Advancements in field measurement of Ethernet performance

An Ethernet service provider needs to demonstrate to his customer that the service he is providing is compliant with the service level agreement. A network installer needs to demonstrate the functionality of a newly turned-up Ethernet link. A network troubleshooter needs to resolve complaints about slow networks.

Ethernet performance measurement can help. Various metrics can quantify and characterize performance. Test plans can be written to satisfy varying organizational objectives. This white paper will describe advancements in field measurement of end-to-end Ethernet performance.

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Importance of Ethernet performance measurement

Measuring the actual end-to-end Ethernet performance of LAN and WAN links is important to many different organizations. Historically, the carriers who offered Ethernet services cared most about measuring Ethernet performance in the field. There were service level agreements (SLAs) in place between the service provider and the customer that needed to be verified. The SLA specifies, in measureable terms, the services that the provider will furnish, including the expected performance. Performance metrics quantify end-user perceptions of the service provided. We will discuss these metrics later. Field measurement of Ethernet performance was primarily done to assess SLA compliance.

Today, Ethernet service providers and their customers continue to create SLAs and field assessment of those SLAs continues. What has changed is the number of different companies that offer Ethernet services. In addition to carriers, cable television providers (MSOs), utility companies, municipal governments, and others offer Ethernet services. Like traditional carriers, these alternative service providers have SLAs with their customers and need to measure performance to verify SLA compliance. Some private network owners choose not to rely solely on the service provider for SLA compliance assessment, but measure Ethernet performance independently.

We are also seeing private network owners building and maintaining their own Ethernet metropolitan-wide networks. For example, a network owner could lease dark fiber from a local utility company and, by taking advantage of long-distance fiber optic technology, transform his local area network (LAN) into a metropolitan area network (MAN). These owners want the same degree of confidence in the delivery of Ethernet services as if the services were being purchased from a provider. Therefore, they will draft an internal company specification that resembles an SLA and they will measure the performance similarly.

Ethernet performance measurement is useful for more than just SLA compliance testing. It is useful for service turn-up testing and troubleshooting too.

Service turn-up testing occurs after the installation of new network infrastructure or the upgrading of existing infrastructure. Network infrastructure includes layer 1 components like datacom cabling and cable management systems. It includes layer 2 and 3 devices like switches and routers. Today it often includes wireless network devices like access points and bridges. Turn-up testing is used to measure and validate network operation. For example, will the newly installed Ethernet link transmit frames at the maximum rated speed without frame loss and within latency and jitter limits?

Performance measurement is also useful when upgrading existing networks. The performance of the network pre-upgrade is measured and recorded. The performance is measured again post-upgrade. The pre and post measurements are compared for before-and-after analysis.

Ethernet performance measurement assists with troubleshooting networks. By establishing a performance baseline, user complaints of a slow network can be confirmed, or disproved, by comparing current results against the baseline. Users frequently blame the network for slow performance when actually it is an application layer problem. Nevertheless, the network must be ruled out as the cause of slow performance before the real root cause can be discovered and fixed.

Ethernet performance metrics

Several metrics are useful when measuring end-to-end Ethernet performance in the field. Four are defined in the Internet Engineering Task Force (IETF) RFC 2544 “Benchmarking Methodology for Network Interconnect Devices.” These are throughput, latency, frame loss and back-to-back.

- Throughput is the maximum rate at which frames can be transmitted from the source to the destination with zero lost frames or errors. Measured in bits per second (BPS).
- Latency is the total time it takes for a frame to travel from the source to the destination. Measured in microseconds (µs).
- Frame loss rate is the percentage of frames transmitted from the source that are not received at the destination. Measured in percent (%).
- Back-to-back is the maximum number of frames that can be sent from the source to the destination within a specified interval with zero lost frames. This is sometimes called burstability. Measured in seconds(s).

RFC 2544 defines the methodology for performing these tests. It is still the responsibility of the service provider and/or network owner to define what constitutes an acceptable, or passing, level of performance.

In addition to these four RFC 2544 tests, advanced tests enable characterization of other performance attributes that could effect network operation: jitter and bit error rate. Jitter is an important performance attribute when real time applications, like VoIP, are running on the network.

- Jitter is the variation in the arrival time of frames received at the destination. Measured in microseconds (μs).

The bit error rate (BER) provides an indication of how often a frame has to be retransmitted because of errors. Too high a bit error rate may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data. By lowering the data rate, the error rate may be reduced – lowering the number of frames that had to be resent.

- Bit error rate is the percentage of bit errors measured at the destination relative to the number of bits sent by the source. Measured in fractional bit errors (exponential notation, 1e-06 for one error per 1,000,000 bits).

Measurement test plan

There are several issues to consider when creating an Ethernet measurement test plan. It is unlikely that a single plan will be suitable for all organizations because organizations have different objectives. For example, one organization may want the most in-depth, comprehensive, and accurate performance characterization possible. Another might trade-off some testing and accuracy for a reduction in overall test duration. A third might trade-off depth of characterization for a reduction in overall testing costs. The measurement test plan must address the specific performance metrics to measure, the Ethernet links to test, specific test configurations, and the type of test instruments to use.

Select the metrics

When developing the measurement test plan, the service provider or network owner must decide which of the RFC 2544 and advanced tests to run. The fastest and simplest test plan would incorporate just a single test, like throughput, that can run in seconds or minutes. At the other extreme, the plan could incorporate every RFC test plus jitter and bit error rate. The more tests selected the longer the testing duration. Table 1 lists examples of test duration times for the various tests. Results will vary significantly depending upon the specific test configurations and the network link under test.

Test	Test duration times with a sweep of RFC 2544 frame sizes, a peer device as the remote, and a LAN link
RFC 2544 throughput	2 min, 32 sec
RFC 2544 latency	46 sec
RFC 2544 loss	6 min, 52 sec
RFC 2544 back-to-back	45 sec
Jitter	47 sec
Bit error rate	42 sec

Table 1 – Test duration examples

In practice, most service level agreements (SLAs) use the throughput, latency and jitter performance metrics. The frame loss and back-to-back metrics are used more commonly for device (switch, router) characterization. Bit error rate testing is most often used to supplement the RFC 2544 tests as a quick verification of link performance after service turn-up.

Select the links

When measuring performance during service turn-up or when verifying SLA compliance, it is clear which link to test – the link just provisioned. On the other hand, if the objective of performance measurement is for troubleshooting (comparing current test results to baseline performance), a better strategy is inclusion of several links in the measurement plan. Testing several links provides broader visibility into the performance of the entire network. Permanently mounting test instruments at key locations throughout the network allows testing of these links whenever the need arises, or on a periodic basis to spot trends.

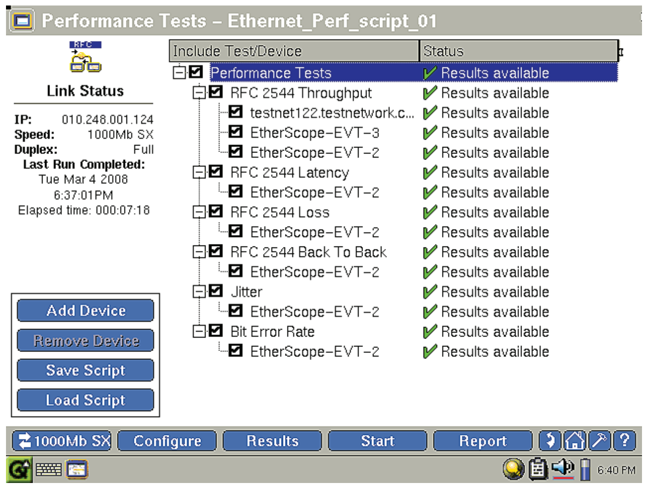

Figure 1: Select the links to test

Configure the tests

While RFC 2544 defines the test methodology, several user-definable settings provide a level of control over test duration and accuracy. Using the throughput test as an example, the user can define:

- The frame size to test, either a single size or a sweep of sizes from 64 to 1518 bytes.
- The duration of each trial, where a trial is defined as the frame-counting period at a given frame size and utilization level. There will be at least one trial for each selected frame size.
- The maximum data rate for the trial.
- The measurement accuracy. Which defines the minimum change in rate between successive iterations of the test. The lower the value, the faster the test will complete.

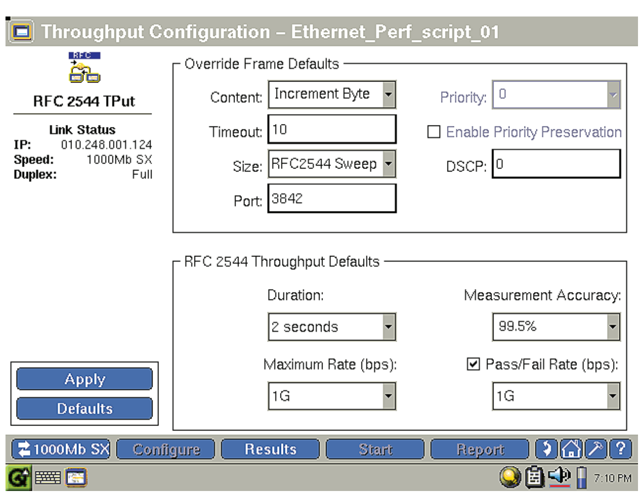

Figure 2: Configure tests

Throughput test configuration	Results with a peer device as remote and a LAN link
Frame size: RFC 2544 sweep **Trial duration:** 30 seconds **Maximum data rate:** 1 Gbps **Measurement accuracy:** 99.95%	**Test duration:** 11 min, 47 sec **Actual rate with 1518 byte frame:** 99,994,608 BPS
Frame size: RFC 2544 sweep **Trial duration:** 60 seconds **Maximum data rate:** 1 Gbps **Measurement accuracy:** 99.95%	**Test duration:** 36 min, 17 sec **Actual rate with 1518 byte frame:** 99,994,608 BPS
Frame size: RFC 2544 sweep **Trial duration:** 60 seconds **Maximum data rate:** 1 Gbps **Measurement accuracy:** 95%	**Test duration:** 23 min, 31 sec **Actual rate with 1518 byte frame:** 90, 225,232 BPS

Table 2 – Throughput results with various configurations

Select the instruments

The RFC 2544 and advanced Ethernet performance measurements described are end-to-end tests. They require a main test instrument at the near-end of the link under test and a remote test instrument at the opposite end. The main instrument initiates the measurement test plan, gathers and processes the results, and provides a user-interface for review and saving of test results. Depending upon the test instrument supplier, there may be a choice of a far-end remote instrument type.

The simplest far-end remote is a loopback. A loop is constructed of a cable that connects the main instrument's transmitting port with its receiving port. For example, a 10/100 RJ-45 loopback can be made by shorting together pins 1-3 and 2-6 at the far-end of the link. Only round-trip results are available using the loopback. Loopbacks are not an option for end-to-end testing in bridged, routed, or LAN environments. In these environments, the frame source and destination addresses must be swapped for the test traffic to return to the main unit.

A reflector is an intelligent loopback that can be used on Layer 2 and 3 networks, as well as Gigabit links. A reflector will swap the destination and source addresses, MAC and IP (optionally). A reflector may be capable of selectively filtering the traffic to be reflected. These reflectors can be used anywhere in the network, at termination points or elsewhere. Only round trip results are available using a reflector.

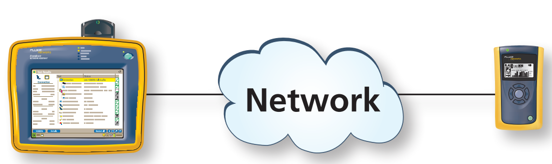

Figure 3: EtherScope analyzer with LinkRunner Pro reflector

A peer device that is the equivalent to the main instrument can also be used as a remote device. Testing to a peer device provides the highest quality measurement. In this configuration, both main and remote units independently generate and analyze traffic. This allows for separate results for upstream (main to remote) and downstream (remote to main) rates. This is very helpful when measuring the performance of asymmetrical links.

Remote instrument	Pros	Cons
Loopback	• inexpensive	• can not be used in Layer 2 or 3 networks • round trip results
Reflector	• lower cost • used anywhere in Layer 2 or 3 networks	• round trip results
Peer	• used anywhere in Layer 2 or 3 networks • upstream and downstream results • initiate test plan from either end	• higher cost

Table 3

Conclusion

Measuring end-to-end Ethernet performance is necessary to verify SLA compliance. It is also used to turn-up new services and troubleshoot existing networks. Several metrics are used to quantify Ethernet performance. A combination of RFC 2544 and advanced metrics can thoroughly characterize performance. There are several elements to consider when creating a measurement test plan. Organizational objectives will guide the selection of metrics (tests) to include in the plan, the links to test, specific test configurations, and the selection of test instruments.

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