100 Mb/s EFM over Copper

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Overview

- Opportunity
- Copper Based Signaling
- Loop Plant Characteristics
- Capacity Analysis
- Conclusions

Opportunity: Leverage vs Legacy

Advances in technology

- Low cost signal processing
- Optimization for loop plant (characteristics)

Fiber (EPON) deployments

- New topology ➔ shorter copper loops
- Reduced CO-DSLAM constraints

Up to 100 Mbps Ethernet over twisted pair

Loop Plant Characteristics

- Typically 26AWG or a mixture of 24/26
- Alien and Self Crosstalk
  - NEXT
  - FEXT
- Various Disturbers (AM radio, Impulse noise,..)
- Bridged taps

Copper PHY Duplexing Options

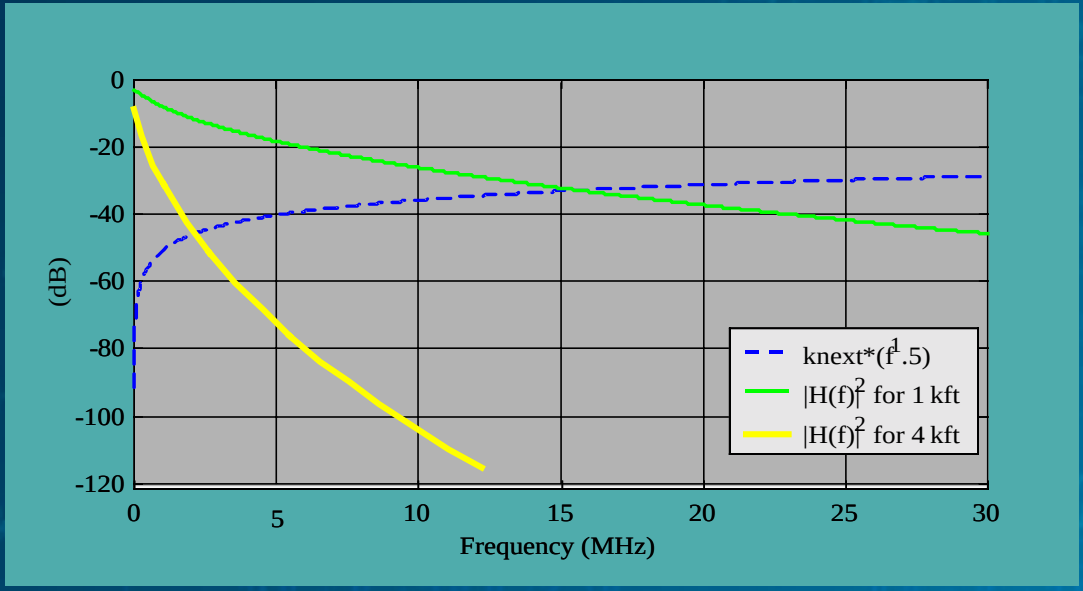
The following approaches to full duplex have been used

- FDFB: Full Duplex Full Band
- FDD: Frequency Division Duplex
- TDD: Time Division Duplex

Full Duplex Full Band

Optimum for short loops or narrow band

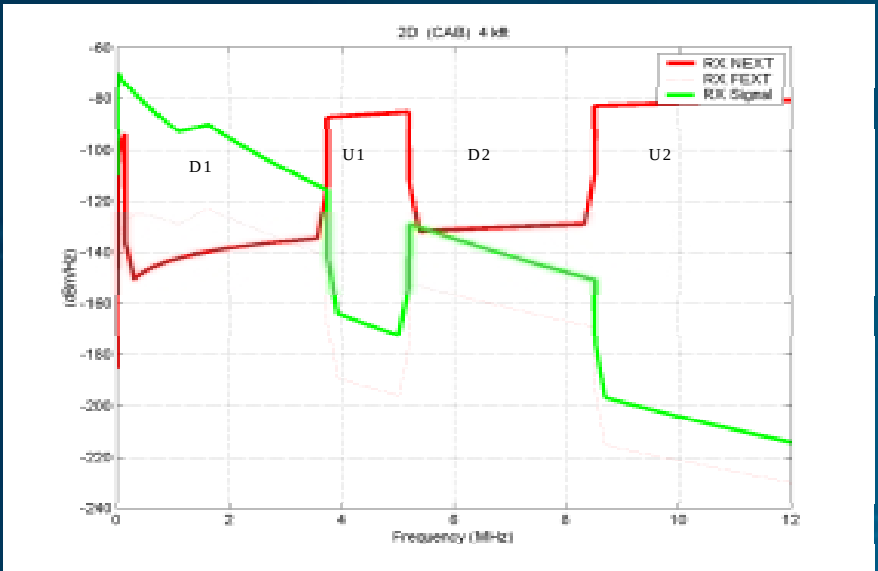
- At long loop lengths receiver performance is dominated by NEXT and local echo



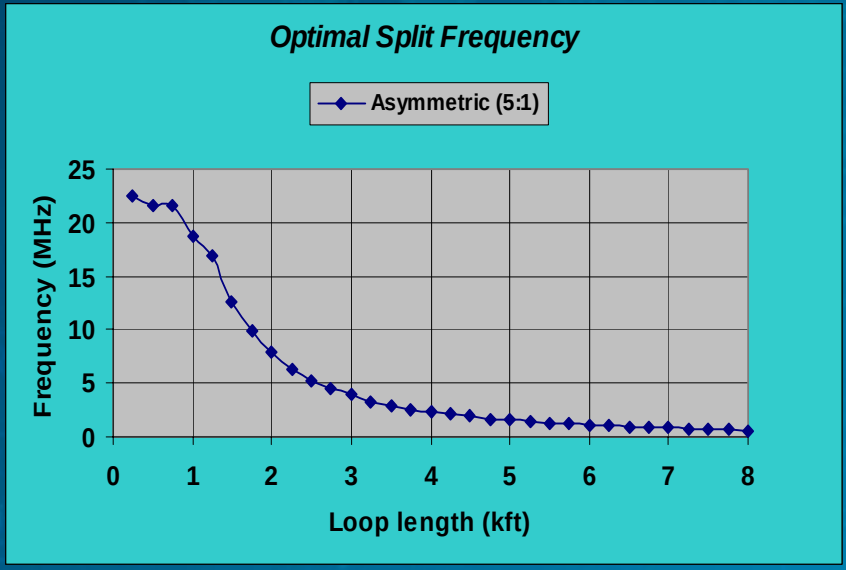
Frequency Division Duplex

No echo cancellation - Mitigates NEXT

NEXT is still a problem



Frequency split is different for each loop length



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Time Division Duplex

- Eliminates NEXT
- Flexible upstream/downstream ratio
- Lower dynamic range required
  - No capacity advantage at very short loops
  - Not as advantageous at very long loops
    - need greater guard time interval

How do we best take advantage of the loop plant characteristics in the 500 to 3000 feet range ?

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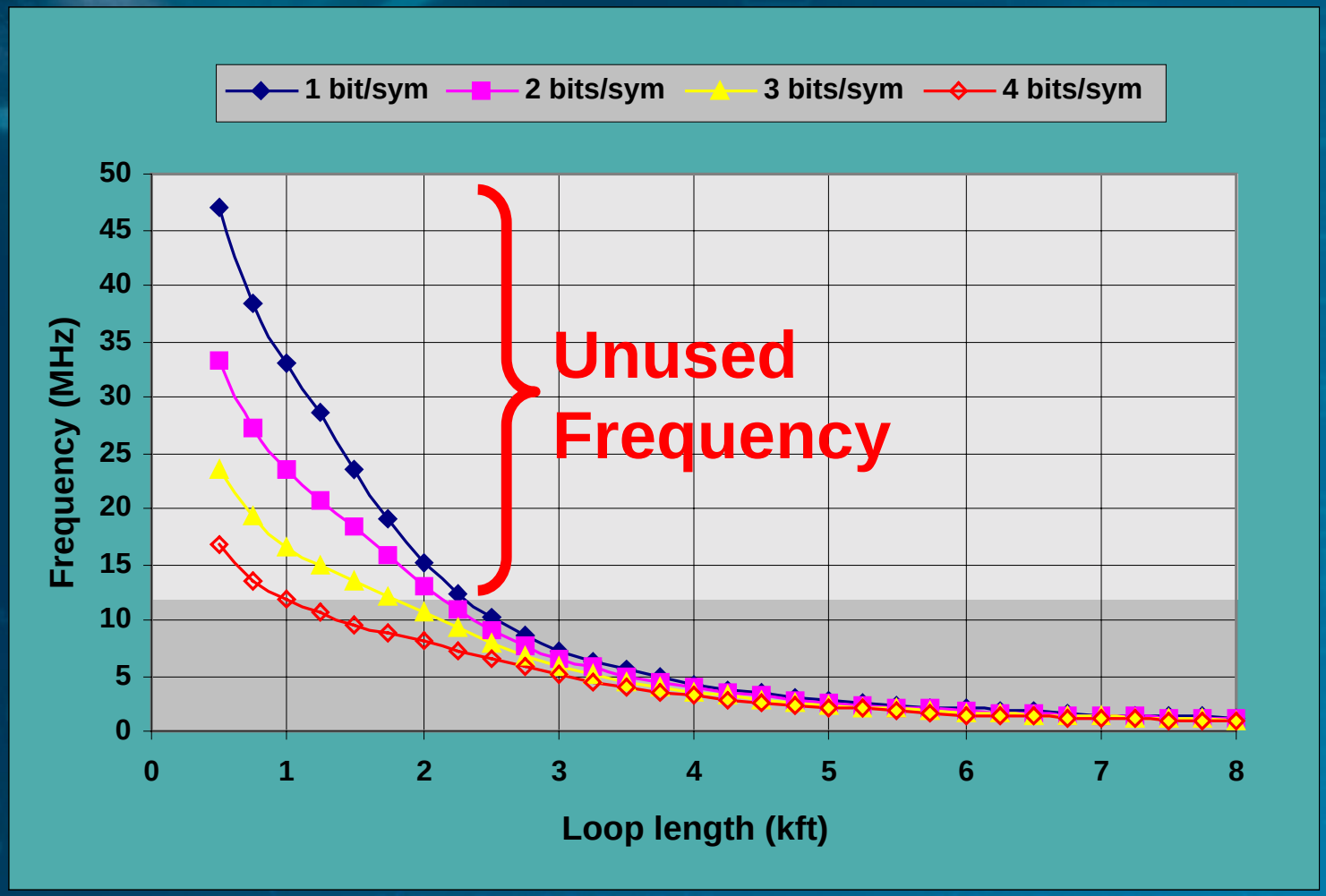
Choosing the frequency limit



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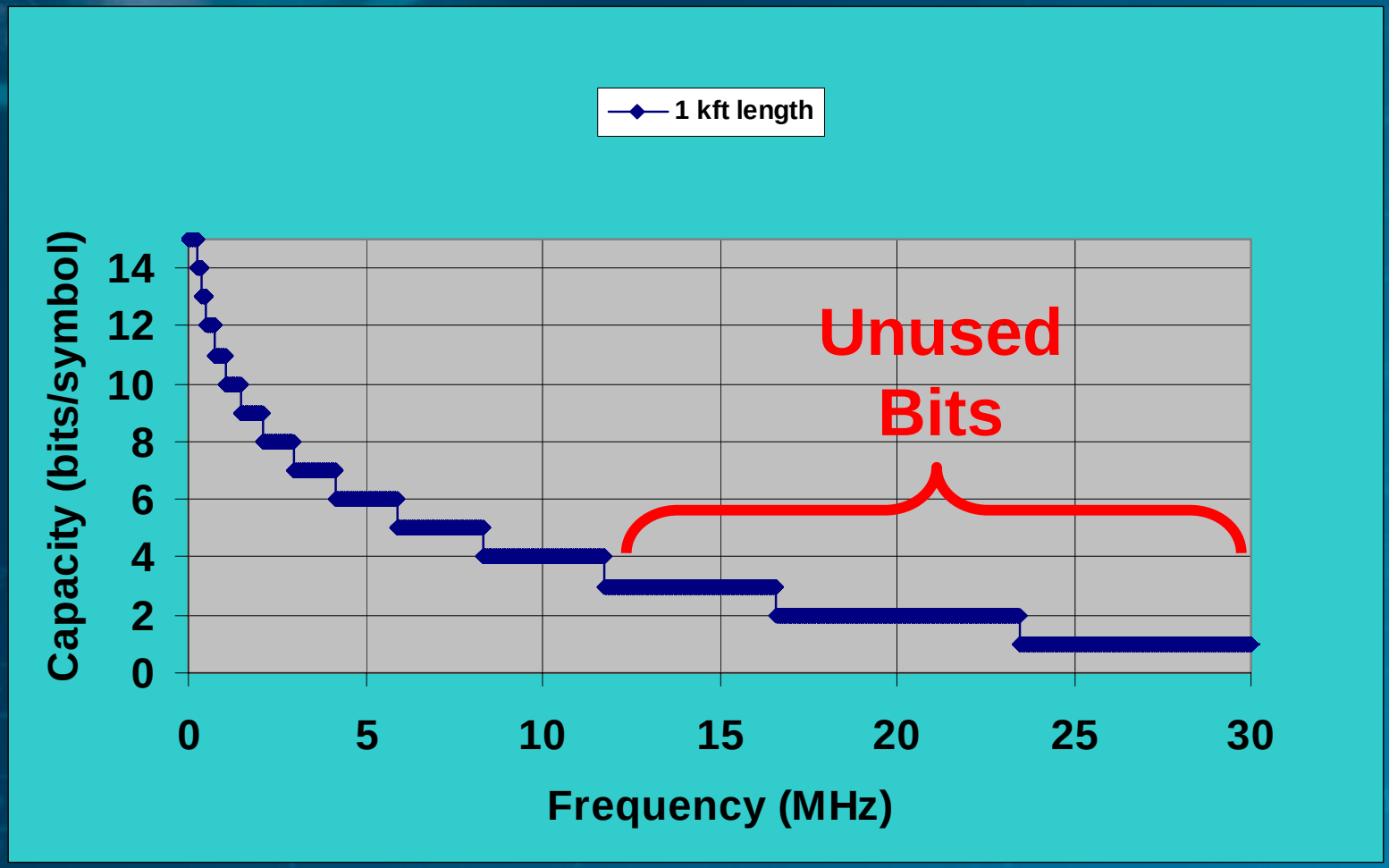
Choosing the constellation size



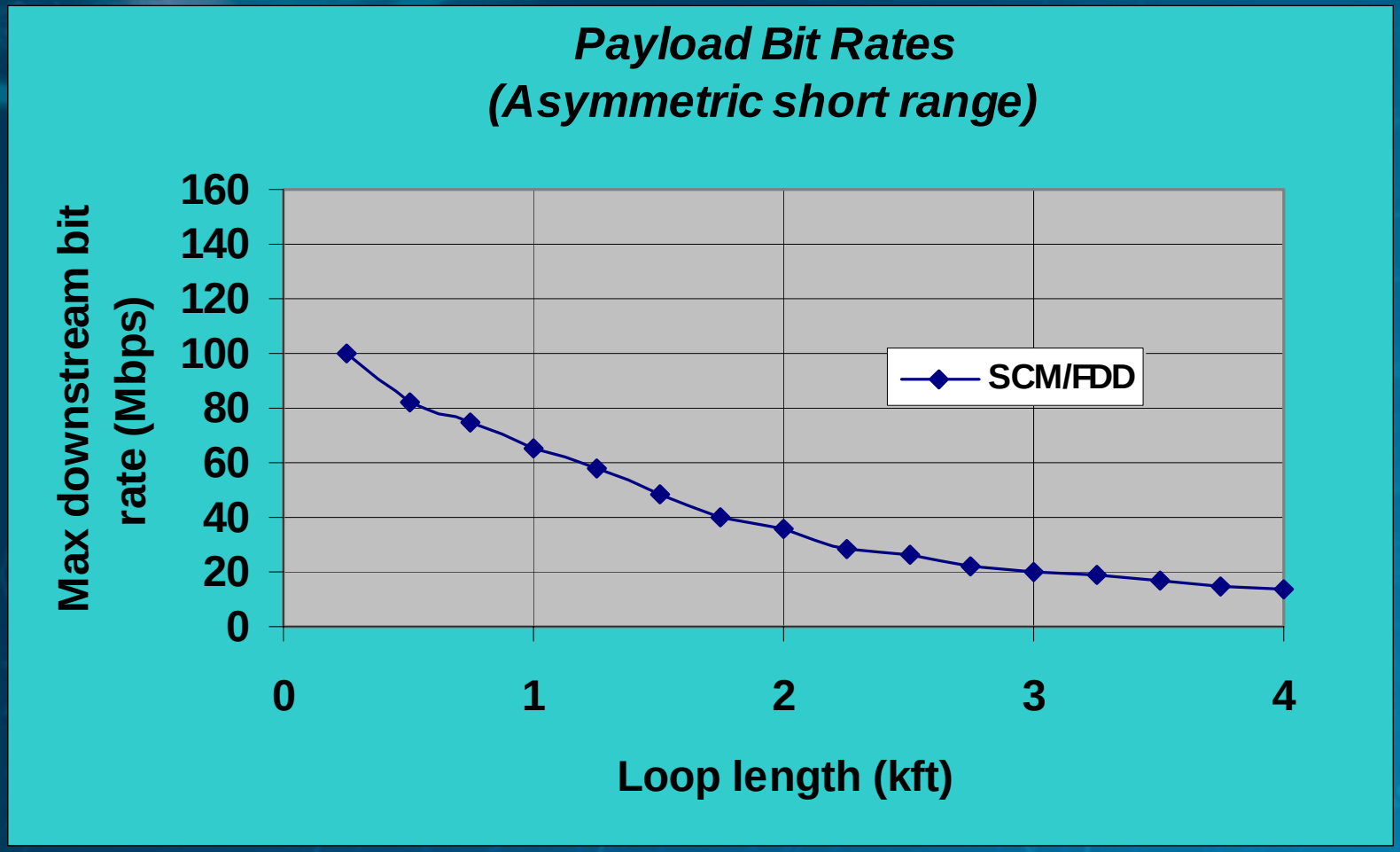
How do we take advantage of the loop plant characteristics ?

- Increase Bandwidth up to 30 MHz
- Increase maximum constellation size up to 15 bits/carrier/symbol
- Optimum Duplexing so no bandwidth is wasted
- Must maintain spectral compatibility

Simulation Conditions

- 10 Self NEXT/FEXT, no Alien Crosstalk
- -140 dBm/Hz AWGN noise floor
- 1e-7 BER with 6 dB margin
- 5:1 Downstream:Upstream Ratio
- VDSL spectral mask extended to 30 MHz
  - PSD less than –53 dBm/Hz
  - Transmitted power less than 14.5 dBm

SCM/FDD: Payload Capacity



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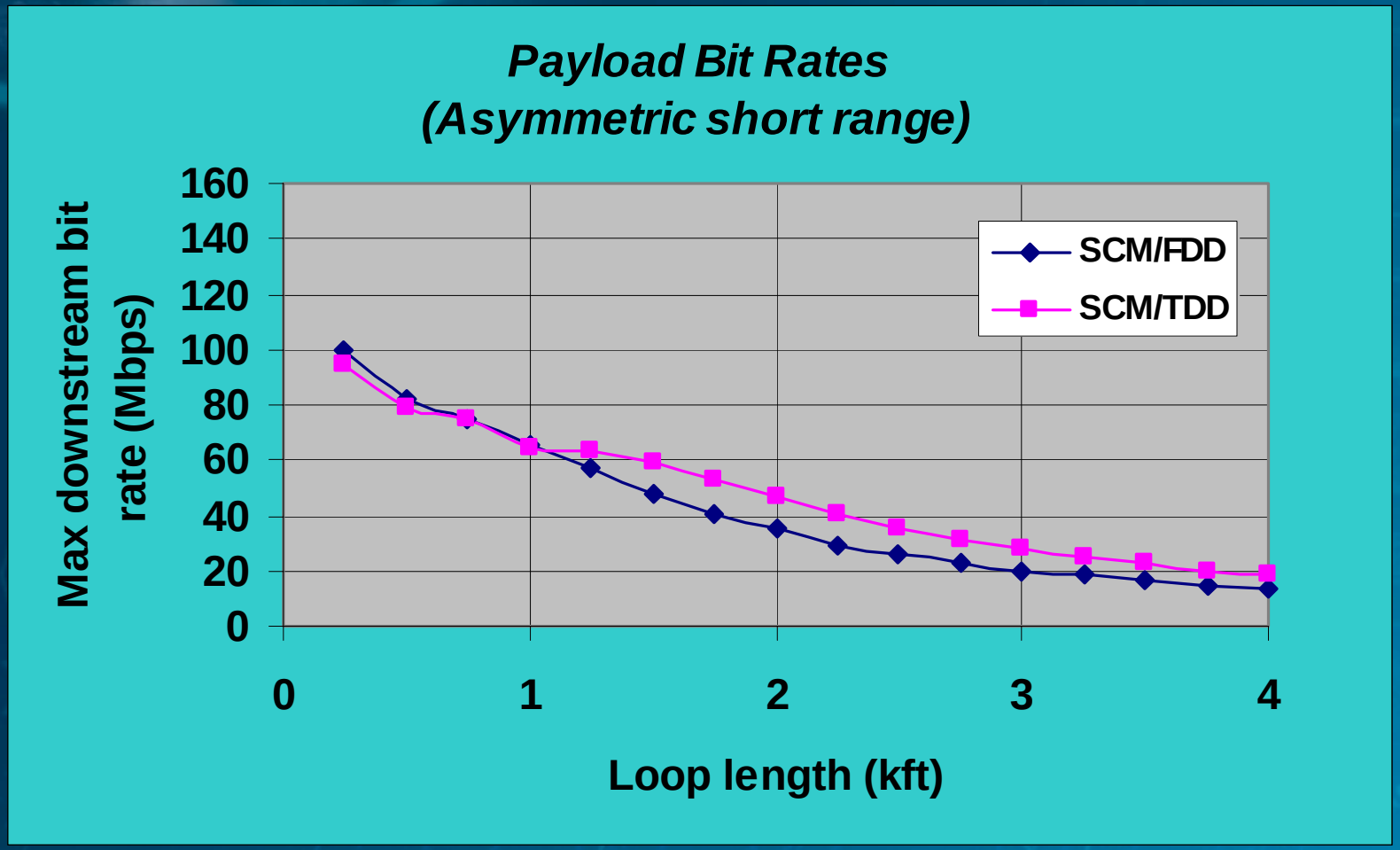
SCM/TDD: Payload Capacity



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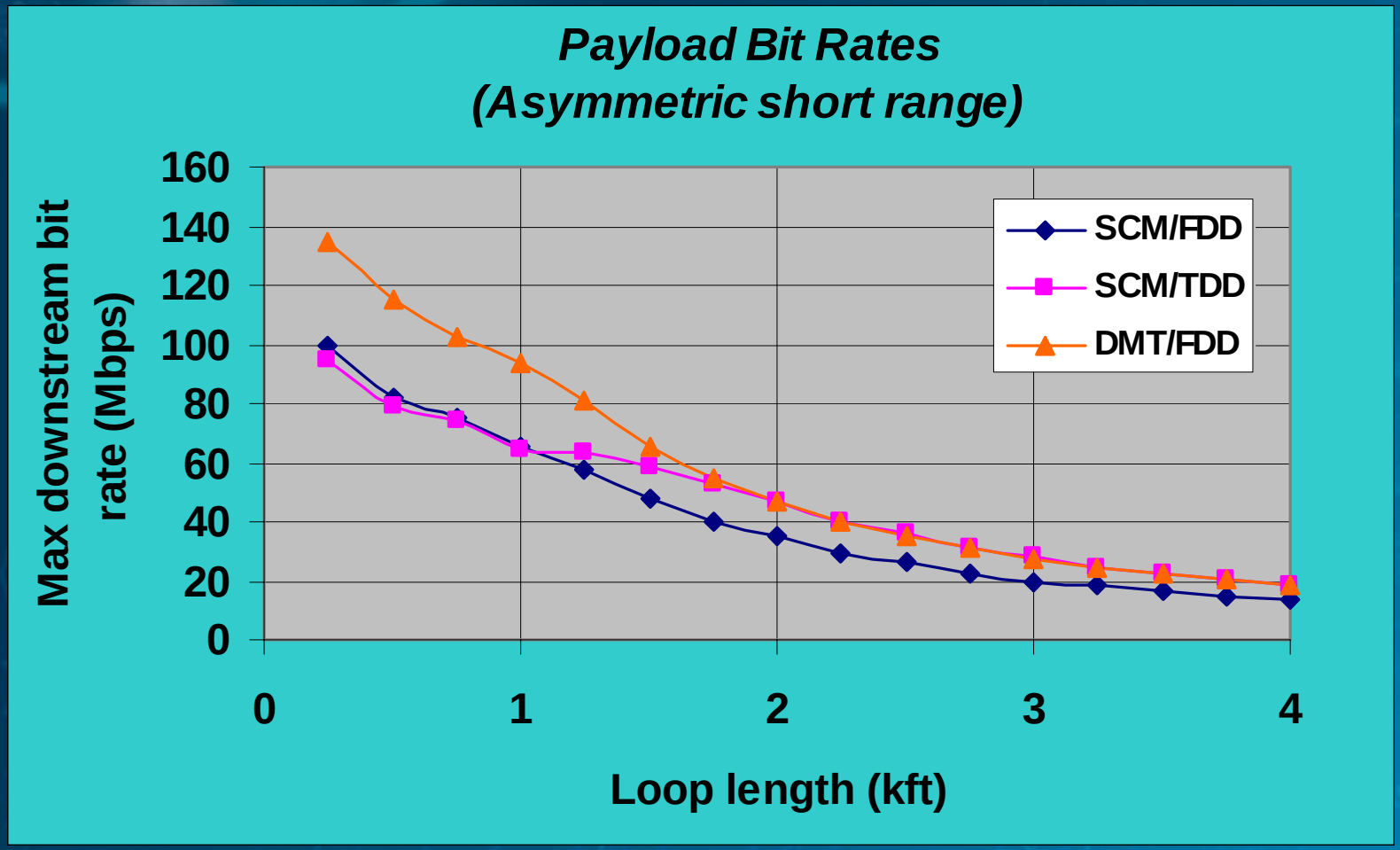
DMT/FDD Payload Capacity



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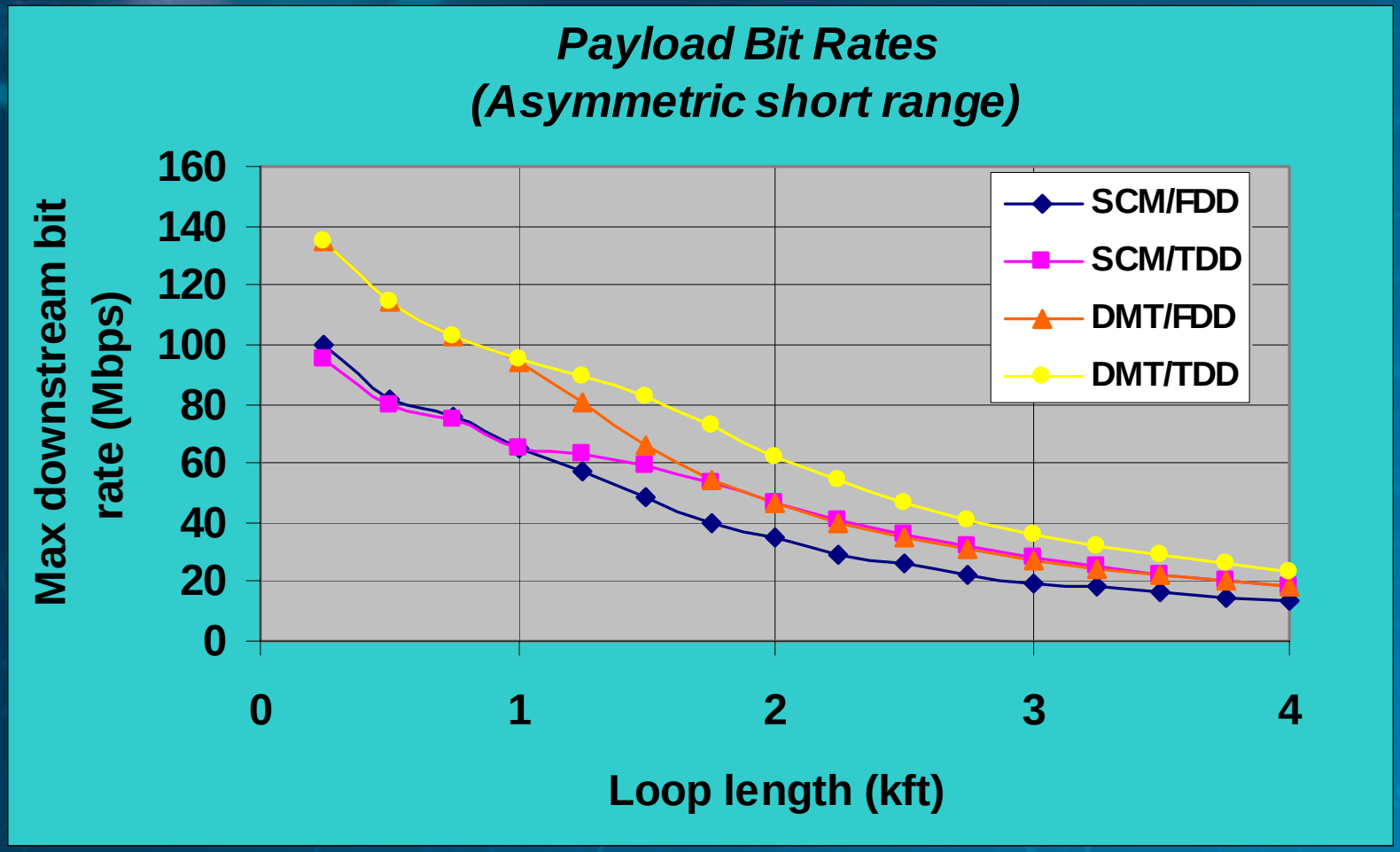
DMT/TDD Payload Capacity



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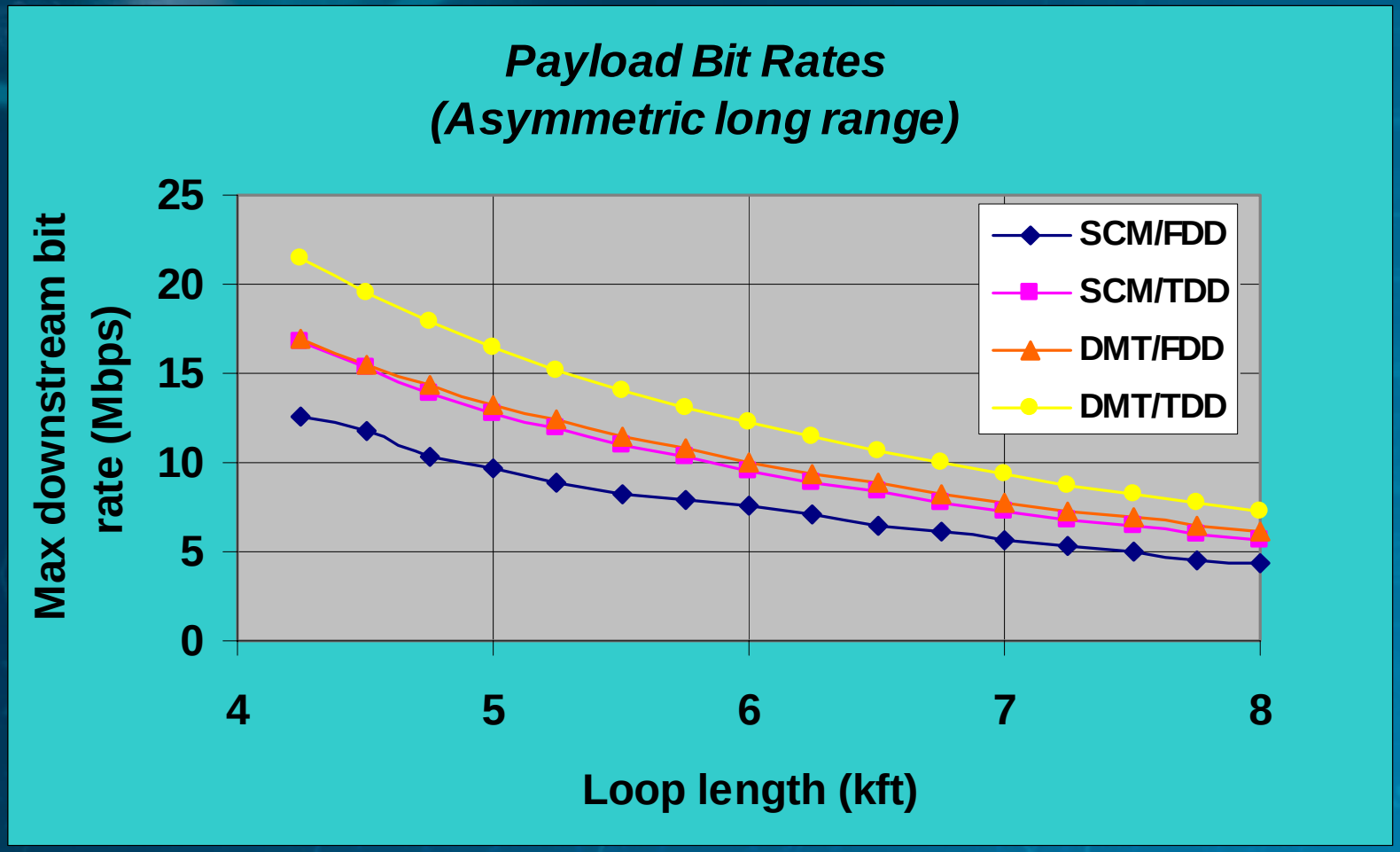
Long Loop Payload Comparison



Conclusions

EFM over copper can deliver 100 Mb/s

- Differentiate EFM from competing standards
- Future proof EFM
- Stepping stone to FTTH
- Ethernet Class performance to the home