



Multigigabit over UTP Copper
An Independent Assessment of
Cisco Catalyst 3850 and 4500E
Multigigabit Performance



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1 - Executive Summary

Miercom was engaged by Cisco Systems to independently validate the performance of its new Multigigabit technology for transmitting data at rates greater than 1 Gbps over unshielded twisted pair (UTP) cabling, including already widely installed Cat5e. Two Cisco switches that support Multigigabit ports – the stackable Catalyst 3850 and the modular Catalyst 4500E – were used in the testing.

The testing focused mainly on Multigigabit ports' ability to consistently and cleanly send and receive data at Multigigabit/s rates over UTP copper cabling. In Ethernet auto-negotiation the two ends of the link choose the "Highest Common Denominator" (HCD) speed. This does not take into account the capability of the cabling infrastructure to support the selected speed. Multigigabit ports include additional capabilities to monitor the condition of the link, and choose a slower speed if required (e.g., when using 100M of Cat5e). This capability is called "DownShift".

Another goal was to confirm Multigigabit ports' UPOE (Universal Power Over Ethernet) support and the ability to deliver up to 60 Watts of electrical power to drive downstream switches and attached devices, including wireless Access Points (APs), and IP security video cameras.

Key Findings and Observations:

- The Multigigabit ports of the Cisco Catalyst Multigigabit switches work as advertised. After attaching a 100-meter Cat6a cable, the Multigigabit ports auto-negotiate and operate at the full 10-Gbps rate, in each direction. When connected by a 100-meter length of Cat5e cable, the switches' Multigigabit ports auto-negotiate down to 5 Gbps.
- A 100-meter run of Cat5e/Cat6 UTP cable connecting Multigigabit ports on Catalyst 4500E and 3850 switches, can support 5 Gbps of full duplex line rate.
- A 100-meter run of Cat6a UTP cable, connecting Multigigabit ports on Catalyst 4500E and 3850 switches, can support 10 Gbps of full duplex line rate.
- RJ-45 Multigigabit ports support all the same in-line power options as conventional RJ-45/UTP switch ports, including standard Power-over-Ethernet (PoE) and delivery of 60W of power via Cisco Universal Power Over Ethernet (UPOE).

Based on the impressive results of our testing, we proudly award the **Miercom Performance Verified Certification** to Cisco Multigigabit technology, as implemented and now available on the Cisco Catalyst 4500E and 3850 switches.

Robert Smithers
CEO
Miercom



2 - Product Overview

Can 8-conductor unshielded twisted pair really carry more than 1 Gigabit/s of data? The short answer, based on our testing of Cisco Multigigabit technology, is a resounding "Yes."

It became clear in recent years that even 1-Gbps links to the furthest reaches of the network would not be enough for much longer. Indeed, the latest generation of Access Points, called Wave 2, is enabling even wireless devices to push the data-rate envelope beyond 1 Gbps.

However, installing new cable everywhere is prohibitively expensive for many organizations. Most existing network infrastructures, except within the data center, still run on unshielded copper cabling – out to the desktop, out to wireless APs and even for connecting backbone and remote switches.

In October 2014 Cisco was a founding member of the NBASE-T Alliance which promotes solutions for more speed over installed Category 5e and 6 cables. Now Cisco is introducing the fruit of that effort – Multigigabit technology – that Cisco had already implemented across the compact, fixed and modular access switches.

Multigigabit technology can deliver data rates beyond 1-Gigabit/s data rates on existing Category 5e cabling. In addition, Multigigabit supports (PoE, PoE+, and Cisco's UPOE), so new electrical circuits don't need to be installed to power such out-of-the-way devices as wireless AP's, IP phones and IP security cameras.

Cisco is implementing Multigigabit technology in the form of modules for its high performance Catalyst switches. Multigigabit modules are now available for several Catalyst switches. Two of these, with Multigigabit modules, were employed in this testing – the Catalyst 4500E and 3850.

Catalyst 4503E

One of the two Cisco Catalyst Switches used for this testing was a modular Catalyst 4503E, with three module slots (see below).



Cisco Catalyst 4503E

Multigigabit is supported via a new line card, the WS-X4748-12X48U+E.



Multigigabit Line Card for Catalyst 4503E
(WS-X4748-12X48U+E)

This is a 48-port (RJ-45) line card with 12 Multigigabit ports and 36 x 10/100/1000 ports, all supporting Power over Ethernet (PoE), per IEEE 802.3af/at, PoE+, and Cisco UPOE, up to 1,440W (Watts) per line card. UPOE can deliver up to 60W of power per RJ-45 port. IEEE-standard PoE supports delivery of just 15W. PoE+ is an intermediate standard, supporting 30W.

The Catalyst 4503E with the Sup 8-E supervisor (WS-X45-SUP8-E) was tested running version IOS XE 3.8.0.E release software.

Catalyst 3850

The other Catalyst Switch used for this testing was a stackable Catalyst 3850 (see below), model **WS-C3850-12X48U-E**.



Cisco Catalyst 3850
Multigigabit Switches

This 1-RU (1.75-inch high) Catalyst 3850 switch model supports 12 Multigigabit ports and 36 x 1-Gigabit ports, all RJ-45. These ports likewise support PoE, PoE+ and UPOE in-line power options. The switch was tested running version IOS XE Denali 16.1.1E release software.

3 - Test Bed: How We Did It

These variations of the test bed were employed:

1. **Cat6a cable:** To test the ability of Cisco Multigigabit ports to successfully select 10-Gbps speed and achieve 10 Gbps throughput, in each direction, when connected with a 100 meter length of Cat6a cable.
2. **Cat5e cable:** To test the ability of Cisco Multigigabit ports to successfully select the highest possible speed of 5 Gbps, and achieve 5 Gbps throughput, in each direction, when connected with a 100 meter length of Cat5e cable.
3. **Cat6 cable:** To test the ability of Cisco Multigigabit ports to successfully auto-negotiate the highest possible speed of 5 Gbps, and achieve 5 Gbps throughput, in each direction, when connected with a 100 meter length of Cat6 cable.
4. **60W power:** To test the ability of Cisco Multigigabit ports to deliver up to 60W of electrical power via Cat5E/6/6a cable.

Ixia. Common to all three test environments was an Ixia (www.ixiacom.com) traffic-generator test system. The Ixia XM12 is a chassis-based system driven by software that includes dozens of popular canned tests.

RFC 2544. For all the tests in this report, the Ixia XM12 calculated bi-directional throughput using the industry standard Internet RFC 2544. This standard has long been used to calculate throughput over a link connecting two devices.

In our case, the RFC 2544 throughput test determines the maximum rate at which the Cisco Catalyst switches can send and receive traffic without frame loss over a connecting link. Layer-2 frames of a specific size are sent at a specified rate, which is then continually stepped up in subsequent iterations, using a binary search algorithm, until the maximum rate at which the switch forwards data without losing frames is determined.

As seen in the following results, maximum throughput is achieved with large frame sizes. That is because per-frame overhead is minimized when sending maximum-sized frames (i.e., 1518 bytes). The bandwidth that is consumed by overhead, reducing throughput, can be considerable for a lot of small frames (i.e., 64 bytes).

The three test environments – the objective, the process and the results – are detailed in the following sections.

4 - Multigigabit over 100 Meters of Cat6a Cabling

Objective: To show that Cisco Multigigabit ports can successfully auto-negotiate 10 Gigabit/s speed and achieve full 10-Gigabit/s throughput when connected with 100 meters of Cat6a cable.

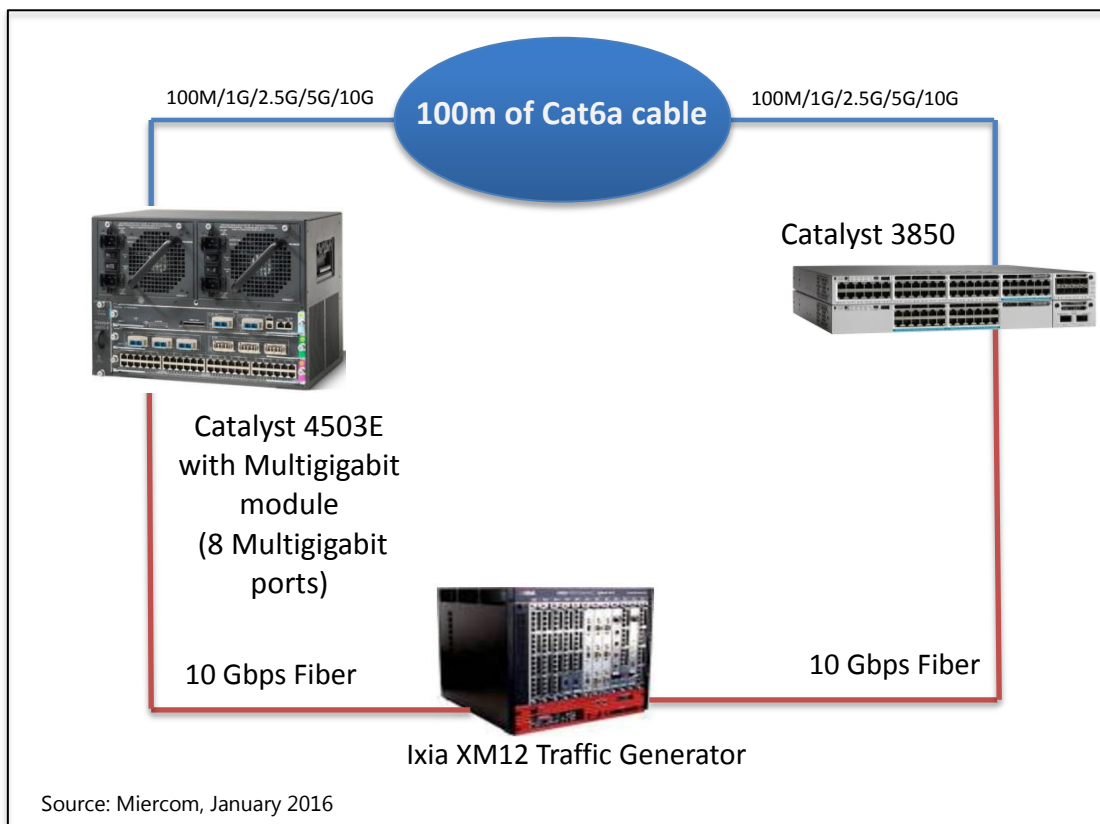
Test procedure: A test bed was assembled as shown in the diagram below. Fiber links are established between 10G ports of the Ixia XM12 traffic generator and 10G ports of both switches.

Then a 100-meter length of Cat6a cable is attached to the RJ-45 of the Multigigabit port of each switch. Via the switches' CLI interface, the speed that is auto-negotiated between the two interfaces is determined. It is expected that the full 10-Gigabit/s rate will be auto-negotiated.

The Ixia XM12 then runs RFC 2544 tests with Layer-2 frames to determine maximum throughput for frame sizes 64, 128, 256, 512, 1,024 and 1,518 bytes.

Then manually reset the Multigigabit link speed to 5, 2.5 and 1 Gigabit/s at both ends and repeat the built-in RFC 2544 tests for each link speed.

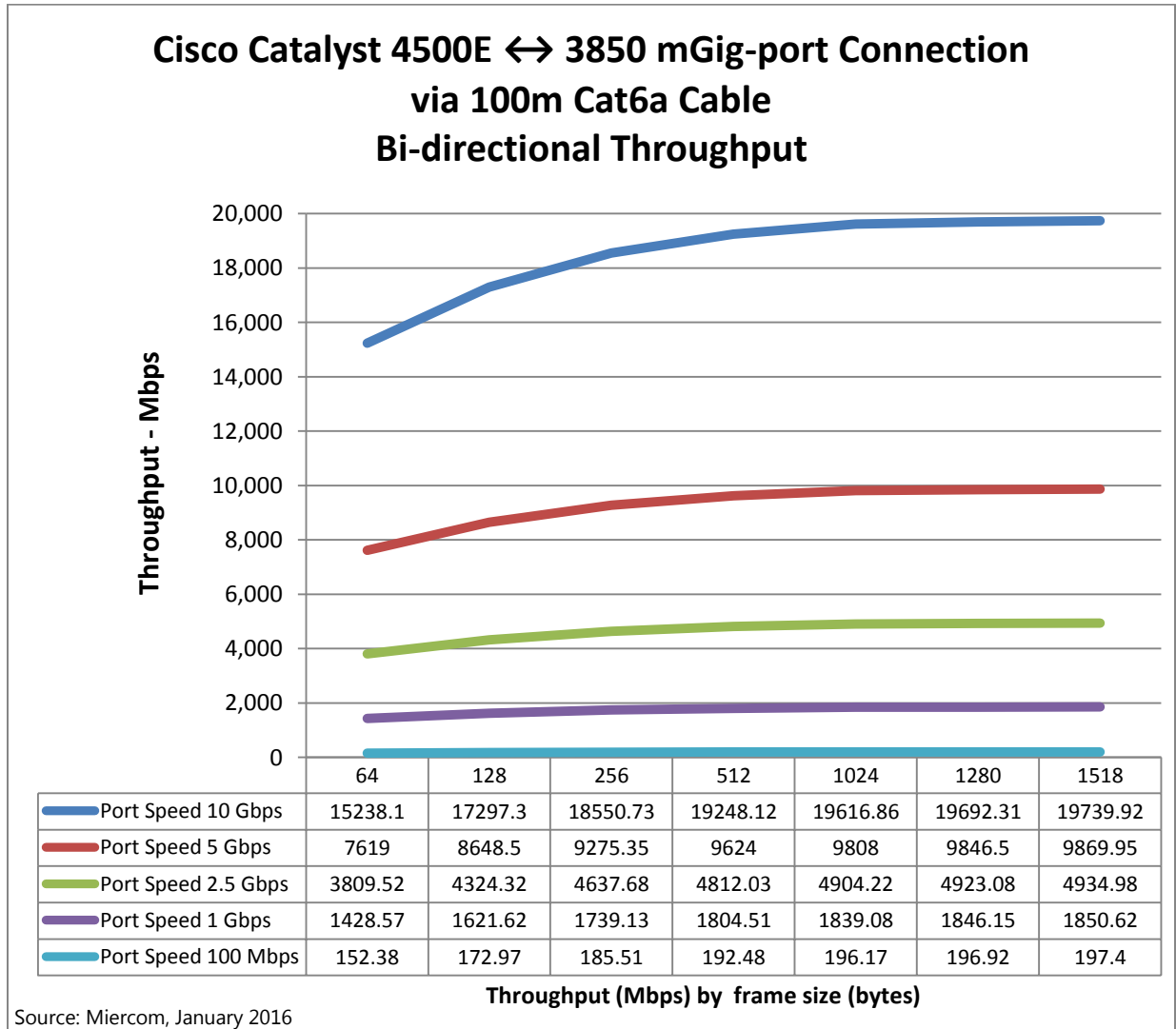
Figure 1: Test bed for Multigigabit throughput test of 100m of Cat6a cable



Results: The bi-directional throughputs achieved over the Multigigabit / Cat6a link (totaled for both directions) are shown below for the different link speeds and frame sizes.

Upon connecting the Cat6a cable, the Multigigabit ports did indeed auto-negotiate at 10 Gigabit/s.

The results show that the full 10-Gigabit/s bandwidth of the Multigigabit link can be tapped for user data. Throughput is maximized with larger frame sizes, and lower for small frames due to per-frame overhead.



5 - Multigigabit over 100 Meters of Cat6 Cabling

Objective: To show that Cisco Multigigabit ports can successfully select 5 Gigabit/s link speed and achieve full 5-Gigabit/s throughput when connected with 100 meters of Cat6 cable. This UTP cable type is also widely installed. Cat6 exhibits electromagnetic and transmission characteristics superior to Cat5e, but not as good as Cat6a.

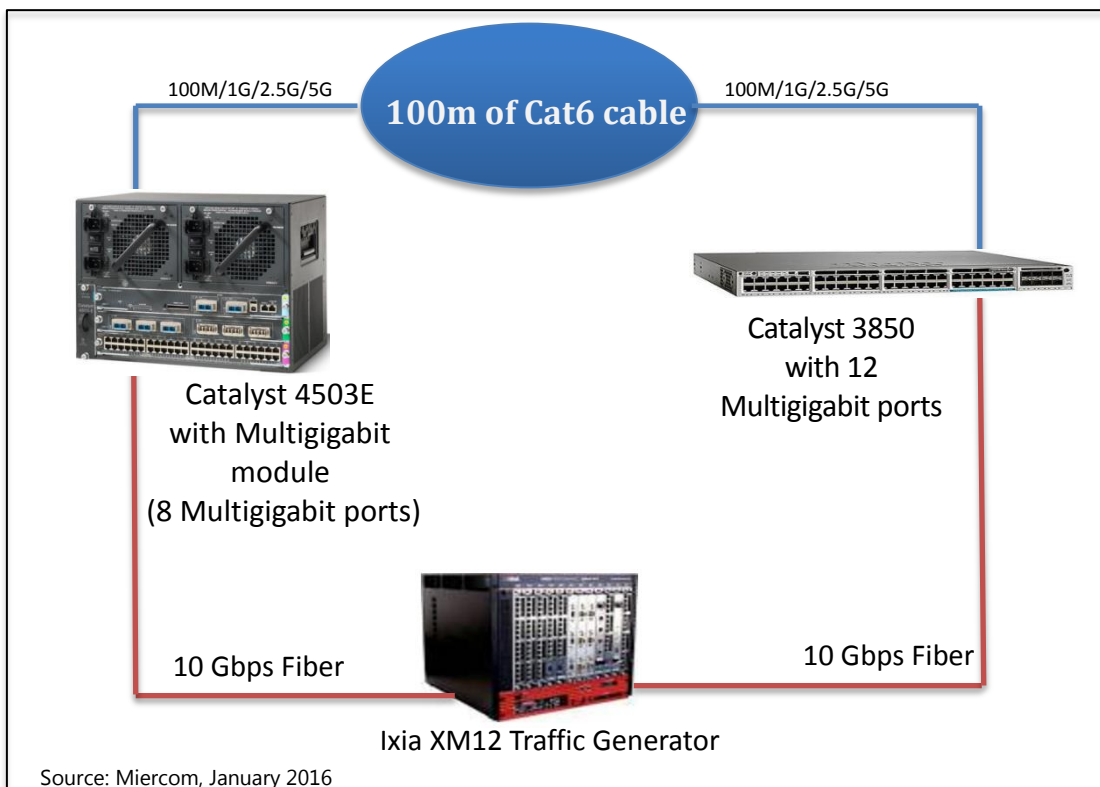
Test procedure: A test bed was assembled as shown in the diagram below. Fiber links are established between 10G ports of the Ixia XM12 traffic generator and 10G ports of both switches.

Then a 100-meter length of Cat6 cable is attached to the RJ-45 of the Multigigabit port of each switch. Via the switches' CLI interface, the speed that is agreed between the two interfaces is determined. It is expected that the 5-Gigabit/s rate will be chosen based on the port signal quality.

The Ixia XM12 then runs RFC 2544 tests with Layer-2 frames to determine maximum throughput for 64, 128, 256, 512, 1,024, 1,280 and 1,518-byte frame sizes.

Then we manually reset the Multigigabit link speed down to 2.5 Gigabits, 1 Gigabit and finally 100 Mbps at one switch end. Both ends then agreed on the manually re-configured link speed and we repeated the battery of RFC 2544 tests for each link speed.

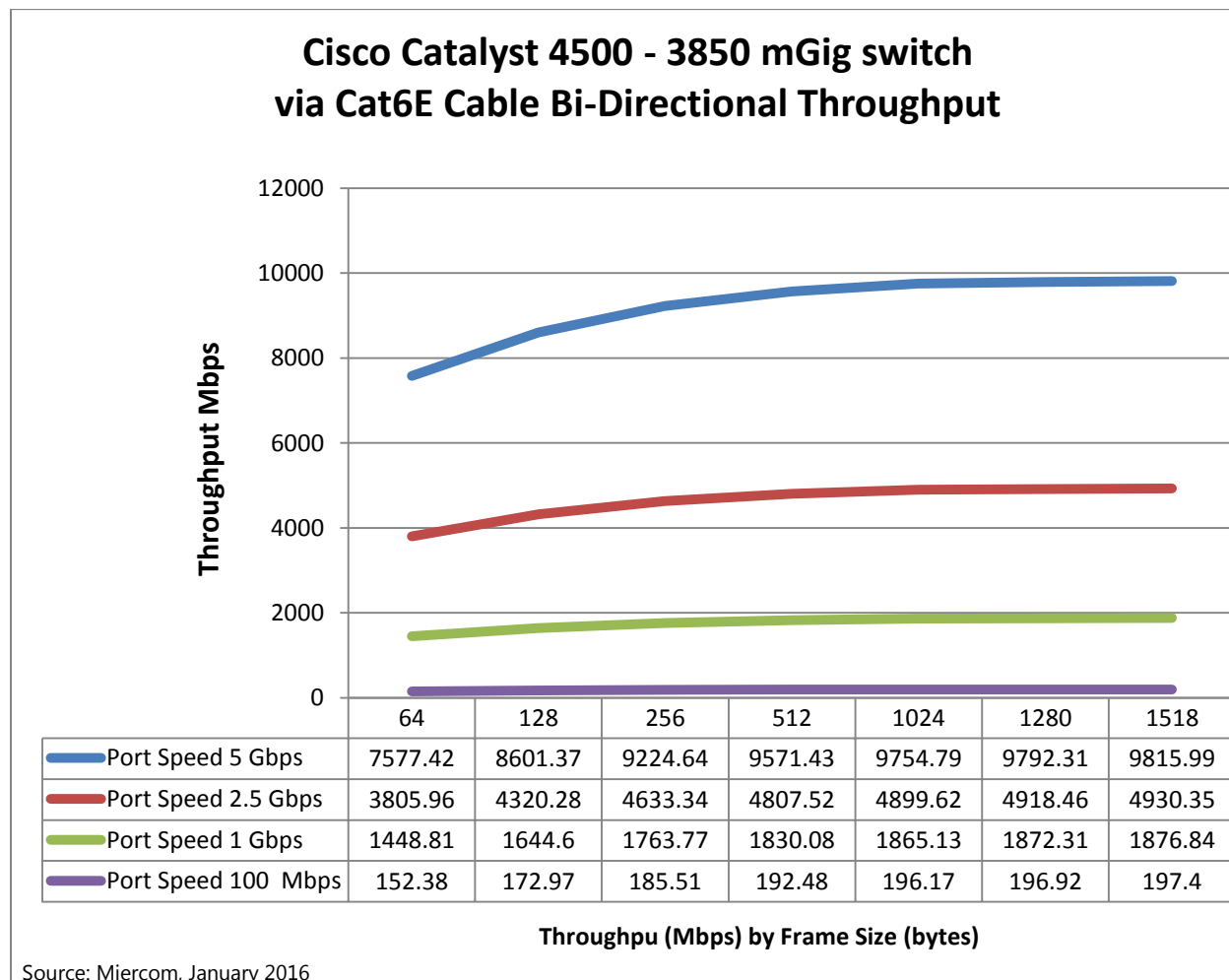
Figure 2: Test bed for Multigigabit throughput test of 100m of Cat6 cable



Results: The bi-directional throughputs achieved over the Multigigabit / Cat6 link (total for both directions) are shown below for the different link speeds and frame sizes.

Upon connecting the Cat6 cable, the Multigigabit ports selected 5 Gigabit/s. This is consistent with Cat6 cabling specifications: Short runs of Cat6, up to about 55 meters, can reportedly support full 10-Gigabit/s speeds in each direction. But in our test bed, with a 100-meter length of Cat6 cable, this drops to 5 Gigabit/s in each direction.

The results show that the full 5-Gigabit/s bandwidth of the Multigigabit link can be tapped for user data. Throughput is maximized with larger frame sizes, and lower for small frames due to per-frame overhead.



6 - Multigigabit over 100 Meters of Cat5e Cabling

Objective: To show that Cisco Multigigabit ports can successfully select the highest possible speed of 5 Gigabit/s and then achieve 5 Gigabit/s throughput when connected with 100 meters of Cat5e cable.

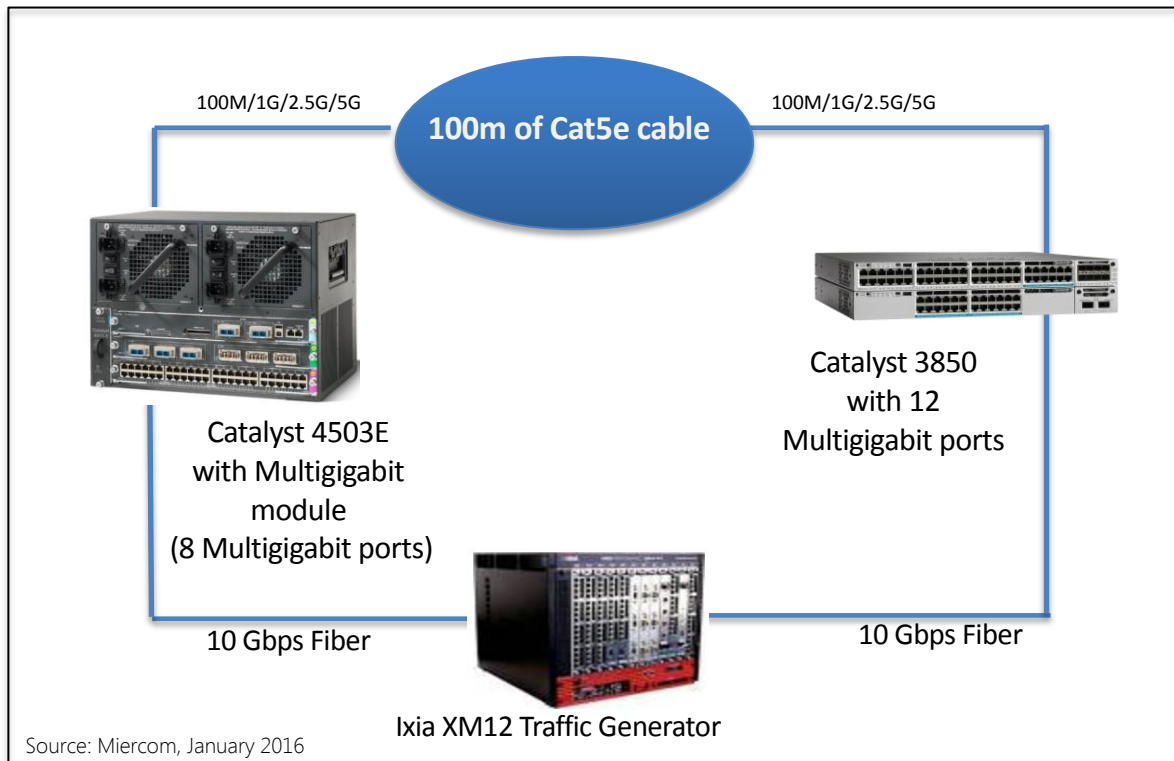
Test procedure: A test bed was assembled as shown below. Fiber links are established between 10G ports of the Ixia XM12 traffic generator and 10G ports of both switches.

Then a 100-meter length of Cat5e cable is attached to the RJ-45 of the Multigigabit port of each switch. Via the switches' CLI interface, the speed that is agreed between the two interfaces is determined. It is expected that the 5-Gigabit/s rate will be chosen based on the port signal quality.

The Ixia XM12 then runs RFC 2544 tests with Layer-2 frames to determine maximum throughput for frame sizes 64, 128, 256, 512, 1,024, 1,280 and 1,518 bytes.

Then we manually reset the Multigigabit link speed to 2.5 and 1 Gigabit/s and finally 100 Mbps, and then repeated the battery of RFC 2544 tests for each link speed.

Figure 3: Test bed for Multigigabit throughput test of 100m of Cat5e cable



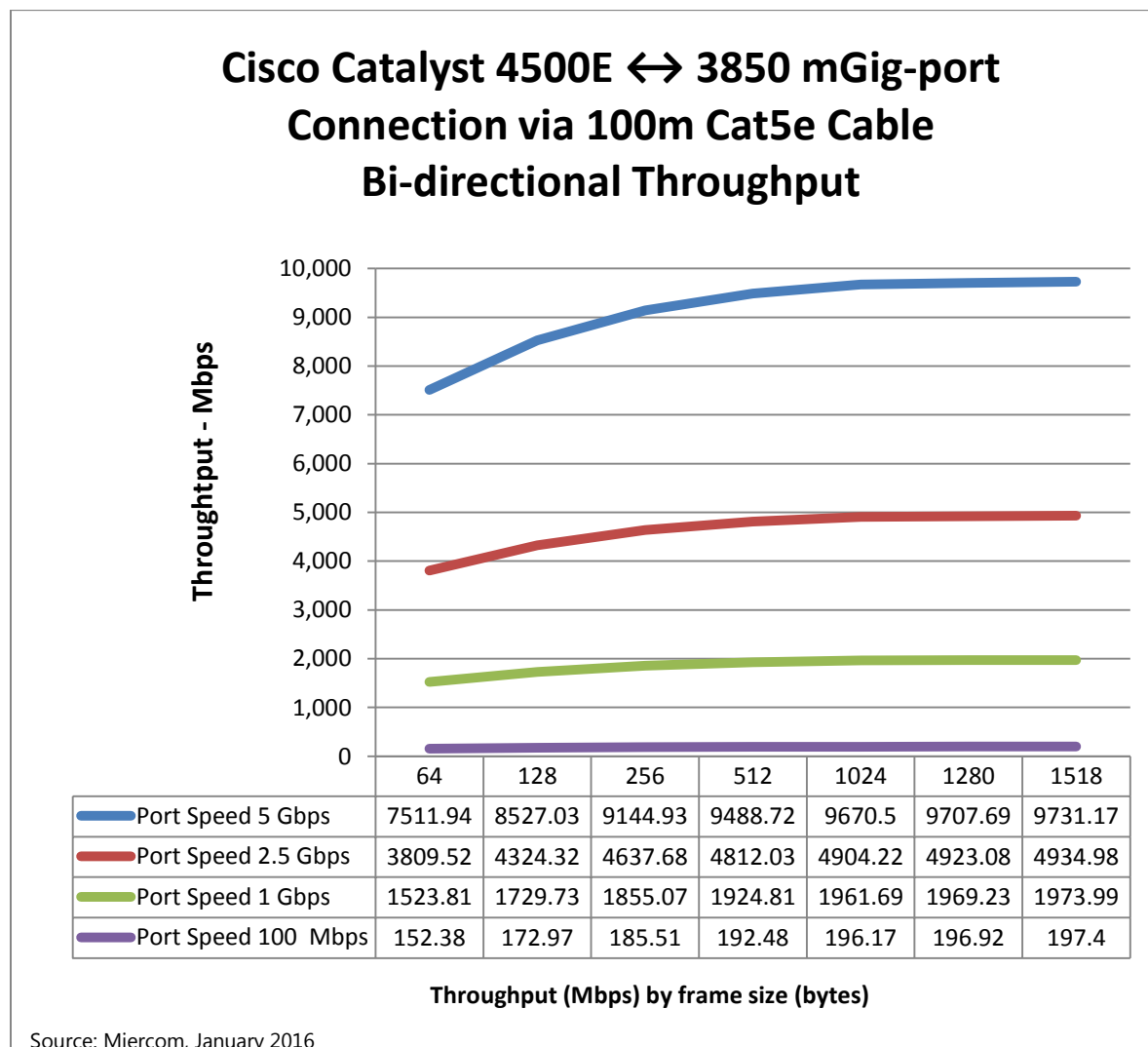
Results: The bi-directional throughputs achieved over the Multigigabit / Cat5e link (total for both directions) are shown below for the different link speeds and frame sizes.

Upon connecting the Cat5e cable, the Multigigabit ports selected and operated at 5 Gigabit/s.
cat4k-mgig#

*Dec 21 15:41:18.265: %C4K_ETHPHY-4-LINKSPEEDDOWNSHIFT: Downshifting to 5000 Mbps speed on port Te2/4 because of Cabling /Channel quality

cat4k-mgig#

The results show that the full 5-Gigabit/s bandwidth of the Multigigabit link is available for user data over the 100-meter length of Cat5e cable. Throughput is maximized with larger frame sizes, and lower for small frames due to per-frame overhead.



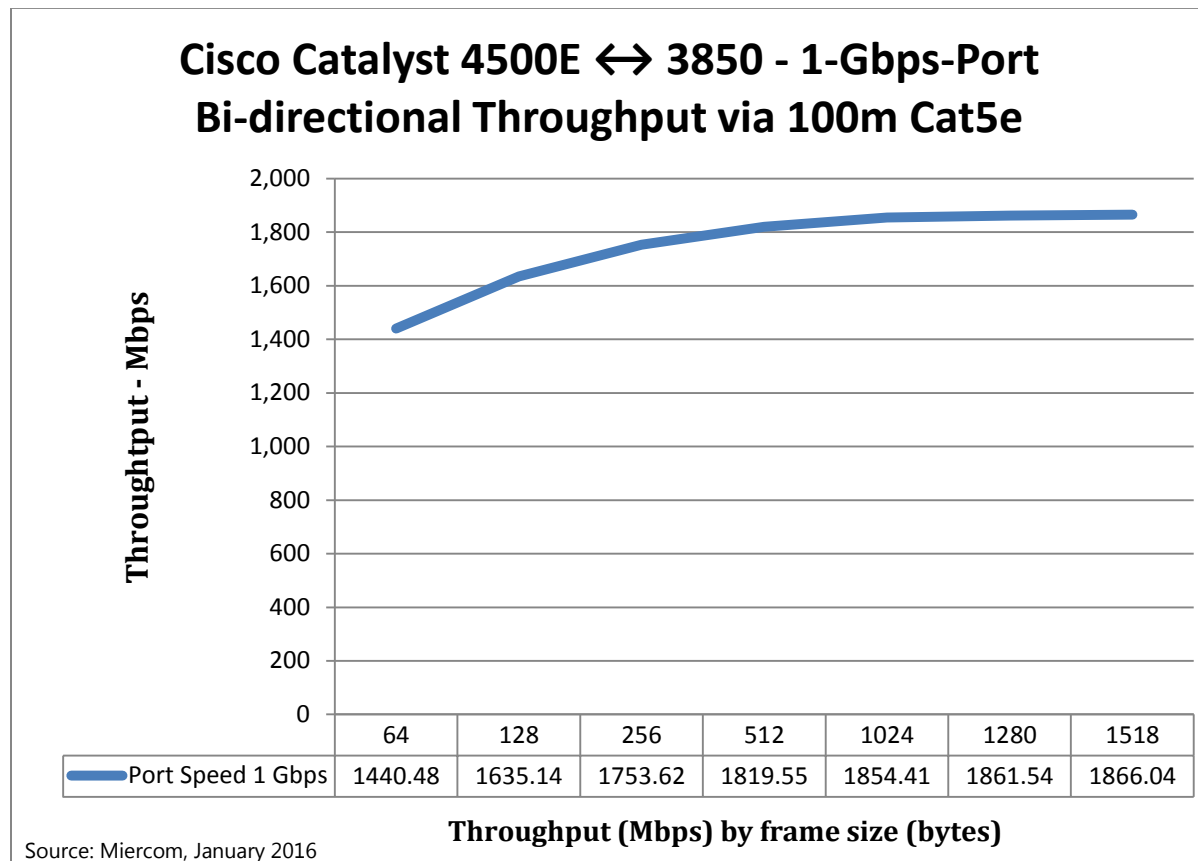
7 - Gigabit-Port Throughput over Cat5e Cabling

Objective: To show that conventional 1-Gigabit/s UTP Catalyst switch ports can deliver ample bi-directional bandwidth over 100-meter lengths of Cat5e cable.

Test procedure: The same test bed shown in Figure 2 was used, except that the 100-meter length of Cat5e cable was moved from Multigigabit ports on the Catalyst 4503E and 3850 switches and onto conventional 1-Gigabit/s UTP/RJ-45 ports. The link automatically comes up at a data rate of 1 Gigabit/s.

The Ixia XM12 then runs RFC 2544 tests with Layer-2 frames to determine maximum throughput for frame sizes 64, 128, 256, 512, 1,024, 1,280 and 1,518 bytes.

Results: As shown below, Catalyst switch 1-Gigabit/s UTP ports make good use of Cat5e cable runs, delivering from 1.5 Gigabit/s of combined, bi-directional throughput with small frames, to more than 1.86 Gigabit/s with large frames.

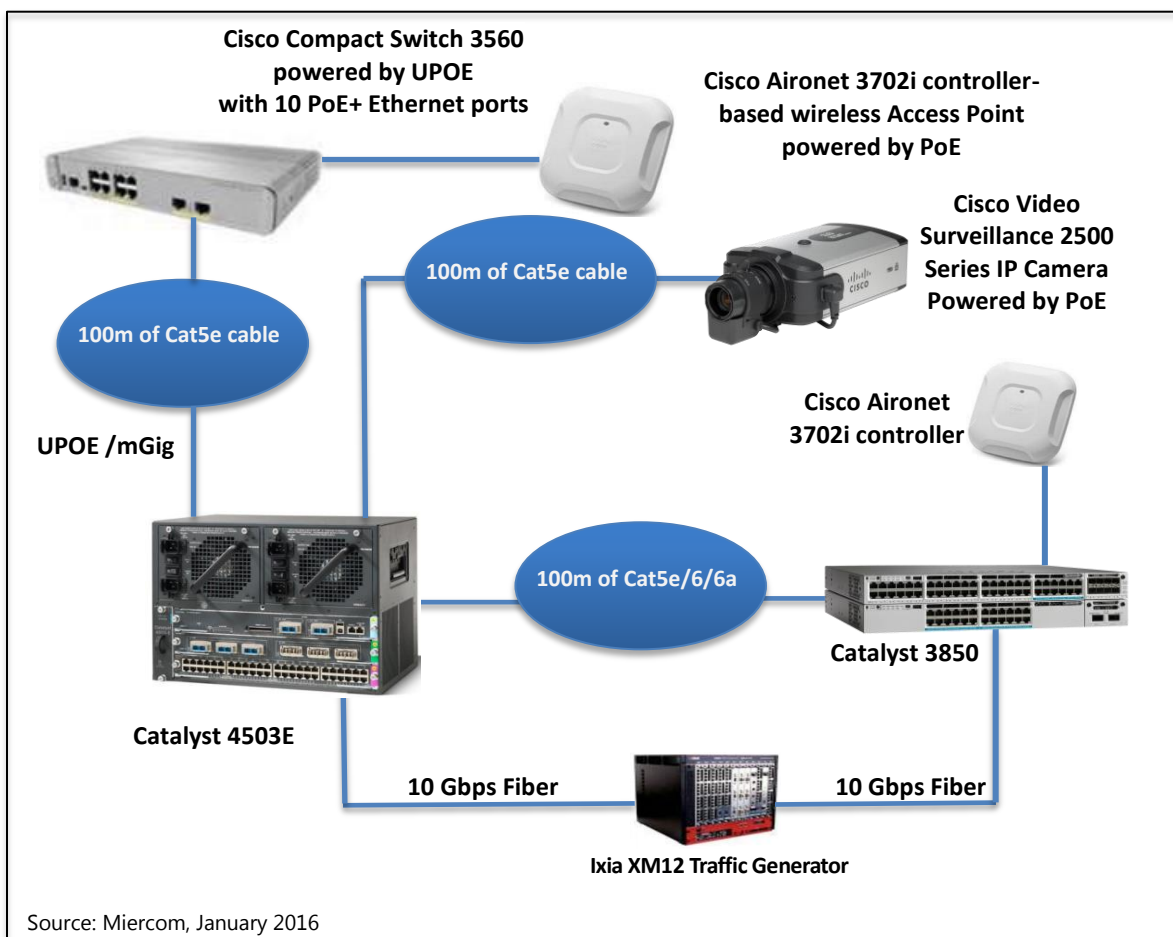


8 - Multigigabit-Port Delivery of UPOE Power over Cat5e Cabling

Objective: To show that Cisco Multigigabit ports can supply UPOE power, up to 60W via a 100-meter length of Cat5e/6/6a cable. This PoE will be used to power both a compact switch and a PoE device connected to the compact switch.

Test procedure: Connect and power a Cisco compact switch using a 100-meter Cat5e cable connected to a Catalyst 4503E Multigigabit UPOE port. Then connect a PoE-powered Access Point to the compact switch. Using another 100-meter Cat5e cable, connect a remote PoE-powered IP security surveillance camera to another Catalyst 4503 port. Then run Multigigabit data over another 100-meter Cat5e cable connecting Multigigabit ports on the switches.

Figure 4: UPOE support by mGig ports via Cat5e cabling



Both the compact switch and attached wireless Access Point will be powered using the power-over-Ethernet supplied by the Catalyst 4503E's Multigigabit UPOE port.

Using the "**show env power**," "**show power**" and "**show power inline**" commands on the compact switch, note the power consumption details. Using the "**show power**" and "**show power inline**" commands on the Catalyst 4503E switch, note the power consumption details.

Results: All connections came up automatically and all devices powered via the UPOE delivered by the 4503E Multigigabit ports operated as expected.

The below "**show power inline**" display of the Catalyst 4503E shows the power status of its 12 Multigigabit ports. Clearly a full 60W is being delivered to the compact switch. The Access Point is drawing 16.8W of PoE power; the video security camera is drawing 9W.

The command line also showed that the Catalyst 4503E has 1440W of in-line power available, that a total of 90W is being used and 1,389W remain.

Interface	Admin	Oper	Power(Watts)		Device	Class
			From PS	To Device		
Te2/1	auto	off	0	0	n/a	n/a
Te2/2	auto	off	0	0	n/a	n/a
Te2/3	auto	off	0	0	n/a	n/a
Te2/4	auto	off	0	0	n/a	n/a
Te2/5	auto	on	63.2	60	WS-C3560CX-8PT-S	4
Te2/6	auto	off	0	0	n/a	n/a
Te2/7	auto	off	0	0	n/a	n/a
Te2/8	auto	off	0	0	n/a	n/a
Te2/9	auto	off	0	0	n/a	n/a
Te2/10	auto	off	0	0	n/a	n/a
Te2/11	auto	on	17.7	16.8	AIR-CAP3702I-A-K9	4
Te2/12	auto	on	9.5	9	CIVS-IPC-2500	3
Gi2/13	auto	off	0	0	n/a	n/a

9 - About "Miercom Performance Verified" Testing

This report was sponsored by Cisco Systems, Inc. The data was obtained completely and independently by Miercom engineers and lab-test staff as part of our Performance Verified assessment. Testing such as this is based on a methodology that is jointly co-developed with the sponsoring vendor. The test cases are designed to focus on specific claims of the sponsoring vendor, and either validate or repudiate those claims. The results are presented in a report such as this one, independently published by Miercom.

10 - About Miercom

Miercom has published hundreds of network-product-comparison analyses in leading trade periodicals and other publications. Miercom's reputation as the leading, independent product test center is undisputed.

Private test services available from Miercom include competitive product analyses, as well as individual product evaluations. Miercom features comprehensive certification and test programs including: Certified Interoperable, Certified Reliable, Certified Secure and Certified Green. Products may also be evaluated under the Performance Verified program, the industry's most thorough and trusted assessment for product usability and performance.

11 - Use of This Report

Every effort was made to ensure the accuracy of the data contained in this report but errors and/or oversights can occur. The information documented in this report may also rely on various test tools, the accuracy of which is beyond our control. Furthermore, the document relies on certain representations by the vendors that were reasonably verified by Miercom but beyond our control to verify to 100 percent certainty.

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