Higher Speed Ethernet Plugfest

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Introduction & Background

The IEEE Std 802.3ba™-2010 40 Gb/s and 100 Gb/s Ethernet amendment of the IEEE Std 802.3™-2008 Ethernet standard was approved on June 17, 2010 by the IEEE Standards Association Standards Board. The development of the standard started in 2006 with the IEEE 802.3 Higher Speed Study Group (HSSG). While the standard matured, vendors developed prototype and production components for the Higher Speed Ethernet (HSE) ecosystem.

The state of HSE components was relatively advanced at the time of the ratification, with experimental and deployed 40 Gb/s and 100 Gb/s devices and networks. In order to determine the extent of the ecosystem and basic interoperability, an initial plugfest event was held from September 14-16, 2010 in Santa Clara, CA, hosted by Ixia at its iSimCity facility. The results of that plugfest are available on the Ethernet Alliance's web site.

A second plugfest was held April 19-21, 2011 at the University of New Hampshire's InterOperability Lab (UNH-IOL), and is the subject of this white paper.

The objective of the second plugfest was very much the same as the first: to determine basic interoperability and not to measure standards conformance. In addition to achieving "link up" for all connections, sufficient layer 1 or layer 2 traffic was sent to ensure conformance to error rates.

The following types of components were used in the plugfest:

1. Transceivers – forming physical layer connections to cables.
    a. CFP MSA – used for both 40 Gb/s and 100 Gb/s.
    b. QSFP+ - used for 40 Gb/s.
2. Optical cables – connecting transceivers.
3. Copper cable assemblies – QSFP+ Direct Attach Copper (DAC) cable assemblies.
4. Systems – including test systems, switches/routers and computers with HSE NICs.
5. Active copper and optical cable assemblies – copper and optical cable assemblies with attached active transceivers. These assemblies are not part of the IEEE 802.3ba™-2010 standard. Results from these tests are included in Appendix B.

The list of components, organized by vendor, is included in Appendix A. In contrast to the first plugfest, there was a dramatic shift away from cables and transceivers to systems. Many more switches, routers, and test systems were available.

HSE Plugfest Objectives

Two series of tests were executed:

1. Cables and transceivers – the test systems were used to test combinations of transceivers and cables, as well as cable assemblies.
2. System – combinations of systems were interconnected.

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Cable and Transceiver Test Results

All cable and transceiver tests were performed by connecting either QSFP+ Direct Attach Copper (DAC) cables or transceiver / cable connections. For each test, one or more test system ports were used to transmit and verify 12 x 10^{12} bits of PRBS-31 patterns to verify a bit error rate of 10^{-12}. One issue was encountered during the tests:

- Very high BERs or no link were observed for one test vendor. It was determined that the issue was caused by the default amplitude and pre-emphasis settings used on the test port. The settings were changed and then passing results were observed over cables using the new settings. This same issue was observed in the first plugfest event.

40 Gb/s QSFP+ DAC Tests

The passive QSFP+ Direct Attach Copper (DAC) cables that were tested can be found in Table 1. All cables tested were observed to successfully pass the BER test with zero errors. Results with active copper and optical cables can be found in Appendix B.

Table 1: QSFP+ DAC Test Results

Vendor	Length	Result
I	1m 30AWG	Pass
	3m 28AWG	Pass
	3m 30AWG	Pass
	5m 26AWG	Pass
	7m 24AWG	Pass
K	1m 30AWG	Pass
	5m 26AWG	Pass
	6m 26AWG	Pass
	7m 24AWG	Pass
N	3m 28AWG	Pass
	3m 30AWG	Pass
	3m 32AWG	Pass

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Transceiver/Cable Combination Tests

The testing of transceivers and fiber optic cables consisted of plugging two QSFP+ or CFP transceivers into test ports, connecting them with the fiber optic cable under test, and then transmitting PRBS-31 to verify the BER.

This was completed using all possible combinations of transceivers and fiber optic cables. The transceiver types tested were:

- 40GBASE-LR4
- 40GBASE-SR4
- 100GBASE-LR4
- 100GBASE-SR10

The fiber optic cable types were SMF with SC connectors, 1x12 MMF with MTP/MPO connectors, and 2x12 MMF with MTP/MPO connectors. Both OM3 and OM4 multimode fibers were tested.

$12x10^{12}$ bits were transmitted to verify BER with 40GBASE-LR4, and 40GBASE-SR4 transceivers. $30x10^{12}$ bits were transmitted to verify BER with 100GBASE-SR10 transceivers. A single vendor supplied the transceiver used in each case. The fiber optic cables tested with a pair of test systems can be found in Tables 2-4. All combinations tested were observed to successfully pass the BER test with zero errors.

Table 2: 40GBASE-LR4 and 100GBASE-LR4 Results

Cable Supplier	SMF Cable Reach	Pass/Fail
I	10km	Pass
K	5m	Pass
	1km	Pass

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Table 3: 40GBASE-SR4 Results

Cable Supplier	Type/Cable Reach	Pass/Fail
A	OM3 / 100m	Pass
	OM4 / 150m	Pass
I	OM3 / 100m	Pass
	OM4 / 150m	Pass
K	OM3 / 100m	Pass
	OM4 / 150m	Pass

Table 4: 100GBASE-SR10 Results

Cable Supplier	Type/Cable Reach	Pass/Fail
A	OM3 / 100m	Pass
	OM4 / 150m	Pass
I	OM3 / 100m	Pass
	OM4 / 150m	Pass

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System Test Results

The system Interoperability and BER tests were performed by transmitting 1518-byte PING packets over several combinations of transceivers and fiber optic cables. A full test involved 960 million packets; however, due to a lack of time some tests only used 1/10th of this amount. Such results are listed in the tables with a "(1/10)" suffix. Likewise, in the interest of time a subset of cables were used; this is noted with a "(S)" suffix.

All combinations tested were observed to successfully pass the BER test with zero errors. Some adjustment of pre-emphasis and amplitude in one of the test systems was required in some cases.

40 Gigabit Ethernet QSFP+ Tests

The test results for 40 Gigabit Ethernet QSFP+ are summarized in Tables 5 and 6.

Six different passive optical cables were used for the 40 Gigabit Ethernet Passive Copper tests:

Table 5: Passive Cables used in Test

Cable Supplier	Cable Reach/AWG
I	3m 30AWG
	7m 24AWG
K	5m 26AWG
	7m 24AWG
N	3m 28AWG
	3m 30AWG

Table 6: System Tests for 40 Gigabit Ethernet QSFP+

	Vendor C System #1	Vendor C System #2	Vendor D Test System	Vendor L Test System
Vendor C System #2	Pass (1/10)			
Vendor D Test System	Pass	Pass (1/10)		
Vendor L Test System	Pass	Pass (1/10)	Pass	

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40GBASE-SR4 Tests

The test results for 40GBASE-SR4 are summarized in Tables 7 and 8. A combination of CFP and QSFP+ transceivers were used, as noted.

The six passive cables listed above, plus the six cables passive optical cables listed below were used for the 40GBASE-SR4 tests:

Table 7: OM3/OM4 Cables used in Test

Cable Supplier	Type/ Cable Reach
A	OM3 100m
	OM4 150m
I	OM3 100m
	OM4 150m
K	OM3 100m
	OM4 150m

Table 8: System Tests for 40GBASE-SR4

	Vendor B System (CFP)	Vendor C System #1 (QSFP+)	Vendor C System #2 (QSFP+)	Vendor D Test System (QSFP+)	Vendor E Test System (CFP)	Vendor L Test System (QSFP+)
Vendor C System #1 (QSFP+)	Pass (S)					
Vendor C System #2 (QSFP+)	Pass (1/10) (S)	Pass (1/10) (S)				
Vendor D Test System (QSFP+)	Pass (S)	Pass	Pass (1/10) (S)			
Vendor E Test System (CFP)	Pass	Pass (S)	Pass (1/10) (S)	Pass (S)		
Vendor L Test System (QSFP+)	Pass	Pass (S)	Pass (1/10) (S)	Pass (S)	Pass (S)	
Vendor G System (QSFP+)	Not tested	Pass (1/10) (S)	Pass (1/10) (S)	Pass (1/10)	Not tested	Pass (1/10) (S)

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40GBASE-LR4 Tests

The test results for 40GBASE-LR4 are summarized in Tables 9 and 10. A pair of CFP transceivers from vendor H was used. Two optical cables listed below were used for the 40GBASE-LR4 tests:

Table 9: Cables used in Test

Cable Supplier	Type/ Cable Reach
I	SMF 10km
K	SMF 1km

Table 10: System Tests for 40GBASE-LR4

	Vendor B System (CFP)	Vendor D Test System (QSFP+)	Vendor E Test System (CFP)
Vendor D Test System (QSFP+)	Pass		
Vendor E Test System (CFP)	Pass	Pass	
Vendor L Test System (QSFP+)	Pass	Pass	Pass

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100GBASE-LR4 Tests

The test results for 100GBASE-LR4 are summarized in Tables 11 and 12. A pair of CFP transceivers from vendor H was used. Two optical cables listed below were used for the 100GBASE-LR4 tests:

Table 11: Cables used in Test

Cable Supplier	Type/ Cable Reach
I	SMF 10km
K	SMF 1km

Table 12: System Tests for 100GBASE-LR4

	Vendor B System (CFP)	Vendor C System #1 (QSFP+)	Vendor C System #2 (QSFP+)	Vendor D Test System (QSFP+)	Vendor E Test System (CFP)	Vendor L Test System (QSFP+)
Vendor C System #1 (QSFP+)	Pass (S)					
Vendor C System #2 (QSFP+)	Pass (1/10) (S)	Pass (1/10) (S)				
Vendor D Test System (QSFP+)	Pass (S)	Pass	Pass (1/10) (S)			
Vendor E Test System (CFP)	Pass	Pass (S)	Pass (1/10) (S)	Pass (S)		
Vendor L Test System (QSFP+)	Pass	Pass (S)	Pass (1/10) (S)	Pass (S)	Pass (S)	
Vendor G System (QSFP+)	Not tested	Pass (1/10) (S)	Pass (1/10) (S)	Pass (1/10)	Not tested	Pass (1/10) (S)

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100GBASE-SR10 Tests

The test results for 100GBASE-SR10 are summarized in Tables 13 and 14. A pair of CFP transceivers from a non-Ethernet Alliance vendor was used. The optical cables listed below were used for the 100GBASE-SR10 tests:

Table 11: Cables used in Test

Cable Supplier	Type/ Cable Reach
A	OM3 100m
	OM4 150m
I	OM3 100m
	OM4 150m

Table 12: System Tests for 100GBASE-LR4

	Vendor O System	Vendor D Test System	Vendor E Test System	Vendor F System #2
Vendor D Test System	Pass			
Vendor E Test System	Pass	Pass		
Vendor F System #2	Pass (S)	Pass (S)	Pass (S)	
Vendor L Test System	Pass	Pass	Pass	Pass (S)

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Additional BER Tests

Some additional BER testing was performed using cable lengths that exceeded the IEEE Std 802.3ba required maximum lengths to indicate the viability of the HSE ecosystem. A combination of test systems and transceivers were used. In most cases, the failures were expected. In one case (noted as Fail(1)), only a single error occurred. The results are summarized in Table 13.

Table 13: BER Test Results with Additional Cables

Cable Type	Cable Reach	Pass/Fail
QSFP+ Passive Copper	10m	Fail
QSFP+ Active Optical	10m	Pass
	300m	Pass
Multimode OM3, 40GBASE-SR4	200m	Pass
Multimode OM4, 40GBASE-SR4	355m	Pass
	800m	Pass
	900m	Pass
	950m	Pass
Multimode OM4, 100GBASE-SR10	200m	Pass
	400m	Pass
	450m	Fail (1)
	500m	Pass
	600m	Fail
	700m	Pass
	800m	Fail
	900m	Fail
	1km	Fail

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Conclusion

Several things were evident in comparing the results from this event from the first interoperability event last year – just 6 months ago:

- Cables lengths that were within specifications passed without some of the teething pains experienced in the first event.
- Although there were fewer transceivers present, they too interoperated more easily. Only one of the three test system vendors required any adjustments to accommodate amplitude and pre-emphasis differences.
- Many more routers and switches are ready for the market. The number surprised us; it wasn't possible to complete the cross product of systems with cables and transceivers within the allotted time.

This interoperability event demonstrates that the 40 and 100 Gb/s Ethernet ecosystem is real and ready for deployment. The fact that widespread interoperability was so quickly achieved is testament to the strong engineering teams of the member-participants and to the standard itself.

About Ethernet Alliance

The Ethernet Alliance is a global community of Ethernet end users, system and component vendors, industry experts and university and government professionals who are committed to the continued success and expansion of Ethernet. The Ethernet Alliance brings Ethernet standards to life by supporting activities that span from incubation of new Ethernet technologies to interoperability demonstrations, certification, and education.

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Appendix A – Vendor Equipment

Berk-Tek – A Nexans Company
- 40GBASE-SR4, MMF, OM3
- 40GBASE-SR4, MMF, OM4
- 100GBASE-SR10, 1 x 24 MPO, MMF, OM3
- 100GBASE-SR10, 1 x 24 MPO, MMF, OM4

Broadcom
- CFP-based Optical front end system to support 2 x 40GE operation

Brocade
- MLX/MLXe SERIES ROUTERS

Extreme Networks
- Summit-X670 4 x 40Gbps QSFP+ and 48 x 10 Gbps
- BlackDiamond 8810 6 x 40Gbps QSFP+ module

Ixia
- Ixia XM12 chassis supporting multiple load modules
- Ixia "K2" CFP 40/100 GE load modules, software switchable interface
- Ixia "K2" QSFP+ 40 GE load module

JDSU
- ONT-503 with 100/40GigE and OTU3/4 CFP Module

Juniper Networks
- System-1: T1600 Core Router
- System-2: MX240 3D Universal Edge Router

Mellanox
- 40 Gigabit QSFP+ Network Adapter

Opnext
- 40GBASE-LR4 CFP
- 100GBASE-LR4 CFP

Panduit
- 40GBASE-CR4, QSFP+ passive copper cables
- 40GBASE-SR4, 1 x 12 MPO, MMF, OM3
- 40GBASE-SR4, 1 x 12 MPO, MMF, OM4
- 40/100GBASE-LR4, SC, SMF
- 100GBASE-SR10, 1 x 24 MPO, MMF, OM3
- 100GBASE-SR10, 1 x 24 MPO, MMF, OM4

Siemon
- 40GBASE-CR4, QSFP+ passive copper cables
- 40GBASE-CR4, QSFP+ active optical cables
- 40GBASE-SR4, 1 x 12 MPO, MMF, OM3
- 40GBASE-SR4, 1 x 12 MPO, MMF, OM4

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- 40/100GBASE-LR4, SC, SMF

Spirent Communications

- TestCenter chassis
- TestCenter HyperMetrics 40/100G Ethernet test module

TE Connectivity

- 40GBASE QSFP+ optical transceivers

Volex

- 40GBASE-CR4, QSFP+ passive copper cables

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Appendix B – 40 Gb/s Active QSFP+ DAC Tests

The Active QSFP+ Direct Attach Cables that were tested can be found in Table 14. All cables tested were observed to successfully pass the BER test with zero errors.

Table 14: QSFP+ Direct Attached Cable Tests

Copper / Optical	Reach	System	System	Pass/Fail
Copper	10m	40G System #2	40G System #2	Pass
Copper	12m	40G System #2	40G System #2	Pass
Copper	15m	40G System #2	40G System #2	Pass
Optical	10m	40G System #2	40G System #2	Pass
		40G System #2	40G System #3	Pass
		40G System #2	40G System #4	Pass
Optical	10m	40G System #2	40G System #2	Pass
		40G System #2	40G System #3	Pass
		40G System #2	40G System #4	Pass
Optical	15m	40G System #2	40G System #2	Pass
		40G System #2	40G System #3	Pass
		40G System #2	40G System #4	Pass
Optical	100m	40G System #2	40G System #2	Pass

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