



2.5G AND 5GBASE-T TECHNOLOGY – MULTI-VENDOR INTEROP HERE TODAY WEBINAR

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2016 BASE-T Plugfest Report Out

March 9, 2017



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- Opinions expressed during this presentation are the views of the presenters, and should not be considered the views or positions of the Ethernet Alliance or NBASE-T Alliance.



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Today's Speakers



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Principal Engineer, Cisco Systems

The BASE-T Family!



ethernet alliance



Ethernet Alliance – Mission & Priorities

A global community of end users, system vendors, component suppliers and academia

Mission

- Promote existing and emerging IEEE 802 Ethernet standards
- Accelerate industry adoption
- Demonstrate multi-vendor interoperability

2017 Strategic Priorities

- Support existing technology deployment
- Support IEEE 802 standards development
- Marketing & Education



“The Voice of Ethernet”

NBASE-T Alliance – Mission & Priorities

The worldwide network of companies that breathe new life into network infrastructure

Mission

- To facilitate, encourage and expand the widespread use and deployment of 2.5G and 5G BASE-T Ethernet.

2017 Strategic Priorities

- Expand NBASE-T product ecosystem
- Promote 802.3bz standard and NBASE-T specifications
- Sponsor interoperability programs
- Educate market about multiple applications of the technology

2.5GBase-T and
5GBase-T on
Cat5e/Cat6



About UNH-IOL



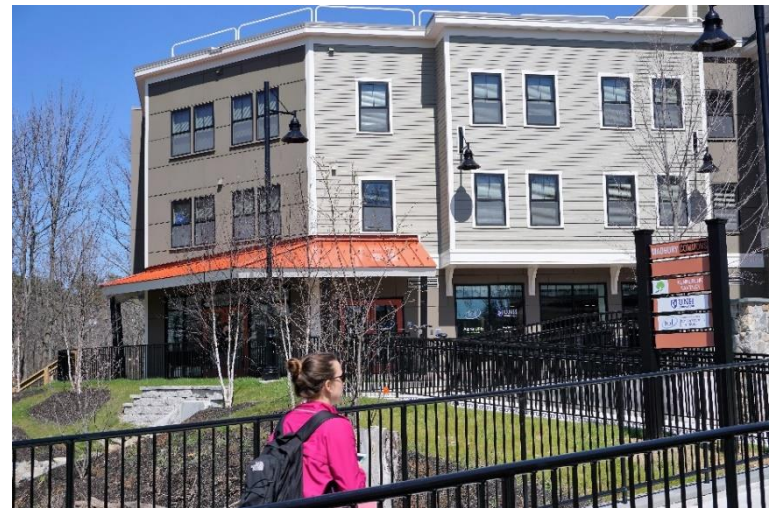
University of New Hampshire
InterOperability
Laboratory

The *UNH-IOL* is a neutral, third-party laboratory dedicated to testing data networking technologies through industry collaboration.



21 Madbury Rd., Ste 100,
Durham, NH 03824
<http://www.iol.unh.edu>

Many thanks to UNH-IOL
for hosting our event!



Agenda

- What is a Plugfest?
- Why 2.5G/5GBASE-T - A Recap
- Plugfest Event Participants
- Test Descriptions
- Results
- Recommendations and Summary

What is a Plugfest?

(a.k.a. Interoperability Event)

- An important element in the Ethernet ecosystem
 - An open, multi-vendor environment has been key to the wide adoption of Ethernet
- Goal: For the benefit of end users - insure that products from different companies, designed to the same specification, can interoperate
- Bring together products and developers from multiple companies in a neutral, confidential environment
 - Confidential because we are often testing pre-released products
- Test new technology, new specification
 - There may be surprises...
- Test pre-release products
 - Find the surprises and fix them before the products hit the market

2016 BASE-T Interoperability Event

- Co-sponsored by the Ethernet Alliance and the NBASE-T Alliance
- Testing venue: Univ. of New Hampshire's Interoperability Lab (UNH-IOL)
- Event held the week of October 10th, 2016
- Event Focus:
 - New technology: 2.5G/5GBASE-T
 - IEEE Std 802.3bz™-2016 ratified in September 2016
 - Demonstrate interoperability of 2.5G/5GBASE-T ports from multiple manufacturers
 - Most ports tested also supported 10GBASE-T, all ports also supported 1000BASE-T
 - Demonstrate speed negotiation capability between supported rates
 - Demonstrate compatibility between NBASE-T and IEEE 802.3bz specifications
 - Provide an opportunity to work the kinks of out of new technology and products
 - Demonstrate that this stuff works!

Participant Overview

15 participating companies representing a cross section of the Ethernet ecosystem: NIC, wireless AP, switches, cabling, conformance test equipment, cable tester, protocol test equipment, PHY silicon



ethernet alliance

802.3 Ethernet and 802.11 WLAN: Deployments Today



Access Switch

Mostly 1000BASE-T ports
PoE PSE (15/30w, 4PPoE)



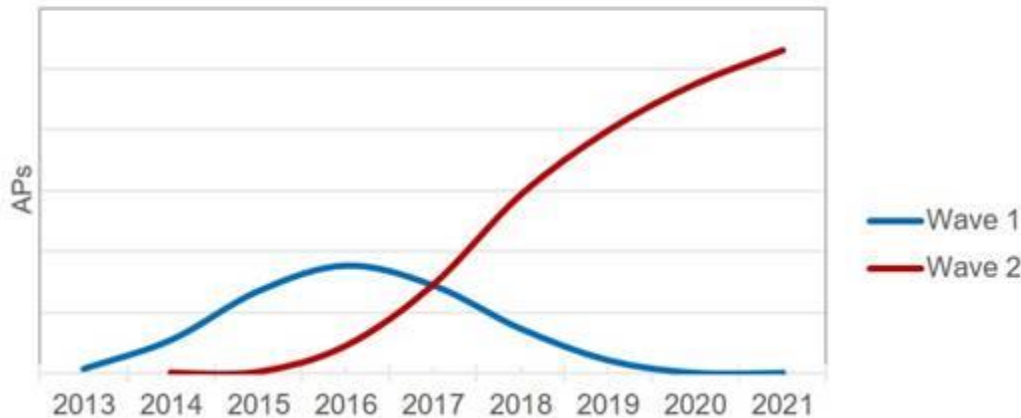
Access Point

Connects 802.11 to 802.3
PoE PD (Powered Device)
Footprint sensitive (e.g. power, heat, etc.)
11acWave 2 drives backhaul traffic > 1 Gb/s.
No easy way to get above 1Gb/s.

Cabling

Cat 5e/6/6A up to 100M
New installs using Cat 6A for 10+yr life

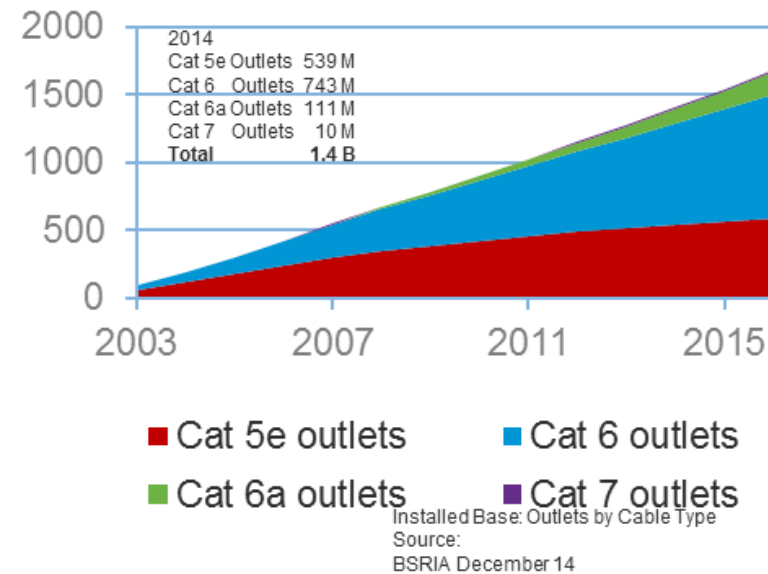
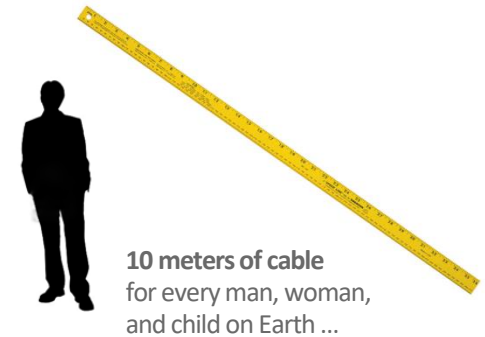
Enterprise AP 802.11ac Wave Transition
Source: Dell'Oro Group Jan 2017



- The needs of 802.11ac Wave 2 access points demanded development of NBASE-T/802.3bz
 - Must support: >1Gbps rates, installed cabling and PoE
 - Ramping fast!

Why 2.5G and 5GBASE-T?

- Between 2003 to 2014 ~70 billion meters¹ of Cat 5e and Cat 6 cabling were sold....
 - In 2014, 1.3 Billion outlets, ~90% of installed base
 - Enormous network infrastructure investment
- Existing specifications support 1Gb/s over this cable, but faster data rates are possible
- BASE-T allows incremental upgrade
 - **Let's get more value from this investment!**
 - **Enable the Next Ethernet Era**

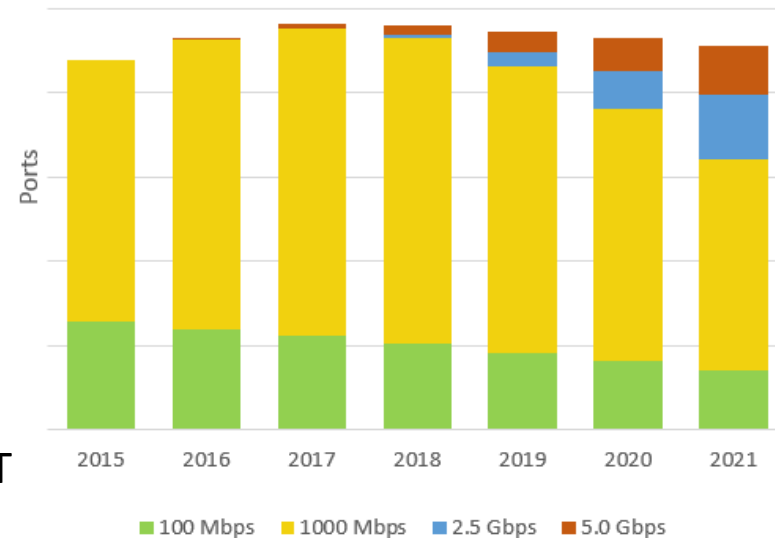


¹Source: BSRIA December 2014

Where are we now?

- Providing 2.5Gbps and 5Gbps over installed cabling
- 802.11ac Wave 2 APs shipping with > 1Gbps wired backhaul
- IEEE Std 802.3bz™-2016 received final approval September 2016
- Joint EA & NBASE-T Plugfest October 16
- Cabling guideline documents now available to support rollouts
- Rapid transition from 100/1000M to 2.5G/5GBASE-T
 - **Combined forecast says 25% of switch ports will be 2.5G/5GBASE-T**
 - **5 million switch ports in 2017, growing to over 100M in 2021***

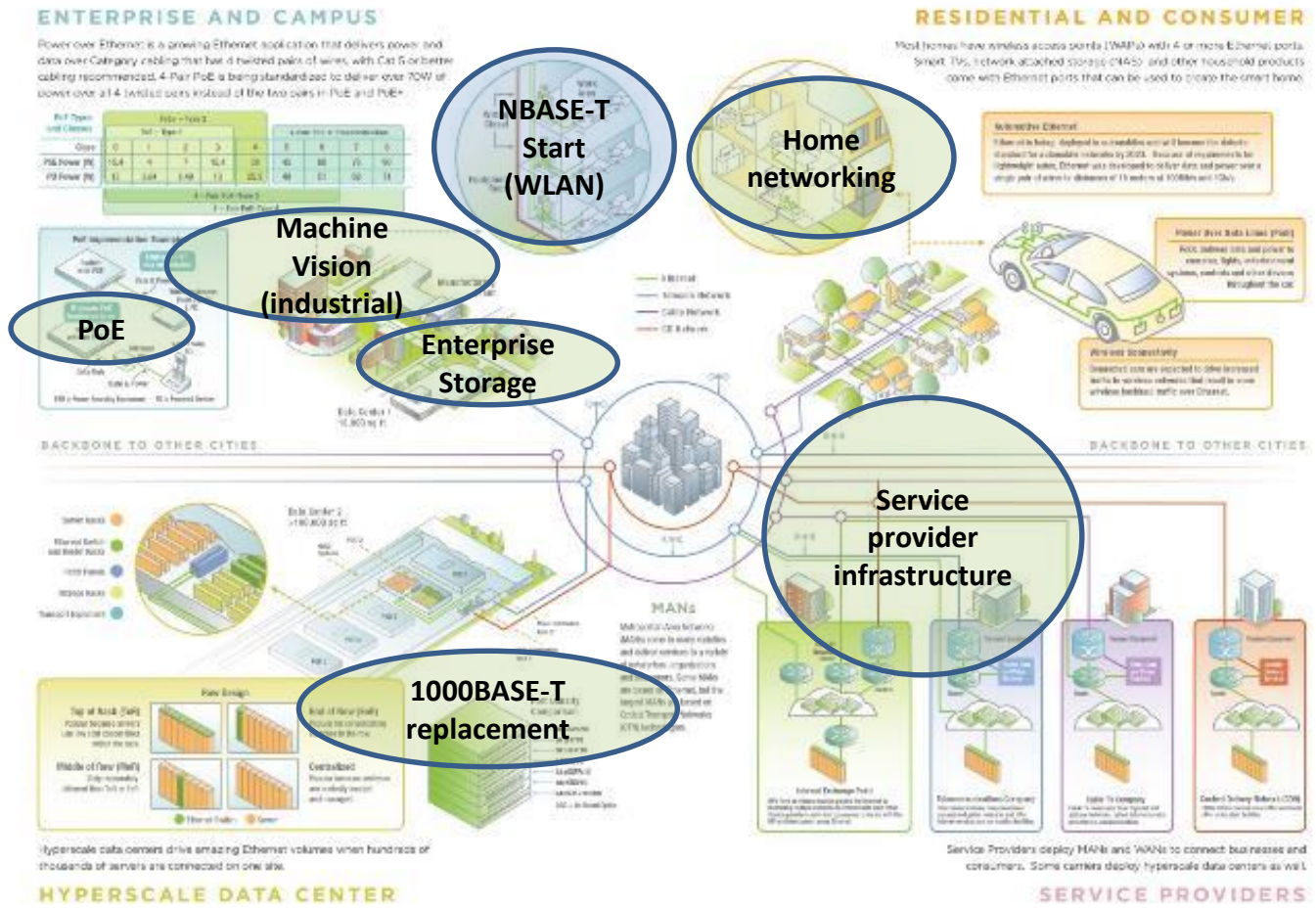
100M/1000M to 2.5G/5G transition
Source: Dell'Oro Group Jan 2017



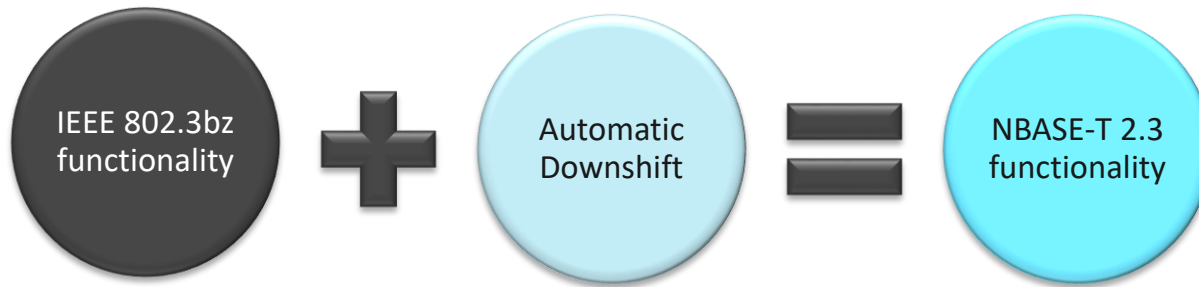
* Dell Oro – January 2017

Filling out the Roadmap

ETHERNET ECOSYSTEM



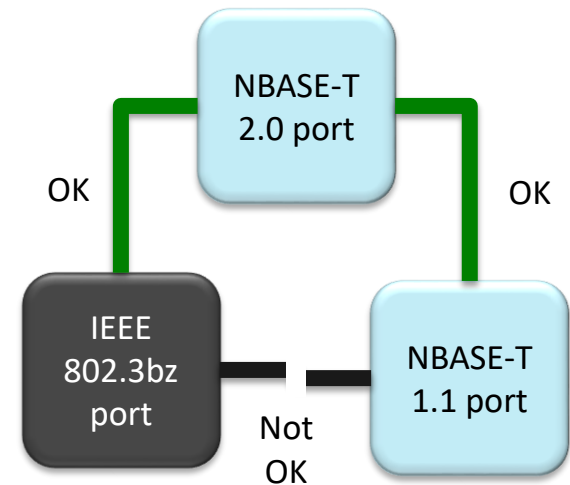
IEEE/NBASE-T Comparison



- Automatic Downshift capability supported with NBASE-T 2.3
 - Prevents loss of connectivity in challenging cable environments

IEEE and NBASE-T: Compatibility and functionality with NBASE-T 2.3

- History: NBASE-T 1.0 released prior to start of IEEE P802.3bz
- NBASE-T 2.3 covers compatibility with both IEEE Std 802.3bz™ - 2016 and NBASE-T 1.1
- Recommend building new products with NBASE-T 2.3 support (not just IEEE 802.3bz) to maintain compatibility with legacy NBASE-T 1.1 ports
- Upgrade NBASE-T 1.1 ports with new NBASE-T 2.3 firmware



Test Case Overview

Interoperability Testing

- **Link up test:** Tests the basic capability for two devices under test (DUT) to establish link
- **Frame Error Rate (FER) test:** Data frames were passes between devices and monitored for errors to demonstrate 1E-12 bit error ratio required by the specifications

Downshift Testing

- By injecting a controlled amount of noise onto the Cat5e cables using test equipment, downshift tests demonstrate that ports can transition to lower data rates when the noise exceeds the specifications for a higher data rate

6 Around 1 Testing

- Although not a requirement of the standard, 6-around-1 tests provide an informative demonstration of a port's ability to operate in the presence of noise. In this case, noise is injected onto the "victim" cable by tightly coupling 6 "aggressor" cables around the victim, and running active links (1000BASE-T, 2.5GBASE-T) on the aggressor cables while FER tests are run on the victim.

Conformance Testing:

- Electrical test equipment was provided by two different vendors. Tests were run on the active ports using this equipment to show conformance to the 2.5G/5GBASE-T specifications. Test and measurement vendors also benefit from plugfest by having more ports to test and optimize their test suites.

Interoperability Test Cases

13 different devices from 10 companies - 78 unique pairings

For every interoperability pair, up to 12 tests were performed

1. Basic Link establishment

- Link @ IEEE 2.5G
- Link @ IEEE 5G
- Link @ NBASE-T 2.5G
- Link @ NBASE-T 5G

2. Basic FER*

With Panduit Category 5e channels...	With Berk-Tek Category 5e channels...
<ul style="list-style-type: none">• FER @ 2.5G with 5meter link segment• FER @ 2.5G with 100meter link segment• FER @ 5G with 5meter link segment• FER @ 5G with 100meter link segment	<ul style="list-style-type: none">• FER @ 2.5G with 5meter link segment• FER @ 2.5G with 100meter link segment• FER @ 5G with 5meter link segment• FER @ 5G with 100meter link segment

- *8-minute tests, 800-byte frames -> Verifies 1e-12 BER @ 5G and 2e-12 @ 2.5G

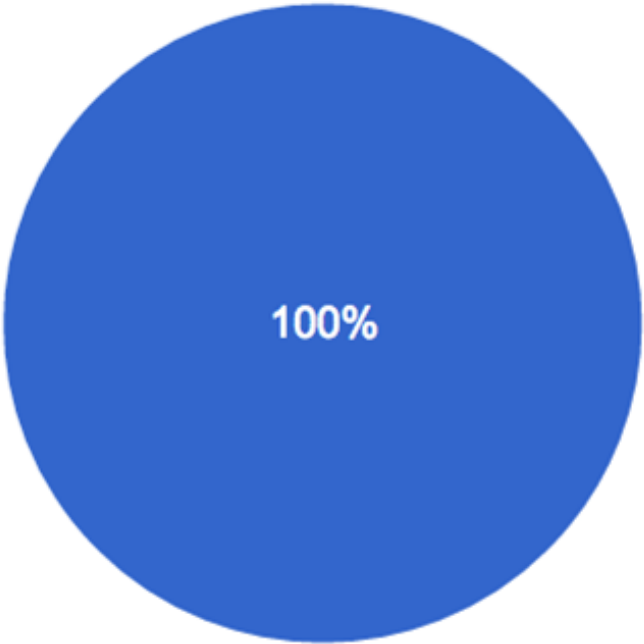
Basic Link/FER Pairings – 78 Combinations

	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	DUT9	DUT10	DUT11	DUT12	DUT13
DUT1													
DUT2	x												
DUT3	x	x											
DUT4	x	x	x										
DUT5	x	x	x	x									
DUT6	x	x	x	D	x								
DUT7	x	x	x	D	x	x							
DUT8	x	x	x	x	x	x	x						
DUT9	x	x	x	x	x	x	x	x					
DUT10	x	x	x		x	x	x	x	x				
DUT11	x	x	x	D	x	x	x	x	x	D			
DUT12	x	x	x	x	x	x	x	x	x	x	x		
DUT13		x	x	D		x		x	D		x	x	

Basic Link Results Overview

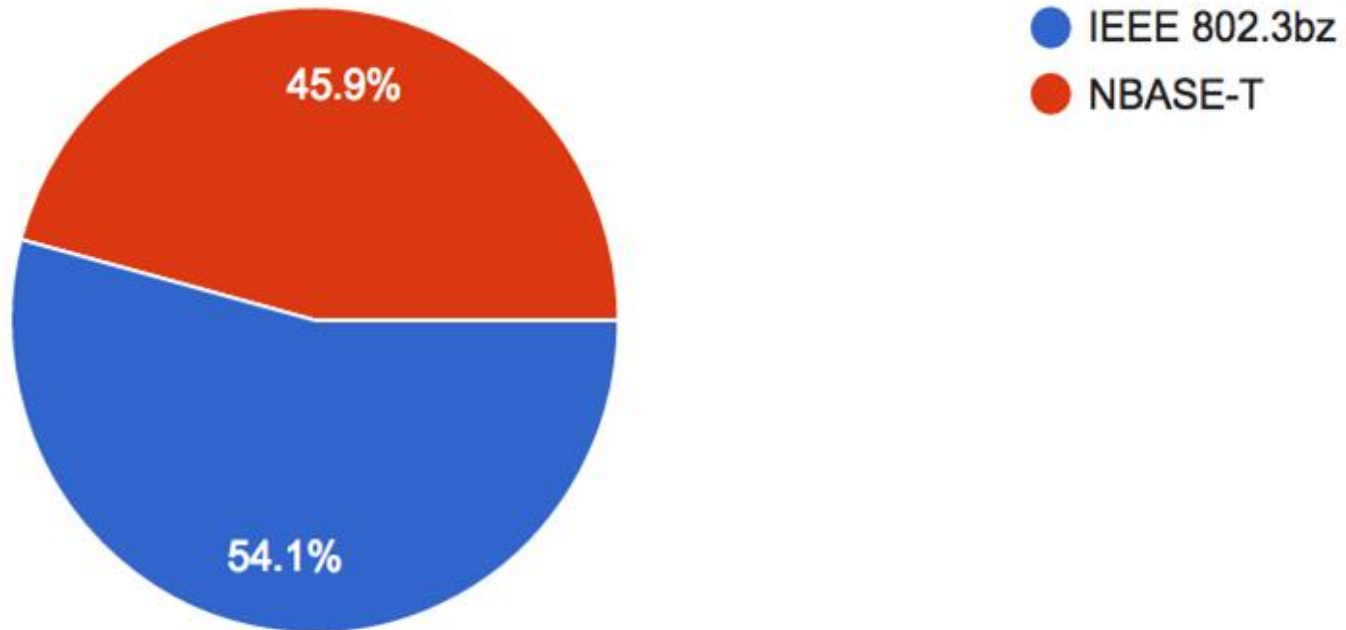
Results for 591 Link Up Trials

Link Success Rate

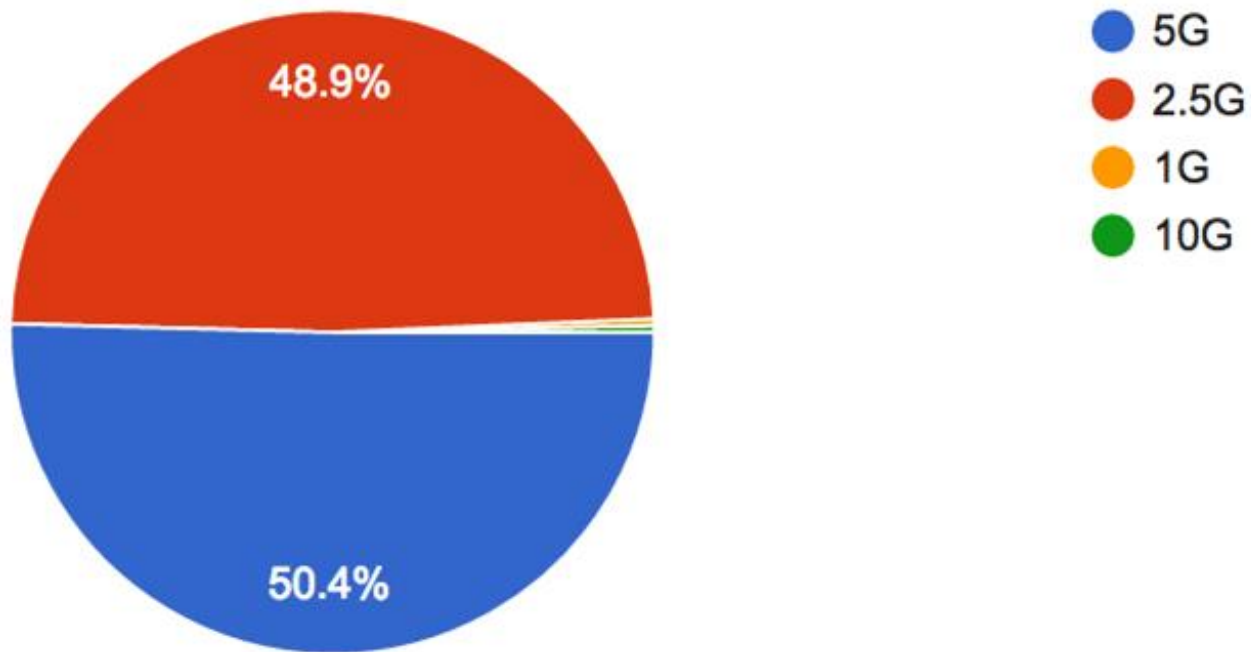


- Yes
- No

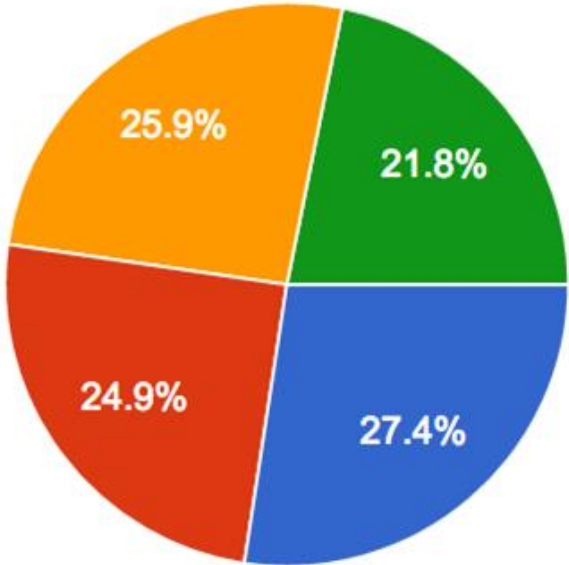
Specification Used for Auto-Negotiation



Speed of Link



Category 5e Link Segment Used

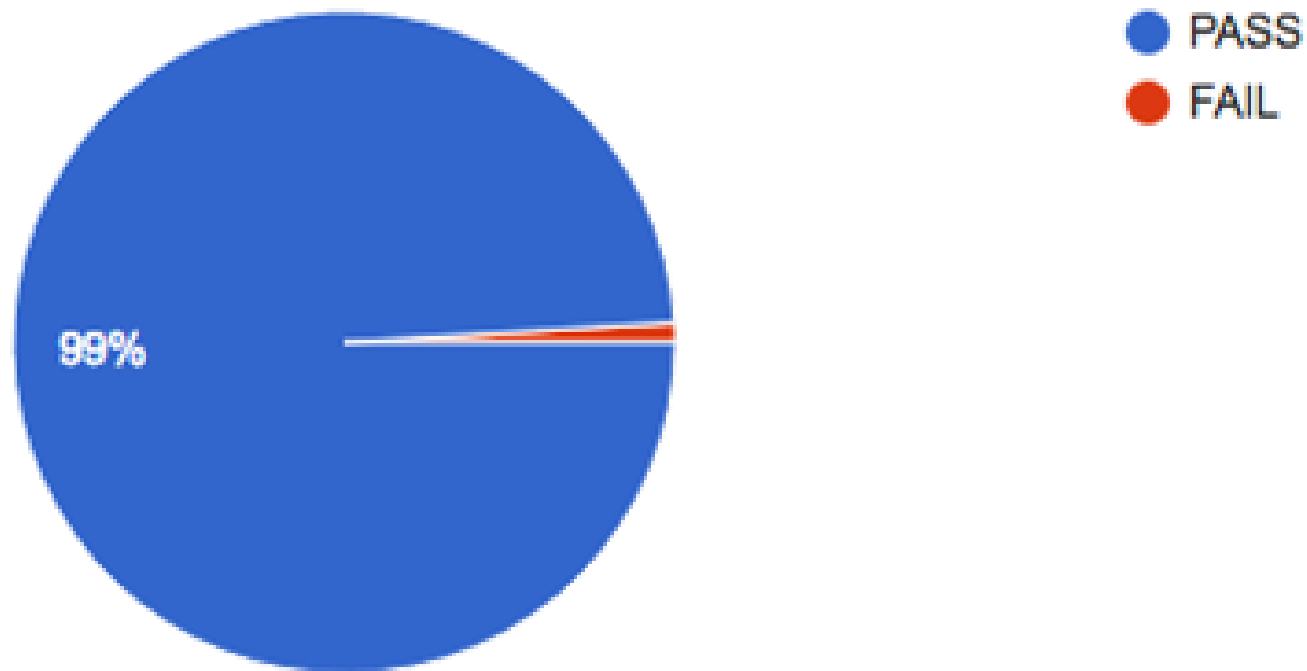


- Vendor A Short (5m)
- Vendor A Long (100m)
- Vendor B Short (5m)
- Vendor B Long (100m)

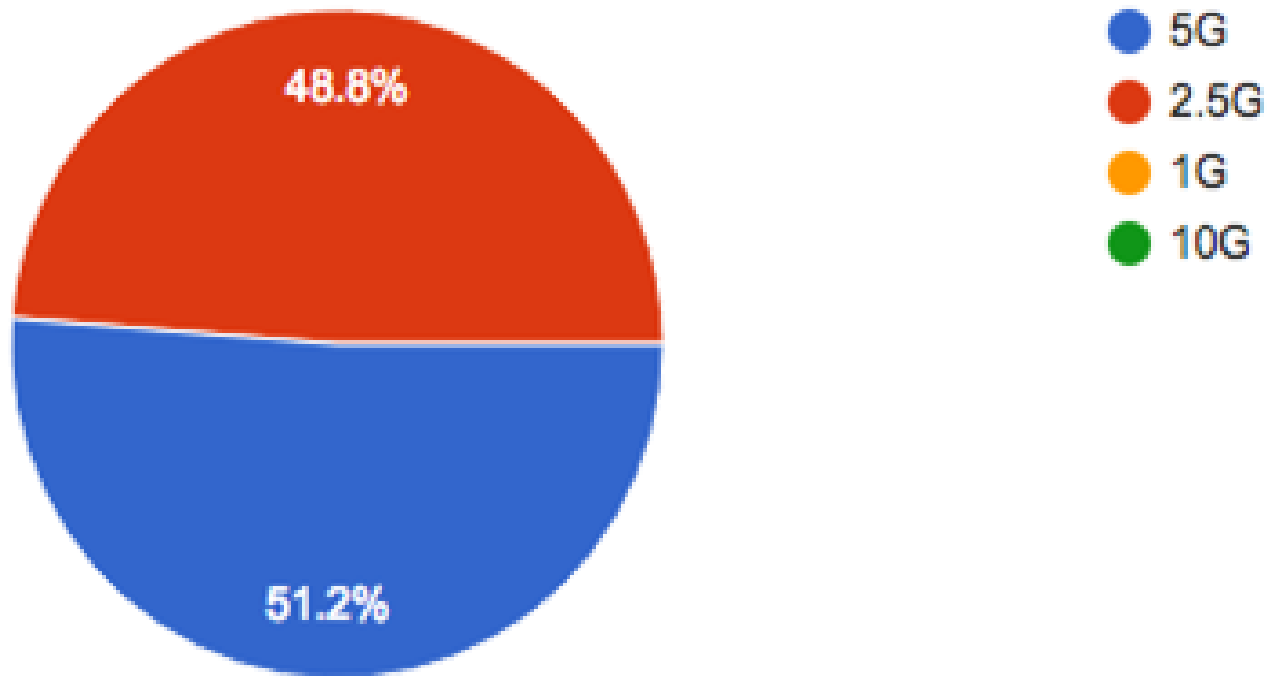
FER Results Overview

Results over 523 trials

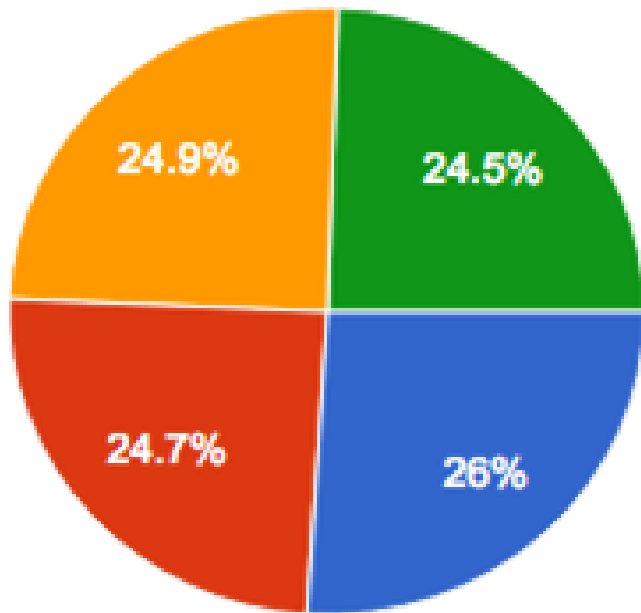
Frame Error Rate Results



Speed Tested



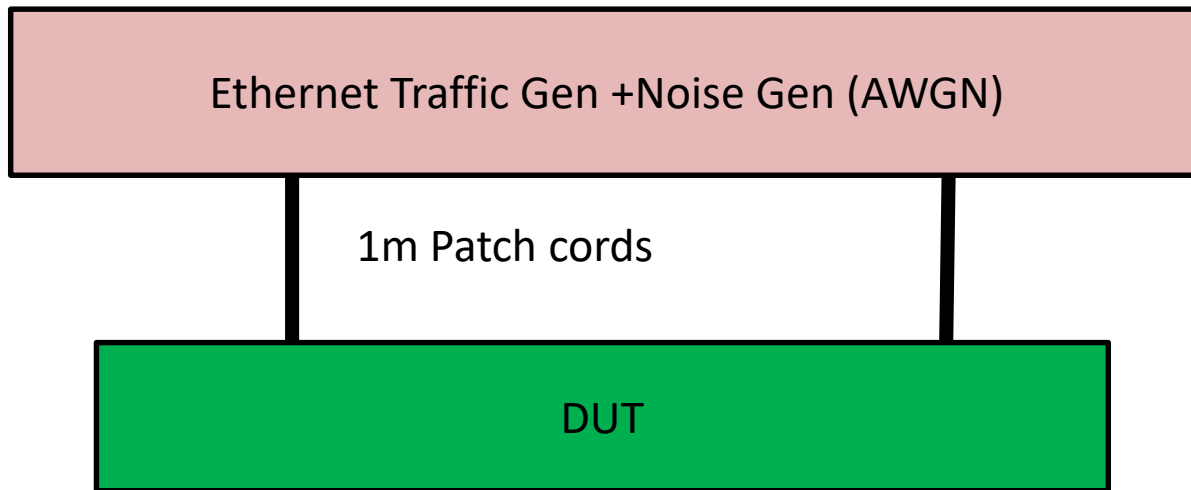
Link Segment Used



- Vendor A Short (5m)
- Vendor A Long (100m)
- Vendor B Short (5m)
- Vendor B Long (100m)

Downshift Test Setup/Procedure

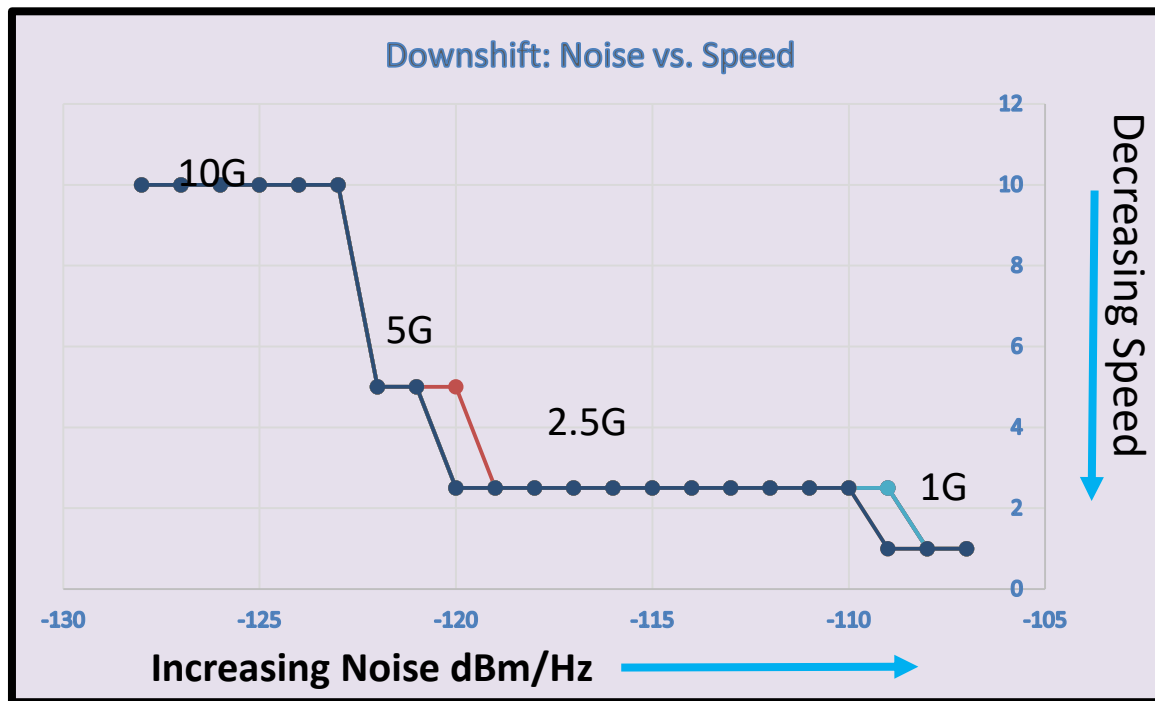
- Devices connected to tester via 1m patch cable
- All speeds enabled on both devices
- Link events initiated by the tester by restarting auto-negotiation
- After link is established at the highest speed supported by DUT (10G or 5G)
 - AWGN noise is injected into the test channel while link is active
 - The noise power is increased in 1dB increments; recorded noise level which triggered downshift



Noise Generator allows consistent repeatable test compared to 6-a-1 test

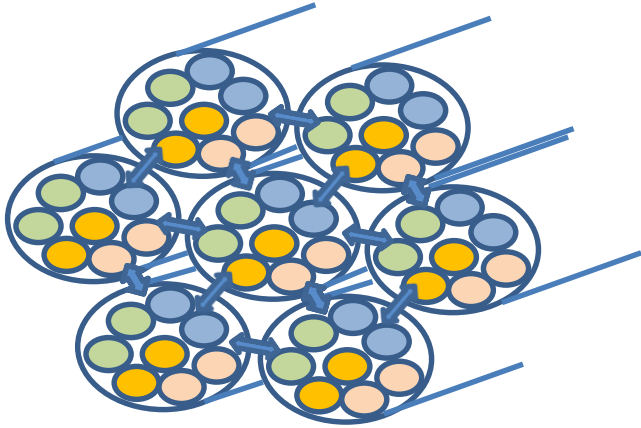
Downshift Test: Results

- All ports implementing Downshift showed success!
 - 10G-capable ports (ten DUTs) performed Downshift from 10G -> 5G ->2.5G -> 1G as noise increased from -122 dBm to -108 dBm within 1dBm/Hz
 - 5G-max ports (two DUTs) performed Downshift from 5G -> 2.5G -> 1G as noise increased from -119 dBm to -108 dBm within 1dBm/Hz
 - Only one DUT present did not implement downshift feature



What about the “6 Around 1” Test?

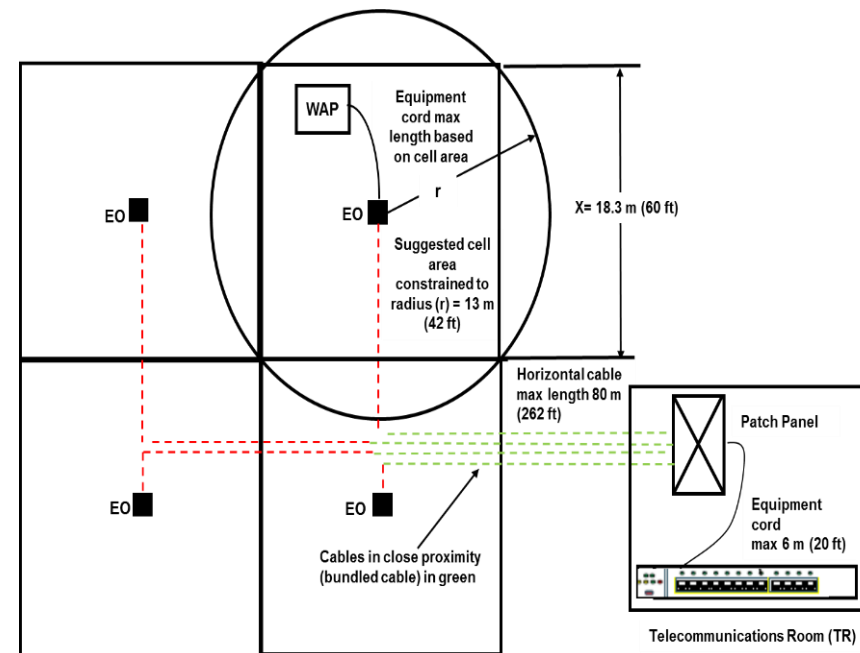
- 6-around-1 cable bundle configuration was used to calculate worst-case alien crosstalk for Cat6a cables for IEEE 802.3 10GBASE-T... making the term “6 around 1” well known in the cabling industry for 10GBASE-T.



- Inner cable is victim of 6 aggressors
- Noise depends on what signals are in the cables

- Use Cases

- Most 2.5G/5GBASE-T deployments have <<100m bundling: close proximity at switch end, then fan out to end points. This makes 100m of bundling a very pessimistic model.

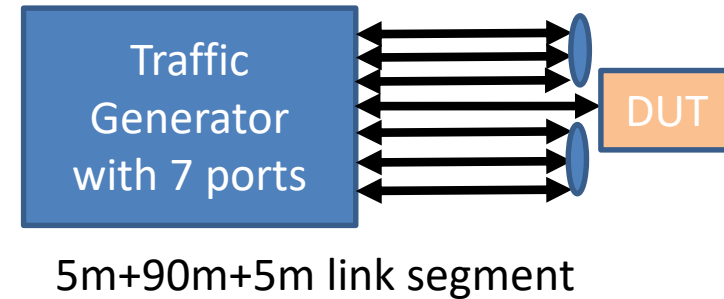


Does it Meet IEEE 802.3bz Specifications?

- ❑ IEEE 802.3bz evaluates cabling alien crosstalk by determining the best Signal-to-Noise Ratio (SNR) that a PHY could achieve using measurements of the alien crosstalk characteristics of the cabling – this is called Alien Limited SNR (ALSNR)
- ❑ Alien Limited SNR – 2.5G/5G performance is limited by cross-talk than any other cable parameter, hence term ALSNR
- ❑ IEEE 802.3bz specifies the link segment based on the worst possible set of aggressors, independent of cable type or 6-a-1 cable bundle configuration, that meet a test for alien noise level (called the ALSNR criterion)
- ❑ IEEE 802.3bz specify that the PHY provide a bit error ratio (BER) better than or equal to 10^{-12} at the MAC/PLS service interface

“6 Around 1” Test Setup and Results

- Plugfest Test
 - ALSNR was calculated for each set of disturbers, but due to limited time, no attempt was made to ensure ALSNR met IEEE 802.3bz Link Segment specification
- Test setup
 - 6-a-1 Cable bundle used was worst case: full 100m bundling of Cat5e. Exceeds 802.3bz ALSNR specs for any configuration...
 - ...but close to the spec for 2.5G victim with 1G aggressors.



- **Test results :**
 - **2.5G device under test with 1G aggressors generally worked well, matching specification for this configuration**

Future Plugfest Recommendations

- Replace 6-a-1 cable test with controlled noise source emulate ALSNR as specified in Clause 126.5.4.4 Alien cross-talk noise rejection
- Benefits
 - Repeatable and consistent results
 - Easier to create ALSNR for different combination of victim/aggressor speed
 - Maps more closely to specifications and use cases

Results Discussion

Interoperability tests: Over 1,000 test cases run!

- **Link up test:** 591 link trials with 100% success
- **Frame Error Rate tests:** 523 FER tests with 99% pass rate
- Interoperability test cases were a near even split of
 - NBASE-T vs. IEEE 802.3bz autonegotiation
 - 2.5GBASE-T vs. 5GBASE-T operation
 - Short vs. long (5m/100m) cabling from two suppliers

Downshift Testing

- Downshift testing with 12 devices demonstrating the capability to operate at the best possible speed when noise factors exceed specification limits

6 Around 1 Testing

- Demonstrates that devices can operate in the presence of noise on cable plants exceeding the specification limits for alien crosstalk (ALSNR). ...but there may be a better way to test this next time.

Conformance and Cable Testing:

- Test equipment available from multiple suppliers demonstrates that the test & measurement capability is in place to enable the work of component and system designers, equipment and cable installers to deploy 2.5GBASE-T and 5GBASE-T products with confidence.

Summary

- A successful event!
 - 2.5G/5GBASE-T multi-vendor interoperability demonstrated
 - Compatibility between NBASE-T and IEEE 802.3bz demonstrated
- Rich Ecosystem Developing for 2.5G/5GBASE-T
 - Wide variety of product types and test equipment available now
 - Many more in development
 - We should do this again!

Questions? Ideas?



Thank You!

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