MEGATRENDS DRIVING NEED FOR NEXT GENERATION CONNECTIVITY

- Transition to Next Generation Ethernet Solution Required
- Must Alleviate Critical Bandwidth Constraints in Global IT Infrastructure

Source: Cisco VNI Report, 2015
ENTERPRISE NETWORK STRUCTURE

• Enterprise networks follow: **Three Tier Design** Approach
  • Proven
  • Widespread
  • Stable topology

• More than 70% of enterprise campus wiring = Cat5e/Cat6

• Aquantia ICs increase speeds on Cat5e/Cat6 links:
  • Enterprise access switches
  • Wireless APs
WLAN UPGRADE CREATING BOTTLENECK IN ENTERPRISE NETWORKS

- Legacy wireless access connections dominated by 1000Base-T - 30W PoE
- Wireless transition to 802.11ac (Wave 1 & Wave 2) needs:
  - Multi-Gigabit speeds + 60W UPoE
- Aquantia’s 28nm ICs were designed for 5 speeds on 100 meters:
  - 10G Cat6A and Cat7
  - 5G/2.5G/1G/100M on Cat6A, Cat6, and Cat5e

New AP Deployments Require > 1G

WAPI Small Cell

802.11ac Wave 2: Creating bottlenecks on the AP and switch

CAT 5e: 5 Gbps

Wiring Closet
Enterprise Switch

4x1.25G

802.11ac: 6.9Gbps
802.11n: 600Mbps
802.11a/g: 54Mbps
802.11b: 11Mbps
802.11: 2Mbps

802.11ac Wave 2: Creating bottlenecks on the AP and switch

Aquantia: founding member
- 2.5G/5G electrical & interoperability specifications
MULTI-GIGABIT APPLICATION SPACE
1000BASE-T | 2.5G | 5.0G | 10GBASE-T SIGNALING

- Duplex transmission → Echo power >> Received power
- Self Near End (NEXT) and Far End (FEXT) Crosstalk
- Alien crosstalk noise from adjacent cables
- Environment specific interferences (e.g. Enterprise)
ESD IMPULSE NOISE IN ENTERPRISE

- ESD events are generally band pass (80MHz to 200 MHz)
  - Low duration, frequent in enterprise that interferes with the operation of data rates above 1000BASE-T
  - Such interference events increases the bit error rate of an otherwise properly operating data link
  - Example enterprise space: Visitors taking a seat & getting up in a public library
CABLING QUALITY: DATA CENTERS VS. ENTERPRISE

• Next generation Data Centers are built cleanly from scratch with new cabling

• Goal in Enterprise is to extend the life of existing cabling to the next generation

• Many enterprise cabling setups are qualified only up to 1000BASE-T (<62MHz)

• Poor cable return loss leads to large impulse reflections in full-duplex links
NON-LINEARITY IN TRANSMIT SIGNAL & RETURN LOSS

[Diagram showing signal transmission and echo cancellation]

- Tx
- Hybrid
- Magnetic
- Rx
- Echo Canceller
- Linear Echo
- Nonlinear Echo
- Cntr
10GBASE-T CODING

- 10GBase-T DSQ128 allows 128 combinations
- There are 7 bits/DSQ128 symbol
  - 3MSBs are uncoded
  - 4LSBs are FEC coded through LDPC
- These 3 uncoded bits are most vulnerable to large impulse noise
  - Dominant in Enterprise
HOW TO PROTECT ALL TRANSMIT BITS WITH LDPC?

• Gray-coded PAM16 signaling
  • PAM 16 = 4 bits per symbol
    • 8bits vs 7bits per 2 symbols
  • Additional bits per frame used to protect uncoded bits by same LDPC machinery
  • Combination of LSB & MSB bits in the LDPC Frame
    • Higher number of encoding bits improves FEC gain by over 1dB

• Robust to non-stationary impulse noise & AFE imperfections

• Otherwise, a scaled version of 10BASE-T
• 5Gb/s via fully LDPC coded PAM 16 running at 400Ms/s
• 2.5Gb/s via fully LDPC coded PAM 16 running at 200Ms/s
• Fully Encoded PAM16 An FEC extended to uncoded bits
  • Removes errors caused by noise spikes
  • Provides additional margin for ESD events
  • Relaxes the PHY transmit linearity spec significantly
  • Relaxes the magnetic RL requirement
AQUANTIA PHY BLOCK DIAGRAM

- PHY analog & digital blocks architected to power scale proportional to data rates 10G/5.0G/2.5G
  - Analog power saving achieved by modifying performance requirement
- USXGMII SerDes runs at fixed 10Gbps at all PHY data rates to simplify system interface
AQUANTIA PHY CHIP (28nm)

- Analog frontend with 5 receive channels and 4 transmit channels
  - 5\textsuperscript{th} receive to sense/cancel in band RFI
  - Combination of LC & ring PLLs to cover all required speeds
- High-Gain LDPC FEC $\rightarrow$ 128DSQ: $\sim8$dB, PAM16: $>9$dB
- Modular FIR filters combined with convergence engines
- Supporting:
  - 1588 & PTP Features, Energy Efficient Ethernet (EEE), MACSEC

- Chip Area: 40mm\textsuperscript{2}
- Power: 1W, 2W, 3W for 2.5G, 5G, 10G
IEEE PERFORMANCE SPECIFICATION FOR 2.5G | 5.0G

- **2.5 Gb/s PHY** specified for operation over:
  - Up to at least 100m on four-pair Class D (Cat5e) balanced copper cabling on defined use cases and deployment configurations

- **5 Gb/s PHY** specified for operation over:
  - Up to at least 100m on Class E (Cat6) balanced copper cabling on defined use cases and deployment configurations
  - Up to 100m on Class D (Cat5e) balanced copper cabling on defined use cases and deployment configurations
2.5Gbps ALIEN X-TALK LIMIT LINES (BER<1E-12)

ANEXT

10GBASE-T

18dB

2.5Gbps

AELFEXT

10GBASE-T

18 dB

2.5Gbps
5.0Gbps ALIEN X-TALK LIMIT LINES (BER<1E-12)

ANEXT

5Gbps

10GBASE-T

12dB

AELFEXT

5Gbps

10GBASE-T

12 dB
Cat5e & Cat6 SINGLE-CABLE PERFORMANCE SETUP
2.5Gbps | 5.0Gbps PERFORMANCE OVER SINGLE CABLE

• 2.5Gbps reach for BER<1E-12
  • Over ~195m of Cat5e
    • Cable IL = ~42dB@100MHz → **18dB** exceeding Cat5e limit line

• 5.0Gbps reach for BER<1E-12
  • Over ~125m of Cat5e
  • Over ~135m of Cat6
    • Cable IL = ~43dB@250MHz → **9dB** exceeding Cat6 limit line
6around1 CABLE COMPLIANCE RACKS (Cat6A/Cat6/Cat5e)
2.5Gbps/5.0Gbps PERFORMANCE On 6around1 CABLE

• 2.5Gbps reach for BER<1E-12
  • Over ~135m of Cat5e (Full length 6@1)
    • Cable IL = ~29dB@100MHz → Margin to CAT5e Limit= -5dB

• 5.0Gbps reach for BER<1E-12
  • Over ~100m of Cat6 (Full length 6@1)
    • Cable IL = ~32dB@250MHz → Margin to Cat6 Limit= 2dB
ALIEN X-TALK OF FULL 100M 6around1 CABLE SETUPS

ANEXT

dB

0 25 50 75 100 125 150 175 200 225 250

100m Cat6A 6around1

10Gbps

5Gbps

100m Cat6 6around1

AELFEXT

dB

0 25 50 75 100 125 150 175 200 225 250

100m Cat6A 6around1

10Gbps

5Gbps

100m Cat6 6around1
IEEE DEFINED WAP ENTERPRISE USE CASE

Typical Uniform Cell Size

- **L_max = 13m (42ft)**
- **R = 13m (42ft)**
- **X = 18.3m (60ft)**
- **H_max = 80m (262ft)**
- **max 6m (20ft) equipment cord**
- **Active equipment**

Cell sizing (wireless access points placed anywhere inside the cell)

http://www.ieee802.org/3/NGBASET/email/pdfy0VqAHwIWI.pdf
6around1 CABLE BUNDLED CONFIGURATIONS

- **6@1 Bound by Binders Across the Cable**
  - ~9dB improvement of alien xtalk

- **6@1 Tied by Straps every 4ft (Most Common)**
  - 20dB improvement in alien xtalk

- **Unbound Cables (e.g. Conduits)**
  - 20dB improvement in alien xtalk

http://www.ieee802.org/3/10GBT/public/mar03/vanderlaan_1_0303.pdf
Cat6 ALIEN X-TALK: TYPICAL ENTERPRISE INSTALLATIONS

- Configuration:
  - 24 Cat6 Cables
  - Tied every 5 feet
  - Tied length <80m
  - Victim at center of bundle
  - Routed to the ceiling

- X-Talk Measurement meets the target 5Gbps alien xtalk limit lines!

http://grouper.ieee.org/groups/802/3/tutorial/nov02/tutorial_2_1102.pdf
CONCLUSION

• The ever growing data requirements in the cloud and mobility are creating a bandwidth constraint in global IT infrastructure

• In 2012, Aquantia focused on adding 2.5G/5G speeds on Cat5e/Cat6 Links to address the next generation wireless access bottleneck

• Aquantia’s five speed ICs (single, dual, and quad) are the only commercially available NBASE-T compliant ICs since 2013

• Five speed ICs from Aquantia has been shipping in large volumes in all major switch and AP platforms since 2014