Cut-Through Forwarding (CTF) in Bridges and Bridged Networks

Johannes Specht

DCN 1-21-0009-01-ICne

Context and Objectives

Nendica

- Cut-Through (CTF) is new work - not an approved Standard development project
- Nendica is across IEEE 802 WGs
- Forum to discuss CTF in Bridges and Bridged Networks
- Platform to prepare material → For example, for an IEEE 802 Plenary Workshop
- CTF could be a potential study item

Work towards a potential 802.1 Standard for CTF

- Capture the dominant use-cases and relevant markets
- Capture how to deal with QoS Challenges
- Reach consensus in IEEE 802.1
- Formulate problem statements for discussion in IEEE 802.1 and across IEEE 802 WGs

My Intention

- Develop technical aspects/integrate into IEEE 802.1 Stds environment
- Initiate/lead related discussions
- Present/discuss material

Proposed Material/Output to Develop

Presentation

- Motivation
- *Specific* Use-cases, applications, markets, etc.
- Technical feasibility
- Introduction to the technical document

Technical document (work in progress, individual contribution)

- *Generic* use-cases (widely market- and application unaware)
- Network aspects and constraints
- New protocols/protocol procedures for CTF
- Bridge model integration: "Preview" of core elements in a potential IEEE 802.1 Standard
- Documents technical decisions from discussions
- See also https://www.ieee802.org/1/files/public/docs2021/new-specht-cut-through-update-0121-v02.pdf

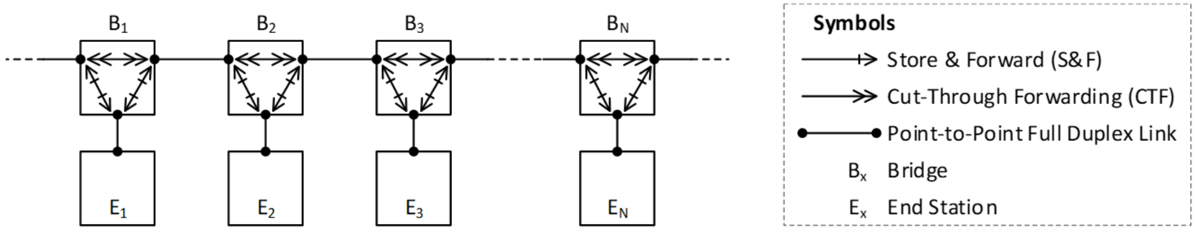
Use-Cases

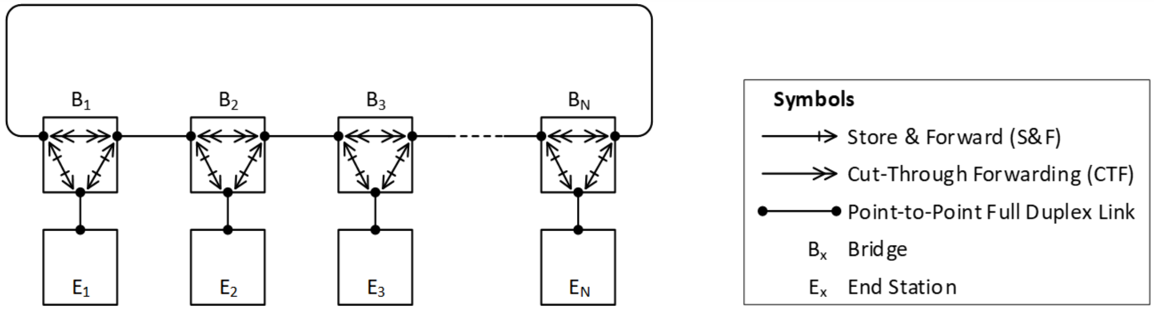
Applications

- CTF is an established technique in Industrial Automation networks
  - Particular details differ, but the basic principle is the same (https://www.ieee802.org/3/ad_hoc/ngrates/public/18_11/woods_nea_01_1118.pdf)
- Other applications under consideration

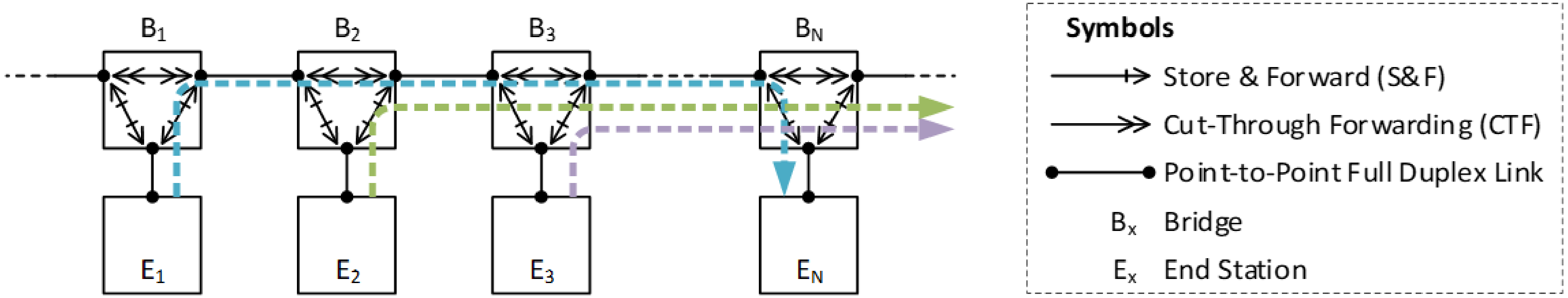
Often linear topologies/segments

- chains,
- rings,
- hierarchies and combinations thereof …
- … but not limited to these topologies!





Delay Performance of Cut-Through

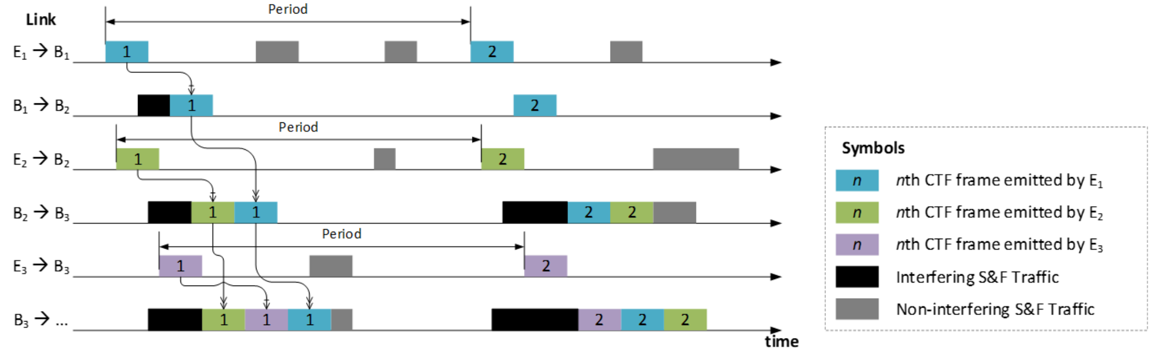


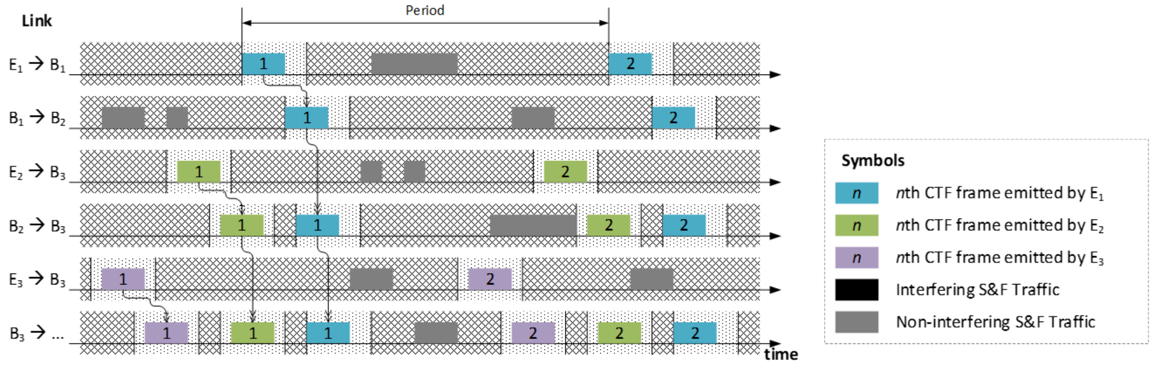
General Observation

- Significance depends on topologies, link speeds, traffic loads and patterns, scheduling [in the broader sense], and how fast Bridges are, etc.
- However, CTF **can always** decrease end-to-end delays

Estimate Delay Performance Range: CTF v.s. S&F

Uncoordinated … … Full TDM





Uncoordinated: SFF-to-CTF end-to-end delay ratio (in percent)

CTF hops	link speed	l_{HP} without preemption (l_{LP}=1542)					l_{HP} with preemption (l_{LP}=128)				
		128	256	512	1024	1542	128	256	512	1024	1542
2	100M	96%	93%	88%	83%	80%	83%	78%	75%	73%	73%
4	100M	95%	91%	85%	79%	75%	79%	73%	69%	66%	65%
8	100M	95%	90%	83%	76%	72%	76%	69%	64%	61%	60%
16	100M	94%	89%	82%	74%	70%	74%	66%	61%	58%	57%
32	100M	94%	89%	81%	73%	68%	73%	65%	59%	56%	55%
64	100M	94%	89%	81%	73%	68%	72%	64%	58%	55%	54%
2	1G	97%	94%	89%	84%	81%	89%	83%	79%	75%	74%
4	1G	96%	92%	86%	80%	76%	87%	79%	73%	69%	67%
8	1G	96%	91%	85%	77%	73%	84%	76%	68%	64%	62%
16	1G	95%	91%	84%	75%	71%	83%	73%	66%	61%	59%
32	1G	95%	90%	83%	74%	70%	82%	72%	64%	59%	57%
64	1G	95%	90%	83%	74%	69%	82%	72%	63%	58%	56%

Full TDM: SFF-to-CTF end-to-end delay ratio (in percent)

CTF hops	Link speed	l_{HP} without preemption (l_{LP}=1542)					l_{HP} with preemption (l_{LP}=128)				
		128	256	512	1024	1542	128	256	512	1024	1542
2	100M	56%	53%	52%	51%	51%	56%	53%	52%	51%	51%
4	100M	42%	38%	35%	34%	34%	42%	38%	35%	34%	34%
8	100M	30%	25%	23%	21%	21%	30%	25%	23%	21%	21%
16	100M	22%	17%	14%	13%	12%	22%	17%	14%	13%	12%
32	100M	18%	12%	9%	7%	7%	18%	12%	9%	7%	7%
64	100M	15%	9%	6%	5%	4%	15%	9%	6%	5%	4%
2	1G	75%	63%	56%	53%	52%	75%	63%	56%	53%	52%
4	1G	67%	50%	42%	38%	36%	67%	50%	42%	38%	36%
8	1G	60%	40%	30%	25%	23%	60%	40%	30%	25%	23%
16	1G	56%	33%	22%	17%	15%	56%	33%	22%	17%	15%
32	1G	53%	29%	18%	12%	10%	53%	29%	18%	12%	10%
64	1G	52%	27%	15%	9%	7%	52%	27%	15%	9%	7%

Lower percent values indicate higher end to end delay performance gains of CTF over S&F. Math. model based on https://www.ieee802.org/1/files/public/docs2017/new-woods-cutthroughconsiderations-0518-v01.pdf with more conservative interference-independent delays from Rx- to Tx- Port(s), assumed periodic streams (one per end station) in a chain, S&F from/to end stations and CTF on the remaining path, constant frame sizes of l_{HP} for high priority traffic (subject to CTF at the respective hops), low priority interference prevention in sender end stations, and periods >> end-to-end delays.

Challenges
(only the new ones in Bridges/Bridged Networks)

Main challenge

- (a) Bit errors in frame headers
- (b) discoverable by FCS verification
- (c) discovered after forwarding and transmission start (i.e., too late)

… translates to …

- false selection of transmission Port(s) during forwarding
- false queue/priority selection in transmission Ports
- Combinations of both

… impact …

- Unexpected congestion → Extra delays, congestion loss
- Circulating frames in stable network loops

… Mitigations

Goals

- Limit (bound) congestion/the impact
- Limit circulation of *rogue* frames, e.g. “at most one round after frame error occurence”

Protocol procedures

- Frame shortening
- Controlled choice of traffic classes and paths for CTF
- Policing
- Uncontrolled flooding slow down

Network constraints

- Topology constraints
- FDB settings, e.g. CTF only for streams with explicit FDB entries
- Dedicated full store and forward/non-CTF nodes in physical loops
- Combinations of the aforementioned

Proposal for Standardization and Realization in Bridges

Dedicated 802.1XX Standard (not an amendment to 802.1Q)

- Existing mechanisms from IEEE 802.1Q not in IEEE 802.1XX → beyond spec
- Adjust existing mechanisms from other IEEE 802.1 Standards: IEEE 802.1CB
- Definition of network constraints

Realization in Bridges - extended forwarding process: stalls, stalls to completion, late discarding

- The forwarding process as a pipeline
- Stalls to completion: Fall back to store and forward for further processing
  - Reception Ports not configured for CTF
  - Transmission traffic classes not configuration for CTF
  - Learning*
  - FDB flooding (i.e., slow down)
  - Sequence recovery function (a.k.a. IEEE 802.1CB “Redundancy merge function“)
  - …

Potential items for Problem Statements

#1: Reception

Implied store and forward operation by the MAC service interface.

#2: FCS Error Marking

Frames with bit errors discovered by FCS verification may be marked during transmission for appropriate error counting on subsequent hops. This requires a marking mechanisms at frame end (e.g., a special CRC).

#3: Transmission

No support for frame shortening and marking of invalid frames by the MAC service interface.

#4: Header Check Sequences

Support for header check sequences may be desirable, but no proposal has been made applicable across different protocols, transitions, and with resulting varying definitions of “header”.

Summary

Towards a potential IEEE 802.1 Standard for CTF

- Reach consensus in 802.1
- Prepare material
  - Technical document – individual contribution/work in progress
  - Presentation
  - Other?
- Involve IEEE 802.3 – there are problems that cannot be solved in IEEE 802.1

Any discussion, feedback and contributions welcome!

Thank you for your Attention!

Questions, Opinions, Ideas?

Johannes Specht
Dipl.-Inform. (FH)
Kurfürstenwall 2
45657 Recklinghausen
North Rhine-Westphalia
GERMANY
M +49 (0)170 718-4422
johannes.specht.standards@gmail.com