

## RFC 2544: HOW IT HELPS QUALIFY A CARRIER ETHERNET NETWORK

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Service providers worldwide are actively turning up new services based on carrier Ethernet technology in a fierce competition to attract premium subscribers. The need for quality services has never been more important, making comprehensive Ethernet testing immediately at service turn-up vital to ensuring service quality and increasing customer satisfaction.

Customer service-level agreements (SLAs) dictate certain performance criteria that must be met, with the majority documenting network availability and mean-time-to-repair values which are easily verified. However, Ethernet performance criteria are more difficult to prove, and demonstrating performance availability, transmission delay, link burstability and service integrity cannot be accomplished accurately by a mere PING command alone.

Portable RFC 2544 test equipment enables field technicians, installers and contractors to immediately capture test results and demonstrate that the Ethernet service meets the customer SLA. These tests can also serve as a performance baseline for future reference.

### What is RFC 2544?

The RFC 2544 standard, established by the Internet Engineering Task Force (IETF) standards body, is the de facto methodology that outlines the tests required to measure and prove performance criteria for carrier Ethernet networks. The standard provides an out-of-service benchmarking methodology to evaluate the performance of network devices using throughput, back-to-back, frame loss and latency tests, with each test validating a specific part of an SLA. The methodology defines the frame size, test duration and number of test iterations. Once completed, these tests will provide performance metrics of the Ethernet network under test.

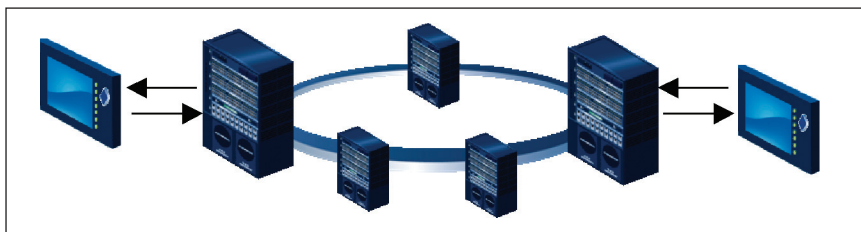
### RFC 2544 Tests

In order to ensure that an Ethernet network is capable of supporting a variety of services (such as VoIP, video, etc.), the RFC 2544 test suite supports seven pre-defined frame sizes (64, 128, 256, 512, 1024, 1280 and 1518 bytes) to simulate various traffic conditions. Small frame sizes increase the number of frames transmitted, thereby stressing the network device as it must switch a large number of frames.

### Throughput Test

The throughput test defines the maximum number of frames per second that can be transmitted without any error. This test is done to measure the rate-limiting capability of an Ethernet switch as found in carrier Ethernet services. The methodology involves starting at a maximum frame rate and then comparing the number of transmitted and received frames. Should frame loss occur, the transmission rate is divided by two and the test is restarted. If during this trial there is no frame loss, then the transmission rate is increased by half of the difference from the previous trial. This methodology is known as the half/doubling method. This trial-and-error methodology is repeated until the rate at which there is no frame loss is found.

The throughput test must be performed for each frame size. Although the test time during which frames are transmitted can be short, it must be at least 60 seconds for the final validation. Each throughput test result must then be recorded in a report, using frames per second (f/s or fps) or bits per second (bit/s or bps) as the measurement unit.



*Figure 1. Throughput test*

## Back-to-Back Test

The back-to-back test (also known as burstability or burst test) assesses the buffering capability of a switch. It measures the maximum number of frames received at full line rate before a frame is lost. In carrier Ethernet networks, this measurement is quite useful as it validates the excess information rate (EIR) as defined in many SLAs.

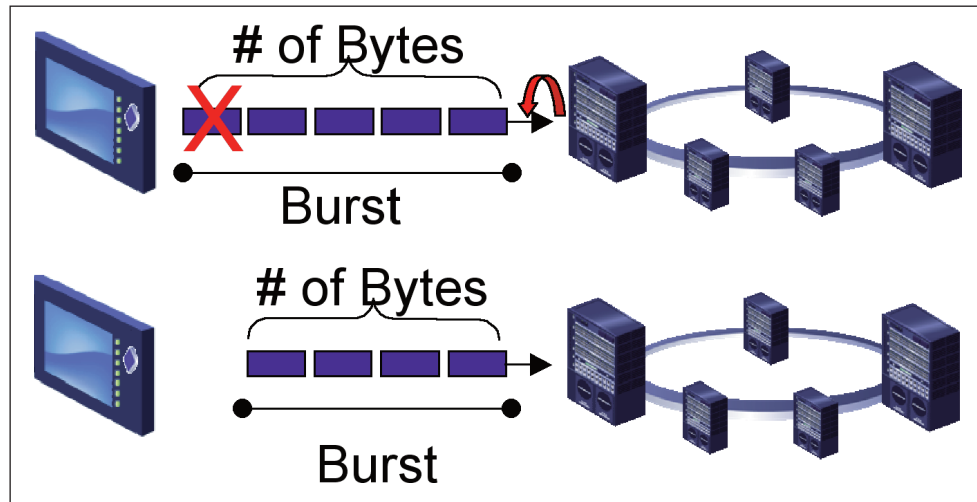


Figure 2: Back-to-back test

As demonstrated in Figure 2, a burst of back-to-back frames is transmitted across the network with minimum interframe gap. Should a frame be dropped, the burst length is shortened. Should it be received without any errors, the burst length will be increased. The trial length must be at least two seconds long and the measurement should be repeated at least 50 times, with the average of the recorded values being reported for each frame size. The average measurement should be logged in the report.

## Frame Loss Test

The frame loss test measures the network's response in overload conditions—a critical indicator of the network's ability to support real-time applications in which a large amount of frame loss will rapidly degrade service quality. As there is no retransmission in real-time applications, these services might rapidly become unusable if frame loss is not controlled.

The test instrument sends traffic at maximum line rate and then measures if the network dropped any frames. If so, the values are recorded, and the test will restart at a slower rate (the rate steps can be as coarse as 10%, although a finer percentage is recommended). This test is repeated until there is no frame loss for three consecutive iterations, at which time a results graph is created for reporting. The results are presented as a percentage of frames that were dropped; i.e., the percentage indicates the variable between the offered load (transmitted frames) vs. the actual load (received frames). Again, this test must be performed for all frame sizes.

<sup>1</sup> Excess Information Rate - EIR means the feature that allows customers to send bursts of data that exceed the allocated bandwidth. All frames within the EIR range are tagged to denote they are eligible for discarding if network congestion occurs.

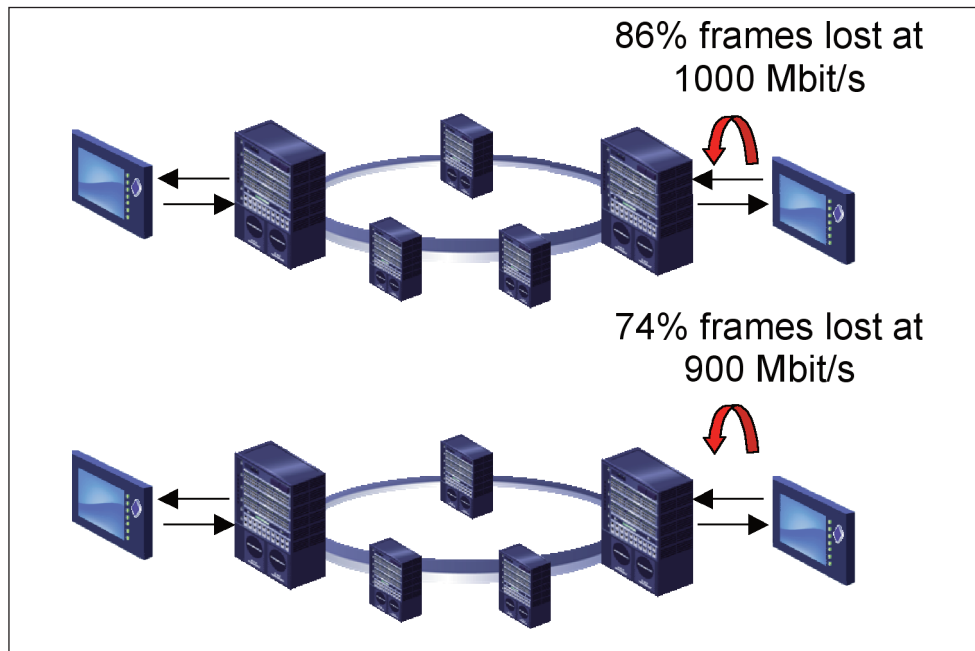


Figure 3: Frame loss test

## Latency Test

The latency test measures the time required for a frame to travel from the originating device through the network to the destination device (also known as end-to-end testing). This test can also be configured to measure the round-trip time; i.e., the time required for a frame to travel from the originating device to the destination device and then back to the originating device.

When the latency time varies from frame to frame, it causes issues with real-time services. For example, latency variation in VoIP applications would degrade the voice quality and create pops or clicks on the line. Long latency can also degrade Ethernet service quality. In client-server applications, the server might time out or poor application performance can occur. For VoIP, this would translate into long delays in the conversation, producing a “satellite call feeling”.

The test procedure begins by measuring and benchmarking the throughput for each frame size to ensure the frames are transmitted without being discarded (i.e., the throughput test). This fills all device buffers, therefore measuring latency in the worst conditions. The second step is for the test instrument to send traffic for 120 seconds. At mid-point in the transmission, a frame must be tagged with a time-stamp and when it is received back at the test instrument, the latency is measured. The transmission should continue for the rest of the time period. This measurement must be taken 20 times for each frame size, and the results should be reported as an average.

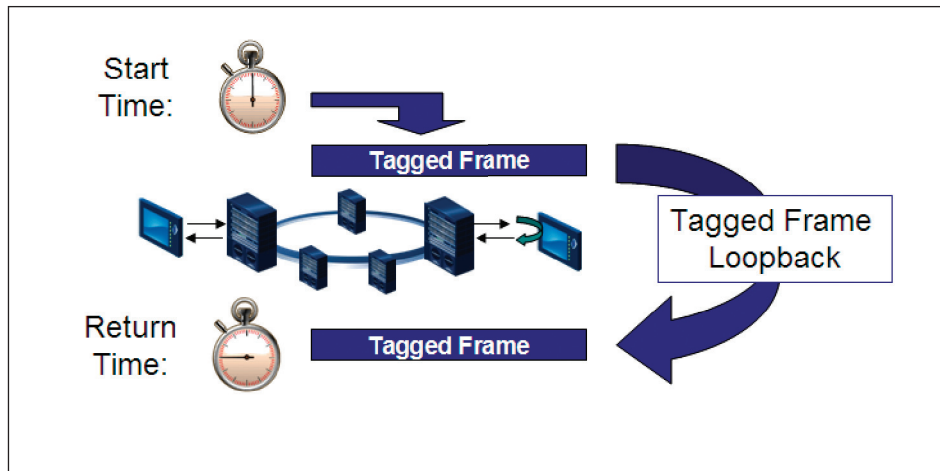


Figure 4: Latency test

## Complementary Testing

Although not included in the defined RFC 2544 standard, another crucial measurement in Ethernet networking is packet jitter. This measurement is critical because excessive jitter can cause major failures in real-time applications such as VoIP or streaming video. In VoIP applications, excessive jitter will cause dropout effects. In video applications, the image will become choppy and pixelization could occur.

As covered in the latency test section above, frame latency will vary over time. It is this variation in inter-packet arrival time that is referred to as packet jitter. Figure 5 provides a graphical view of the occurrence.

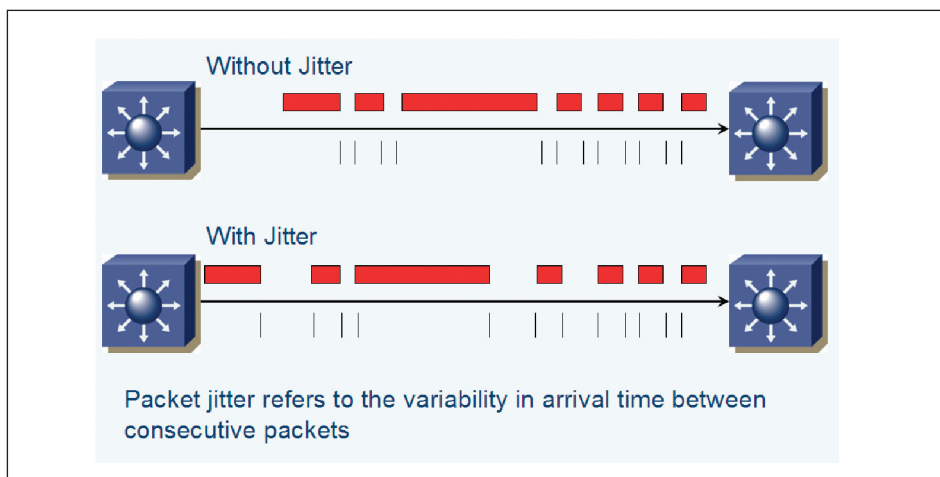


Figure 5: Packet delay variation (packet jitter)

At the start of the transmission, the inter-frame gap between all frames was identical. As the frames navigate through the network, being buffered or routed through different network devices, the inter-frame gap begins to vary.

The packet jitter measurement should be done at maximum frame rate as this is where the most variation will occur.

## Implementing RFC 2544 Testing: Important Considerations

Although RFC 2544 is highly effective for assessing the performance of interconnected network devices, it was originally developed for performance benchmarking of individual network elements, which didn't demand time-sensitive testing scenarios. As an example, the latency test alone calls for testing 20 iterations of 7 different frame sizes – that's 140 tests running 2 minutes each for a minimum test time of 4.6 hours just for the latency test! Because manually completing the entire series of RFC 2544 tests would be quite time-consuming, a certain level of automation is required from today's test solutions in order to thoroughly test and turn up Ethernet services as quickly and efficiently as possible.

Service providers will usually benchmark their network and network elements in the lab and then, from this knowledge, customize their RFC 2544 test routine for field turn-up and installation. For some, the number of frame sizes to test is too large, so they streamline their turn-up testing to include only the extremes; i.e., 64 and 1518 bytes frames (could be longer if VLANs are used). Others might keep all frame sizes but decide to conduct only two tests like throughput and latency, while others will decide to limit the number of tests and the frame sizes. What is critical is that service providers comprehensively test before turning the circuit over to the customer, as it is the last time they have full access to it without affecting subscriber services.

## Conclusion

In the days of time-division multiplexing (TDM) and DS1/DS3/2M dedicated circuits, bit-error-rate (BER) testing was the methodology of choice because the quality of a circuit was easily judged by its capability to deliver error-free bits.

Unfortunately, there are multiple issues related to using BER testing in Ethernet-based networks. Because Ethernet is a Layer 2 switched technology, a hardware loopback might not be the perfect test approach. The integrity of an Ethernet frame is verified at each switching element, and a single bit error will result in the entire frame being discarded. The errored bit will never get to the analyzer and the analyzer will declare a frame loss.

For this reason, the standard BER test is no longer sufficient for performance testing of Ethernet networks, and network element manufacturers and service providers quickly adopted the RFC 2544 methodology as the de facto standard for Ethernet-based testing.

Although testing Ethernet services according to the RFC 2544 standard can be time-consuming, today's test equipment automates test sequences and is easily configured to provide pass/fail criteria. RFC 2544-based Ethernet test solutions provide service providers with the means to fully validate and benchmark their Ethernet network through comprehensive testing and reporting—critical components when establishing performance metrics for customer SLAs and when troubleshooting or maintaining deployed circuits.

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