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IEEE 802.3cg

Collision Detection Reliability in 10BASE-T1S

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Outline

- This work is related to unsatisfied required comments
  - #242 (D2.2) from Yong Kim (NIO)
  - #648 (D2.0) from Geoff Thompson (GraCaSi)
- 10BASE-T1S does not indicate a method for detecting collisions but specifies the requirements for implementations
  - See Clause 147.3.5 on D2.4
- Commenters are asking for a study showing what is the achievable degree of reliability of any collision detect mechanism in 10BASE-T1S when operating over a mixing-segment CSMA/CD network
  - This presentation provides evidence that at least one implementation that fulfills the requirements is possible

Definition

- What does "reliable" collision detection actually mean?
- 802.3 specifications don't define this explicitly
  - In 16.3.4.2 (10BASE-FP) there is mention to have 100% (?) probability of detecting a collision between two or more stations
    - "100%" does not really sound as a technically precise wording
  - The same clause also points to 15.2.2 which is the BER specification.
    - This seems to suggest that the chance of missing a collision has to be "reasonably less than the BER"
  - Another possible interpretation is that 100% actually means "one event in the age of universe", that is 5×10^{24} bit times @10Mb/s
    - For the purpose of this work we assume this (much) more restrictive requirement

Case study

- This work analyzes the reliability of a method based on code violation detection in the PCS
  - Transmitted bits are read-back by the receiver and compared
  - A single bit difference results into a collision
- We need to ensure that in the **worst case** scenario the probability of not detecting a collision is less than $1 / (5 \times 10^{24})$ that is 2×10^{-23}
  - Max IL for the channel and MDI
  - Max allowed capacitance limit
  - Two stations sending identical packets, apart from one bit difference in the source MAC address field of the Ethernet frame
  - "Perfect" in-phase TX alignment between the colliding stations
  - Lowest possible TX voltage levels allowed by the PSD mask (see 147.5.4.4)

Colliding bit detection

- In case two stations are transmitting opposite voltage levels on the line, what's the chance of detecting a bit-flip at the receiver?
- The attenuation of the TX signal on the worst case channel is ~65% (3.7 dB) for an 8 nodes network with 15 pF/node of differential capacitance and 80μH of parallel inductance (→ limits specified in 147.9.2)
  - See http://www.ieee802.org/3/cg/public/May2018/beruto_3cg_02_0518.pdf slide #12
- Considering the minimum allowed TX voltage level of ~850 mV_{p-p} (see 147.5.4.4.2 - Lower PSD mask), the lowest possible interfering signal at the local receiver that could be expected during a collision is > 550 mV_{p-p}
  - This swing can be easily detected by a slicer at mid-range, yielding at least 275 mV_{p-p} of margin for noise
  - Worst case RL (147.7.2) eats away ~120 mV_{p-p} of margin, leaving ~75 mV_p for gaussian noise
  - Alien noise (147.5.5.2) over 40MHz BW is -101 dBm/Hz (12.5 mV_{rms}), which yields margin for ~6 STD
- That is 1×10^{-9} probability of not detecting a single-bit collision

Scrambler

- 1×10^{-9} is not enough to meet the 2×10^{-23} (age of universe) requirement for a single bit difference in the colliding packets
- But 10BASE-T1S features a 17 bit self-synchronizing scrambler

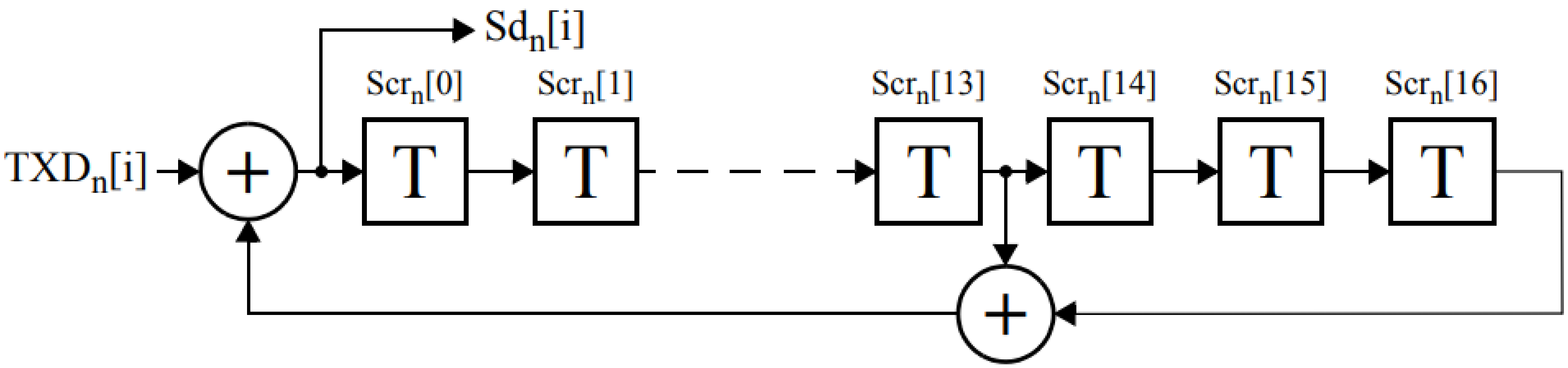

Figure 147–6—Self-synchronizing scrambler

Scrambler

802.3 Ethernet packet and frame structure

Layer	Preamble	Start of frame delimiter	MAC destination	MAC source	802.1Q tag (optional)	Ethertype (Ethernet II) or length (IEEE 802.3)	Payload	Frame check sequence (32-bit CRC)	Interpacket gap
	7 octets	1 octet	6 octets	6 octets	(4 octets)	2 octets	46-1500 octets	4 octets	12 octets
Layer 2 Ethernet frame			← 64–1522 octets →						
Layer 1 Ethernet packet & IPG	← 72–1530 octets →								← 12 octets →

- The MAC always sends a fixed preamble of 8 bytes, plus 6 bytes of destination MAC address (which we assume to be the same for the colliding stations)
- Unless the TX scramblers of the colliding stations have the same seed at that time, we're going to have totally different signals on the line. With at least 3 bits of difference (guaranteed by the scrambler polynomial $x^{17} + x^{14} + 1$) we have a 10^{-27} chance of mis-detection, which is already lower than our 10^{-23} target.
  - In this case, no problem!
- What if the scramblers are aligned at that time?
  - That's $1 / 2^{17}$ probability, that is 7.6×10^{-6}
- But self-synchronizing scramblers are multiplicative!
  - A single bit difference in the source MAC address is turned into at least 3 differing bits on the line!
    - Besides, after a single different bit, the two scramblers diverge, yielding more different bits till the end of the TX
- This gives a safe $7.6 \times 10^{-6} \times 10^{-(9 \times 3)} = \sim 10^{-32}$ which is definitely less than the 10^{-23} target

Additional considerations

- A collision must be detected within one slot time (512 bits @10 Mb/s) to ensure not incurring in a late collision
  - Late collisions are considered errors because a receive mode collision could not be discarded by just examining the fragment length
    - CRC is not enough in this case as $1/2^{32}$ is not less than "one event in the age of universe"
  - Line propagation delays have to be taken into account
  - 10BASE-T1S is designed for small networks (~25 m of cable) with no repeaters where max Tpd is in the range of 2-3 bit times (negligible). Besides, the IL practically limits the maximum achievable cable length to ~50m.
- 512 bits is enough to include the packet preamble, the L2 header and most of the payload of the shortest allowed packet
- If at least one of the N colliding stations detects a collision with the specified method, jamming will follow, giving at least 32 more random bits of chance for the other colliding stations to detect the collision in turn.

Conclusions

- In the worst case scenario, single bit collisions can be detected by the means of code violations with an approximate probability of 10^{-9}
- 10BASE-T1S scrambler multiplies single bit differences between the transmissions by at least a factor of 3
- Packets must differ for at least one bit in the source MAC address, which occurs well before the 512 bit limit set for late collisions
- Current 10BASE-T1S architecture guarantees the chance of missing the detection of a collision to be less than 10^{-23}, that is one event in the age of universe
- At lest one reliable method of detecting collisions in T1S exists
  – Other methods are possible, provided they can fulfill the same requirements

THANK YOU!

Notes

- All calculations are approximated towards the worst case, neglecting additional helping factors, such as
  - The chance of missing exactly one bit **at a specific position** is actually $(1-P)^{N-1}(P)$
    - We deliberately neglected the $(1-P)^{N-1}$ term which would lower the number further
  - The 4B/5B coding also gives a chance of multiplying single bit differences in the TX packet
  - The chance that the two transmitters are in perfect phase-sync during the collision is not computed (it's heavily implementation dependent). But again, that would further reduce the chance of missing the collision
  - The actual chance of having two stations sending two almost identical packets has not been taken into account