802.1 (for Discussion in Nendica)

- Latest PAR&CSD drafts of P802.1DU
  - PAR: https://www.ieee802.org/1/files/public/docs2022/du-draft-PAR-0122-v01.pdf
  - CSD: https://www.ieee802.org/1/files/public/docs2022/du-draft-CSD-0122-v01.pdf
- PAR: Update the scope (5.2) - add a definition of the modelling to the scope of P802.1DU, enable CTF

  "This standard specifies Cut-Through Forwarding (CTF) in Bridges based on the IEEE Std 802.1Q Bridge architecture. CTF Bridges interconnect individual IEEE 802 Local Area Networks (LANs) via different or identical Media Access Control (MAC) methods.

  This standard models the CTF operation, frame transmission start before frame reception completed, by look-ahead functions (similar to prescient functions established in 802.3) that (a) enable the CTF operation in bridges that support it, and (b) allow compatibility to this standard of bridges that do not support it.

  For bridges that support the CTF operation, this standard specifies additions to the procedures in published IEEE 802.1 Stds, including 802.1Q, 802.1AC, 802.1CB, for processing frames that are subject the CTF operation.

  This standard also specifies requirements and recommendations for the usage of CTF in bridged networks including IEEE Std 802.1Q bridged networks."
- CSD: Change compatibility (1.2.2)
  - *"Will the proposed standard comply with IEEE Std 802, IEEE Std 802.1AC and IEEE Std 802.1Q?"* → *"~~No~~Yes"*
  - *"If the answer to a) is no, supply the response from the IEEE 802.1 WG."* → empty

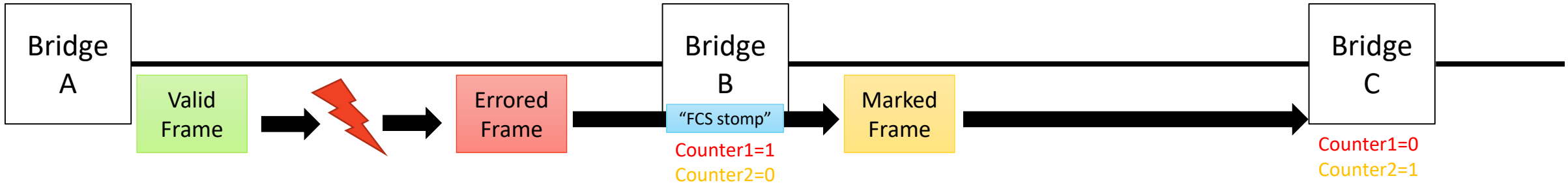
Frames with inconsistent FCS: “FCS stomp” variations & Management Counters

FCS: Passing between MAC ⇔ MAC clients: Introduction

- Author's recollection and interpretation of related concerns discussed:
  - Existing frame and byte counters in Std 802.3 count different than desirable for CTF.
  - Additional counters are desirable for distinction between frames becoming erroneous on the attached link and frames being marked as erroneous ("FCS stomp") from a link further upstream.
  - There are various different ways of marking erroneous frames found in existing implementations (e.g., inverted FCSs, only partially inverted FCS's, physical layer encoding, etc.)

    →It is unclear which one or ones to standardize
- Related items presented on April 27
  (https://www.ieee802.org/3/ad_hoc/ngrates/public/calls/22_0427/jones_nea_01_220427.pdf)
  - Slide 14
  - Slide 15
  - Slide 16 (Except the first bullet item)
  - Slide 17

FCS stomp" Variations & Management Counters (1)

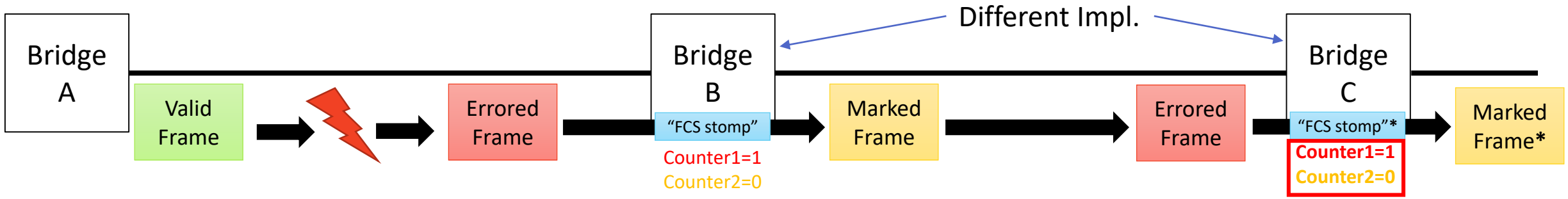


- Observations
  - Already standardized counters should not change their standardized semantics

  →***New counters desirable instead***
  - The counters are for diagnosis - the main CTF operation seems independent of presence (or absence) of the exact marking mechanism of erroneous frames and associated counters

  →***It appears acceptable to treat these both, marking mechanism and new counters, as optional (i.e., not mandatory for conformance)***

FCS stomp” Variations & Management Counters (1)



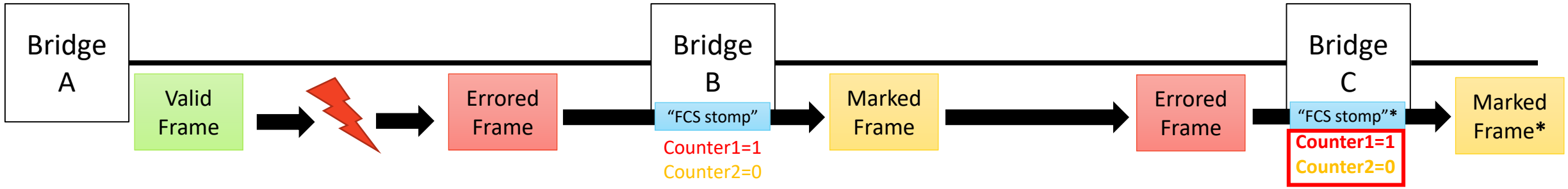
- Observations
  - Already standardized counters should not change their standardized semantics/behavior

  →***New counters desirable instead (different conclusion)***
  - The counters are for diagnosis - the main CTF operation seems independent of presence (or absence) of the exact marking mechanism of erroneous frames and associated counters

  →***It appears acceptable to treat these both, marking mechanism and new counters, as optional (i.e., not mandatory for conformance)***
  - If there are different ways flavors of marking in existing implementations, it seems likely that counters, from a network perspective can already be inconsistent

  →***Even if only one flavor would be standardized, standardizing would not deteriorate the present situation with regard to interoperability, but can improve it instead***

FCS stomp” Variations & Management Counters (2)



- Modelling
  - For FCS-based marking, an 802.1 Std (P802.1DU) appears to be a valid location
    - 802.1Q already requires partial (e.g., re-tagging) or full (different MAC methods) recalculation of FCSs (see 6.5.7 of IEEE Std 802.1Q-2018)
    - 802.1Q already defines per port counters – optional new ones could be located at this level (see 12.4.2.1 of 802.1Q)
  - Which flavor or flavors - there are different options, like:
    - Picking one found in an implementation
    - Picking one that is not found in any implementation
    - Supporting multiple different flavors, potentially in conjunction with some negotiation

→ However, it appears reasonable and common to the author to determine by the 802 Stds development process itself!

Summary, Conclusion & Proposals for WG 802.1

Topic \ Aspect	Modelling: Existing 802 Stds	Modelling: New 802 Stds on CTF	Conformance/Compat.: Existing S&F Impl.	Conformance/Compat.: Existing CTF Impl.
Main CTF operation	X	X	X	[X]
Frames with inconsistent FCS: Processing by 802.3 MACs	X		X	
Frames with inconsistent FCS: Passing between 802.3 MACs ⇔ MAC clients (bridge)	X		X	
Frames with inconsistent FCS: "FCS stomp" variations		X		X
Management counters		X		X
Locating CTF in IEEE 802 WGs/projects		X		

Stds 802, 802.1Q, 802.1AC and MAC Stds (802.3)

-"New Features" for CTF
-No existing 802 Stds
-Only for diagnosis

P802.1DU, MAC WGs?

Summary & Conclusion

- It appears that standardizing erroneous frame marking would not deteriorate the current situation in terms of the interoperability of different implementations.
  → But standardizing can improve the current situation.
- The main CTF operation is independent of marking.
  → **Erroneous frame marking (and the associated counters) can be an optional feature, not mandatory for conformance. Irrespectively of the flavor present in an existing implementation, this allows such implementation to be conformant.**
- It appears valid that both, erroneous frame marking and associated counters, could be done in P802.1DU
  → **Would not require changes in Std 802.3.**

Proposals for WG 802.1 (for Discussion in Nendica)

- Latest PAR&CSD drafts of P802.1DU
  - PAR: https://www.ieee802.org/1/files/public/docs2022/du-draft-PAR-0122-v01.pdf
  - CSD: https://www.ieee802.org/1/files/public/docs2022/du-draft-CSD-0122-v01.pdf
- PAR: Update the scope (5.2) - add a definition of the modelling to the scope of P802.1DU, enable CTF

  "This standard specifies Cut-Through Forwarding (CTF) in Bridges based on the IEEE Std 802.1Q Bridge architecture. CTF Bridges interconnect individual IEEE 802 Local Area Networks (LANs) via different or identical Media Access Control (MAC) methods.

  This standard models the CTF operation, frame transmission start before frame reception completed, by look-ahead functions (similar to prescient functions established in 802.3) that (a) enable the CTF operation in bridges that support it, and (b) allow compatibility to this standard of bridges that do not support it.

  For bridges that support the CTF operation, this standard specifies additions to the procedures in published IEEE 802.1 Stds, including 802.1Q, 802.1AC, 802.1CB, for processing frames that are subject the CTF operation.

  These additions include one or more methods for marking erroneous frames and associated new counters, which are optional and not mandatory for conformance to this standard.

  This standard also specifies requirements and recommendations for the usage of CTF in bridged networks including IEEE Std 802.1Q bridged networks."
- CSD: Change compatibility (1.2.2)
  - *"Will the proposed standard comply with IEEE Std 802, IEEE Std 802.1AC and IEEE Std 802.1Q?"* → *"~~No~~Yes"*
  - *"If the answer to a) is no, supply the response from the IEEE 802.1 WG."* → empty

Locating CTF in 802 WG/Projects

P802.1DU vs. Amendments

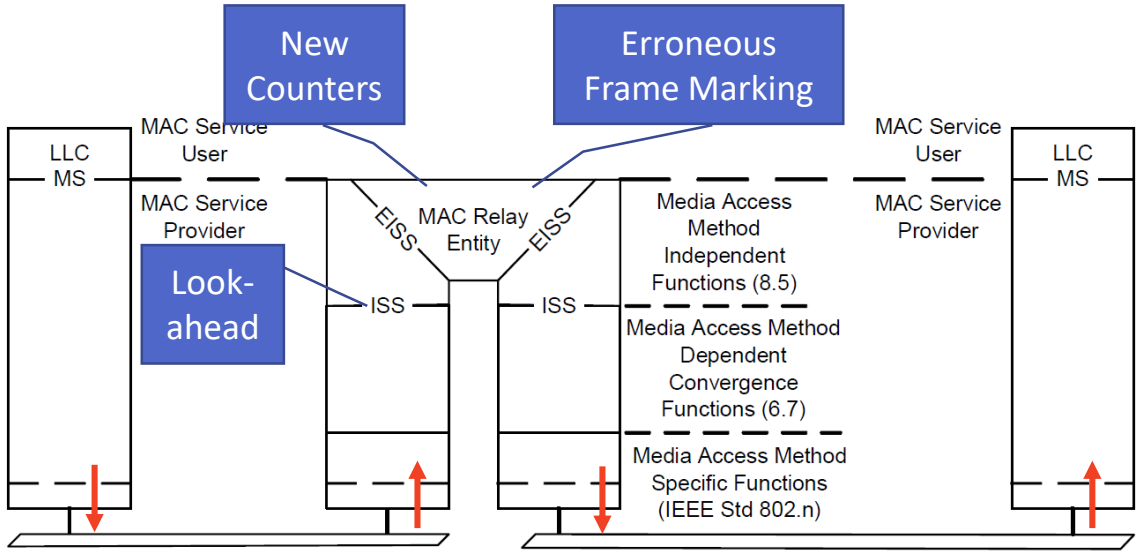
- Recap from earlier sections:
  - The CTF components in Bridges can be treated as optional features on P802.1DU

  →Existing S&F Implementations conformant to Stds 802, 802.1AC and 802.1Q can be conformant to 802.1DU
- Why a new 802.1 Base Standard, instead of amendments?

→July 2021 Tutorial
(https://mentor.ieee.org/802.1/dcn/21/1-21-0037-00-ICne-ieee-802-tutorial-cut-through-forwarding-ctf-among-ethernet-networks.pdf)

  - Readability - localize CTF specifics in a single Standard, instead of spreading these over several Stds (802.1Q, 802.1AC, 802.1CB, …)
  - Network-wide considerations, not found in the published 802.1 Stds in question
  - Compactness by selective “Diff” and references to existing parts of the published 802.1 Stds in question where possible

Existing Architecture (for Discussion in Nendica)



NOTE—The notation "IEEE Std 802.n" in this figure indicates that the specifications for these functions can be found in the relevant standard for the media access method concerned; for example, n would be 3 (IEEE Std 802.3) in the case of Ethernet.

Figure 6-1—Internal organization of the MAC sublayer

Source: IEEE Std 802.1Q-2018

- As summarized in the previous sections, it is unclear which parts of CTF cannot be done in P802.1DU and inevitably require changes in MAC Stds (802.3).
- This does not imply that MAC companion projects to P802.1DU would be inacceptable (e.g., if WG 802.3 decides to start such a project)
  – but it means that P802.1DU could finish with or without such companion projects.
- It may discussed if the components for modelling CTF could be shifted a bit up/down in the stack.

Thank You for Your Attention!

Questions,
Comments,
Opinions,
Ideas?