Temperature effects in EFM optics

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Top-down presentation

1. What is an 802.3 standard for
2. Temperature specific issues
3. Laser temperature issues
4. Conclusions
5. Backup

   Trail of motions from the minutes

   More IEC environmental references

What is International Standard 802.3 trying to do?

- Standards are modular
- This one aims to enforce “horizontal compatibility” (interoperability)
  - So can buy switch from A, computer from B, cable plant from C
  - This enables the market
  - Standards should be stable and long lived
- Based on defined interfaces (signals)
  - “System level standard”
  - Not a component spec
  - Not a procurement spec
    - But may be included in one
- Standard specifies outcomes (the signal) not means (the size, the materials …)
  - Because to do otherwise would stifle innovation
    - Products are more numerous and varied and revised more frequently than standards
- Bear in mind the diversity of the whole world
- Need to write a standard with restraint

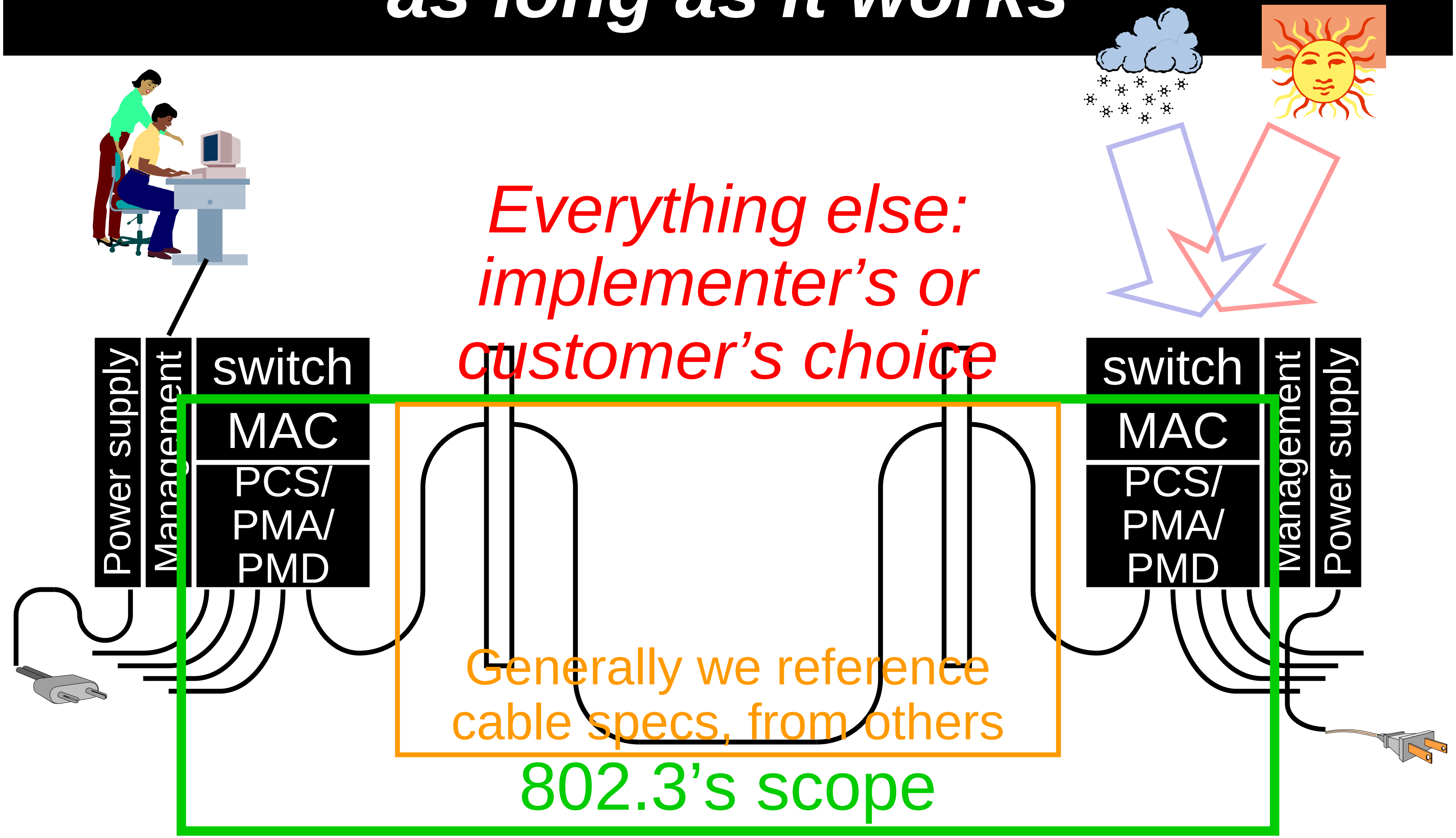
What’s in scope?

- In scope: International Standard IEEE 802.3, ISO/IEC 8802-3 specifies
  - Signals to/from the medium fully defined
  - Logical behaviour from MAC to medium
  - Behavioural (abstract) definition of internal interfaces below MAC
  - Some other other optional real (exposed) interfaces, signals e.g. MDIO
  - Optional station management interface (e.g. MDIO)
- Specifies some by reference although in scope
  - 100BASE-FX by ISO/IEC 9314-3
- Standardized by others
  - SNMP management information base (MIB) by IETF
  - Cable specs by ITU-T or ISO/IEC or ANSI/TIA/EIA
  - Some electrical interfaces by JEDEC
  - More?

Not in scope: other body(s) may standardize

- Network management (802.1 or SNMP), station management system
- Above the MAC: e.g. switch design (802.1), NIC card interface (e.g. PCMCIA)
- Means of implementation
  - Materials
  - Power supplies
- Mechanical, environmental
  - Sizes (several MSAs address this)
  - Temperature of environment (IEC, ETSI)
  - Temperature of PMD "case", temperature of ASICs
  - Shock and vibration tolerance
- Commercial
  - Prices
- Geographical or national issues
- These are not interoperability

We don't care what's in the black box - as long as it works



Standard specifies the signal

- Transceivers in different form factors/ price points/ temperature grades have the **SAME identity** as PMDs
  - Identity of a PMD is a description of an optical signal
    - Specification point is in the fiber
  - Optical specs are agnostic to form factors/ price points/ temperature grades - they don't determine interoperability
- **We wouldn't want it otherwise**
  - EFM scenarios have different port densities, form factors and temperature ranges at the two ends of a link
  - Installers want a really simple look-up table of what to connect to what
  - Don't have to know about the temperature or form factor of the other end of the link
  - Implementer/installer are responsible for their own environmentals
    - Part of their business, not this standard's
- **Temperature is out of scope of the standard**
- Same as all other generations of Ethernet

From 14. Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-T

14.7.3.2 Temperature and humidity

The twisted-pair link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). **Specific requirements and values for these parameters are considered to be beyond the scope of this standard.**

It is recommended that manufacturers indicate in the literature associated with the MAU the operating environmental conditions to facilitate selection, installation, and maintenance.

It is recommended that manufacturers indicate,in the literature associated with the components of the twisted-pair link segment, the distance and operating environmental conditions over which the specifications of 14.4 will be met.

From 15. Fiber optic medium and common elements of medium attachment units and star, type 10BASE-F

15.6.3 Other environmental requirements

The MAUs, stars, and associated connector/cable systems are expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling such as shock and vibration. Specific requirements and values for these parameters are considered to be beyond the scope of this standard. Manufacturers should indicate in the literature associated with a unit (and on the unit if possible) the operating environment specifications to facilitate selection, installation, and maintenance of these components. **It is further recommended that such specifications be stated in standard terms, as specified in IEC 60068, IEC 60874-10:1992, IEC 60793-1:1992, and IEC 60794-1:1993.**

(see backup for these references)

Temperature is within the scope of the standardisation project 1/2

- Within our "worry space"
- We have agreed we wish to enable extended temperature optics
- Motions with large majority for: write for -40 to 85°C PMD case (CPE end) for multiple optical PMDs, and for "informative annex"
  - See backup slide
- We have written the specs to **allow and enable** extended temperature optics
  - We have consistently considered the extended temperature range in choosing optical spec limits
- We do not **demand** extended temperature anything

Temperature is within the scope of the standardisation project 2/2

- Attempts to outlaw optics appropriate to temperate, maritime and tropical locations, if successful, would **INCREASE** the cost of extended temperature optics
  - In particular, DFBs
- All 802.3ah needs to do is document the assumptions behind what it has done, then get out of the way of those trying to deploy EFM
- **“Informative Annex”**
  - which naturally does not contain PICS.
  - We have no time to get involved in temperature testing
  - We are not experts
  - MSAs do some temperature work. NEMs and operators do it.
  - See draft Annex 66A in comment database

Temperature requirements are varied 1/3

- Climates vary
- IEC 60721-2-1describes **9 classes of climate**
  - not including the Central Antarctic or altitudes >5000 m
  - groups the classes into four groups
- The customers that are buying, mostly do not have an extreme climate
  - Japan, Sweden, Italy, Korea
  - Each phone company imposes its own temperature specs
  - Most of the world does not live in an extreme climate
  - Many network operators inhabit a single climate, not several
- Not right to impose specific local preferences on the early adopters

Temperature requirements are varied 2/3

- **See world maps** in IEC 60721-2-1 Ed 1.1 2002-10, Classification of environmental conditions. Part 2-1: Environmental conditions appearing in nature
  - CHF 99 from http://webstore.iec.ch
- Many more IEC documents in this series
  - Also IEC 60068, environmental testing
- Other references: e.g. ETSI EN 300 019-1-4
  - Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment;
  - Part 1-1: Classification of environmental conditions; Storage
  - Part 1-3: Classification of environmental conditions; Stationary use at weatherprotected locations
  - Part 1-4: Classification of environmental conditions; Stationary use at non-weatherprotected locations
  - Part 1-8: Classification of environmental conditions; Stationary use at underground locations

Temperature requirements are varied 3/3

- Locations vary
  - Network operators' deployment/installation strategies vary
  - Most customers appear NOT to be single-family houses
    - Apartments, offices
  - Most FTTB does not need external optoelectronics
    - Basements, hallways, car parks, comms rooms ...
- NEMs' temperature strategies vary
  - Forced air cooling or not, ports/blade, temperature-control the room or the box or the laser?
  - NEMs will choose wisely, but not identically
- Mechanicals vary
  - Product might specify the air, the case, the sunlight, …
- Market forces steer us to the right temperature grades
- We (standards body) must stay out of this time-wasting rat-hole!

Reliability

- Out of scope of the standard but in project's worry space
- Repairs cost much more outside than in the office
- High temperatures stress reliability
- Wide temperature ranges stress reliability
- Looks like reliable semiconductors (silicon, lasers and photodiode) can be achieved with care

Key issues: semiconductors, mechanical, thermal

- Much silicon can be made to work predictably over a wide temperature range
  - Wide temperature range costs:
    - Design tolerance or performance e.g. CDR jitter
    - Test time
    - More expensive packaging e.g. materials, heatsinking
  - Temperature coefficients are well understood
- pin photodiodes seem OK over temperature
- Mechanical expansion distorts the optical path over temperature
- High temperature operation demands better heatsinking
- *Notice no-one is proposing standardizing the temperature of these items even though they are affected by temperature*

Key issues: cabling

- Less convenient to temperature-control the cable than the terminals!
- 1. Optical cable
  - –Dispersion varies little with temperature
    - •Fiber appears to meet spec over the extended temperature range
  - –Loss variation with temperature
  - –Loss is also affected by bending
- 2. Electrical cable
  - –Plastic insulation's properties may change with temperature
  - –See e.g. 14.4.2.1

"NOTE —Multipair PVC-insulated 0.5 mm [24 AWG] cable typically exhibits an attenuation of 8 dB to 10 dB/100 m at 20 °C.The loss of PVC-insulated cable exhibits significant temperature dependence.At temperatures greater than 40 °C, it may be necessary to use a less temperature-dependent cable, such as most plenum-rated cables."

Key issues: semiconductor lasers

- Lasers evolve slowly and unevenly
  - Feature sizes are set by wavelength
  - No process of feature size reduction
  - No Moore’s law
  - Last significant innovation for long wavelength lasers was quantum wells in the mid 1990s
  - Recent improvements e.g. in temperature sensitivity have been evolutionary and incremental
- Long wavelength lasers are much more temperature sensitive than silicon
  - One reason is the lower bandgap, necessary to give the right wavelength
  - Threshold can vary by 5x and more over extended temperature range
  - Wavelength is temperature dependent

Semiconductor laser types

- Effects depend on laser type, therefore PMD type
  - Medium spectral width: Fabry-Perot
    - 100BASE-LX10, 100BASE-BX10, 1000BASE-X10, 1000BASE-BX10-U, 1000BASE-PX10-U
  - Narrow spectral width: Distributed FeedBack (DFB)
    - 1000BASE-BX10-D, 1000BASE-PX10-U, 1000BASE-PX20-U
- FP lasers are cheaper than DFBs
  - Cheaper to make
  - No isolator
  - Cheaper testing

Fabry-Perot lasers

- Made in volume for both telecomms and datacomms (weatherprotected locations)
- Modern FP lasers can be made to work over extended temperature range
- Can consider extended temperature FPs as a fraction of the higher volume production and markets
- FP wavelength varies with temperature
  - $d\lambda/dT \sim 0.45$ nm/K
    - 0.45 * (85-(-40)) ~ 55 nm
    - We have allowed the full wavelength range of the fibre (100 nm) around 1310 nm, and 100 nm in 1550 band also
  - OK so far

Fabry-Perot lasers cont.

- FP spectral width is an issue
  - TDP needed for 10 km range strongly affected by
  (spectral width) * (wavelength range)
  ~ (spectral width) * (temperature range)
- Spectral width is a statistical phenomenon
  - Varies with temperature, reflections, everything
  - Need margin for variability
  - Not a big issue at 125 MBd
  - At 1250 MBd, 10 km over -40 to 85ºC with solid tolerancing is challenging
  - Nature of degradation is rise in error rate at extremes of distance and temperature, recovering with temperature
  - Happens sometimes (statistical) - like polarization mode dispersion

DFB lasers

- DFB spectral width is normally better than adequate (BUT see later)
- DFB wavelength varies with temperature
  - $d\lambda/dT \sim 0.1$ nm/K
    - 0.1 * (85-(-40)) ~ 12.5 nm
    - We have allowed 20 nm
    - We chose these wavelengths to allow video overlay
  - OK so far
- DFB threshold and spectral properties vary from chip to chip but are repeatable for each chip

A DFB laser has a sweet spot in temperature

DFP spectral width is normally better than adequate, BUT

- Need reasonable alignment of gain peak and allowed wavelength
- Too much difference (“detuning”) causes spectrum to fail
- Gain peak ~0.45 nm/K, allowed wavelength ~0.1 nm/K
- Therefore Detuning (nm) ~ Temperature range
- Yield goes down as temperature range up

DFB lasers are variable 1/2

- DFBs are made by breaking up bars which contain a deeply submicron grating
  - Phase of bar end to grating is not controlled
  - But is set for every chip once it has been made
  - Phase determines tolerance to detuning
- Some chips are no good (bad spectrum) - tested out
- Some chips work over some temperatures
  - Nature of degradation is abrupt rise in error rate at extremes of temperature, recovering with temperature
  - Expected to be reproducible for any one chip
- Some chips work over more temperatures
- Requires testing over temperature
  - with associated cost

DFB lasers are variable 2/2

- Gain profile often assumed to be parabolic
  - Effect of detuning ~ (temperature range)^2
- Yield goes down **strongly** as temperature range up
  - If this is too expensive, Peltier-cooled DFBs are available - at a cost
- Tweaking optical or distance specs will not make any difference here
- Making extended temperature DFBs (without Peltier coolers) necessarily involves making regular-temperature DFBs
- **Attempts to outlaw the latter (if successful) would push up the price of the former**

New technology?

- The industry has been through a boom:
  - any promising new technology would be here, now
- The industry is down
- The business case for FTTH is very weak in most places
  - FTTB is better: apartment and office buildings (mainly weatherprotected locations)
  - but still no certainty of real volume
- There is no financial justification for looking at new technology
- FTTx can re-use technology developed for bigger markets
  - just as optoelectronics re-uses silicon technology from the PC and cellular markets
  - Just as 100M is reusing SDH STM-1 technology

New technology?

- Forget it!
- Attempts to differentiate the technology requirements would leave the FTTx market with fewer suppliers
- We have to write the standard with what we’ve got

Conclusions 1/2

- 802.3ah has addressed the wish for extended temperature
  - We satisfy the trail of motions and objectives
  - We do not interfere with implementers' mechanicals/thermals
- Extended temperature optics cost more to make
  - But can be made
  - Cost delta varies between PMD types
  - The cost delta may diminish as volume emerges
- 802.3ah cannot make the access market happen
- But can obstruct it with unnecessary burdens
  - Fragile market has to emerge gradually without obstacles
  - Must let the early adopters continue
  - Must re-use technology from stronger markets
  - May evolve the temperature range as technology allows

Conclusions 2/2

- Environmentals are out of scope
  - Powerful market forces work well for these issues
- 802.3ah cannot control the networks' buyers
  - Network environmental conditions vary
  - The networks will buy the temperature grade they need
  - They are adults
- Economies of scale means synergy with enterprise and telecomms
- Attempts to interfere with networks with medium temperature range will ADD to costs for DFBs
- "Informative Annex" is good

Backup: EFM objectives

From IEEE P802.3ah EFM Task Force Objectives

As Approved by IEEE 802.3 CSMA/CD WG

11-July-2002

- Support subscriber access network topologies:
  - Point to multipoint on optical fiber
  - Point to point on optical fiber
- Provide a family of physical layer specifications:
  - 1000BASE-LX extended temperature range optics
  - 1000BASE-X >= 10km over single SM fiber
  - 100BASE-X >= 10km over SM fiber
  - PHY for PON, >= 10km, 1000Mbps, single SM fiber, >= 1:16
  - PHY for PON, >= 20km, 1000Mbps, single SM fiber, >= 1:16

Backup: trail of motions

All these motions passed. Further motions in optics sub task force

Minutes for the 802.3ah Working Group Interim Meeting, Raleigh, NC, January 14-16 2002, Motion Madness on Wednesday afternoon:

Optical PMD Sub Task Force Report:

Motion #1: The extended temperature range (PMD case) for the 1000BASE-X will be -40C to 85C.

OPMDSTF: Y:30 N:0 A:1

802.3ah: Y:98 N:0 A:7

Motion #2: The temperature ranges (PMD case) for the various PMDs will be:

P2MP ONU end: -40C to 85C

P2P ONU end: -40C to 85C

802.3ah: Y:95 N:4 A:8

802.3 voting members: Y:55 N:3 A:1

Motion #5: Move to change the current objective of defining a temperature extended 1000BASE-X PMD to: 1000BASE-LX extended temperature range optics

802.3ah: Y:63 N:3 A:21

802.3 voting members: Y:45 N:3 A:11

- EFM Task Force Meeting Minutes Tuesday, March 12, 2002
- Motion: To add an objective to the family of physical layer specifications
- 100Base-X >= 10 km over SM fiber
  - ALL – for 105; Against 4; Abstained 22
  - 802.3voters - for 59; Against 3; Abstained 9
- EFM Meeting Minutes Thursday, March 14, 2002
- *P2P Optics track – Vipul Bhatt*
- *Progress Report*
- *Group motions reviewed Motion for extended temp, 4 PON PMDs, 100BASE PMD for single and dual, and Liaison letters ...*
- Motion #10: 802.3ah accept the motions and work of the optics sub task force ...
  - All: For - 105; Against - 0; Abstained - 11;
  - 802.3 voters: For - 61; Against - 0 ; Abstained – 6
- Motion #11: to create informative annex to address environmental considerations.
  - All: For - 59; Against - 1; Abstained - 40;
  - 802.3 voters: For - 40; Against - 1 ; Abstained – 17

More IEC environmental references

IEC 60068-1 - Ed. 6.0

Environmental testing. Part 1: General and guidance

Publication date: 1988-06

Abstract: Enumerates a series of environmental tests and appropriate severities, and prescribes various atmospheric conditions for measurements for the ability of specimens to perform under normal conditions of transportation, storage and operational use.

IEC 60793-1-1 - Ed. 2.0

Optical fibres - Part 1-1: Measurement methods and test procedures - General and guidance

Publication date: 2002-12

Abstract: Provides a list, and gives an overview of, the documents giving the uniform requirements for measuring and testing optical fibres, thereby assisting in the inspection of fibres and cables for commercial (mostly telecommunications) purposes.

IEC 60794-1-1 - Ed. 2.0

Optical fibre cables - Part 1-1: Generic specification - General

Publication date: 2001-07

Abstract: Establishes uniform generic requirements for the geometrical, transmission, material, mechanical, ageing (environmental exposure) and climatic properties of optical fibre cables, and electrical requirements, where appropriate. It applies to optical fibre cables for use with telecommunication equipment and devices, and to cables having a combination of both optical fibres and electrical conductors.

IEC 60874-1 - Ed. 4.0

Connectors for optical fibres and cables - Part 1: Generic specification

Publication date: 1999-07

Abstract: Applies to fibre optic connector sets and individual components (i.e. adaptors, plugs, sockets) for all types, sizes and structures of fibres and cables. Includes connector set requirements and quality assessment procedures.