EFM Copper Objective

- PHY for single pair non-loaded voice grade copper
  
  Distance $\geq 2500$ft and speed $\geq 10$Mbps aggregate

This means:

Single pair, bad wire, long wire
Where is EFM copper?

Customer Premises

LEC
Local Exchange Carrier
Point of Presence

IEC
Inter Exchange Carrier

First Mile

RT
Distribution

Loop

In-building

Home

Feeder

Switch

Trunk

Toll Trunk

Interlata

LATA Boundary

Interoffice

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Some terminology

- In-building:
  - IDF
  - Horizontal
  - Backbone/riser
  - MDF
  - NID
  - CPE
  - Network Interfaces

- Central Office/Point of Presence:
  - Crossbox Cabinet Node Etc.
  - Distribution frame
  - Feeder
  - Insertion point
  - Unbundled Network Element

- Loop:
  - RT
  - Distribution

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What is “voice grade” copper

- **Voice grade**
  - Suitable for transmitting voice, “voiceband” = 300Hz – 3.3kHz
- **Non-loaded**
  - Load coil improves attenuation 0-3kHz (kills signals >3kHz!)
- **Local loop**
  - Path between Central Office (DF) and Network Interface
- **In building**
  - Un-structured cabling – does not meet TIA 568 etc.
- **Many types of cable**
  - Cat-3, Cat-1 (aka “voicegrade”) in local loop
  - Type-1, Type-2, 24AWG – in building
  - Typically 1 twist per foot - 6 twist per foot
  - 25 pair – 3600 pair (25-50 pair binder groups in cable)
- **Installed sometime between 1876 and 2001**
- **Anything that conducts!**
Problems for EFM copper

• Attenuation – increases with frequency
  
  10 Mbps needs > 1 MHz (higher speeds desirable)

• Impedance mis-matches, out of balance and other line impediments (particularly for unstructured)
  
  Signalling above 12 MHz problematic because of emissions

• Bridged taps for in building wiring

• Wet/dry pairs - requirement to share the line with existing service

• Background noise
  
  ANSI T1E1.4 defines AWGN –140dBm/Hz

• Noise sources in binder
  
  Services regulated by spectral planning
  
  Other noise: ringing, on/off hook, in-building noise – bursty and LOUD!
Near-End Crosstalk (NEXT)

Strong Tx signal Kills weak Rx

• Attenuation to Crosstalk Ratio (ACR) gives measure of SNR
• ACR approaches 0 for many EFM cable types at 3kft, 2MHz
Far-End Crosstalk (FEXT) and Equal-Level Far-End Crosstalk (ELFEXT)

- FEXT less limiting than NEXT at EFM frequencies
- ELFEXT determines rate available for most EFM
- Difficult to measure
- Power back off crucial

\[ FEXT = \frac{V_{\text{xtalk}}}{V_{\text{in1}}} \]

\[ ELFEXT = \frac{V_{\text{xtalk}}}{V_{\text{out2}}} \]
How to solve...

Historical precedent – use existing PHY

- Builds on known working Physical Layer (historical precedent)
- Ethernet “value add” – simple & low cost
Candidates – 100BASE-CU

- Burst mode Time Domain Duplexed – reduced NEXT
- Adjustable symmetry
- Flexible spectrum – avoids interference
- Decision Feedback Equalizer and Forward Error Correction
- Flexible corner frequency for deployment over wet pairs

Silent Periods:
- No Crosstalk Generated
- Can measure SNR
- Can Identify Crosstalk Coupled Systems

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100BASE-CU encapsulation

Ex: 100BASE-CU Burst:
31 1518 Byte Frames per Burst
Candidates – EoVDSL

- Frequency division duplexed – no NEXT
- 4 bands (instead of 2) gives more flexibility for performance vs reach
- Decision Feedback Equalizer and Forward Error Correction (interleaved)
- PHY specification from ANSI T1E1.4 (leverage 4 years of work)
- Multiple silicon vendors
### EoVDSL Encapsulation

#### Standard VDSL frame has fast and slow parts

- Fast channel is optional
- $F=0$, $S=200$ for 802.3 compatible operation

#### Continuous transmission

- Ethernet packets encapsulated and stuffed into bitstream

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**Diagram:**

- **Sync Word:** 2 Octets
- **Control Word:** 3 Octets
- **Fast Channel:** F Octets
- **Slow Channel:** S Octets
- **Fast Channel:** F Octets
- **Slow Channel:** S Octets
- **Payload:** 400 Octets
- **Header:** 5 Octets
- **Total:** 405 Octets
- **Continuous transmission:**
  - 200 Octets of Ethernet packets
  - 181 Octets – protected payload
  - 64+ Octets
  - Delimiter + idles

**Legend:**

- **Control Packet:**
- **Header:**
- **Packet:**
- **Header:**
- **…**
- **FEC:**

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**IEEE802.3 EFM SG**

**July 2001**
Summary

Ethernet over Point to Point Copper meets the 5 Criteria