TELEDYNE LECROY
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Sequence Error Detection

APPLICATION NOTE

How Packet Sequence Anomalies Are
Detected by Xena Testers.

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The complexity of modern Ethernet and IP networks is constantly increasing as new technologies and applications are implemented. As data traverses an Ethernet network, the communication stream can be affected by various anomalies, which degrades performance.

Xena Networks Layer 2-3 testers – the XenaBay and XenaCompact equipped with the relevant test modules – are used to verify the performance of networks and network devices. This is done by sending packets on Ethernet links running up to 100 Gbps and checking the packets when they return to the tester. The testers will detect anomalies in the sequence of the received packets and report the anomalies to the user. This Application Note explains how the detection works and how this is shown in the test results.

Figure 1: The versatile and powerful Xena Networks Layer 2-3 testers XenaBay and XenaCompact

PACKET SEQUENCE ANOMALIES

Ideally, when data is sent as packets through a communication network, all the transmitted data packets will arrive at the recipient unaffected and in the same order as they were sent. However, in the real world transmitted data packets can be affected in several ways, which may cause packet sequence anomalies like packet loss, mis-ordered packets or – in rare cases –duplicated packets. If it is essential for an application that all data packets sent are received in the right order, a protocol like the Transmission Control Protocol (TCP) can be used. TCP will ensure that lost packets are re-transmitted and will pass the packets on in the right order without duplicated packets to the recipient of the packets.

PACKET LOSS

Disturbances like cross talk and network equipment failure can change the contents of the transmitted data packets. Data is in most cases sent embedded in Ethernet frames, which at the and includes a check sum – the Frame Check Sequence (FCS). The FCS is calculated based on the contents of the Ethernet frame. In many cases the nodes an Ethernet frame passes on its way through the network will check that the contents of the frame match the FCS – if that is not the case the frame is discarded and will be lost from the end-to-end communication stream.

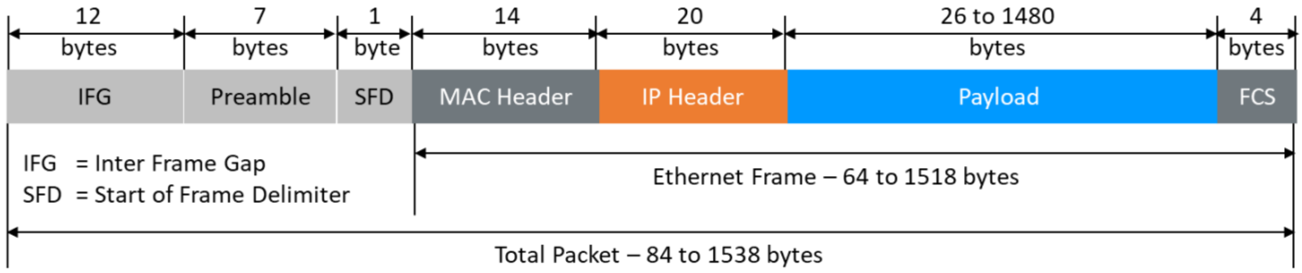

Figure 2: Ethernet/IP frame format

Packet loss can also be caused by failures in the network equipment and overflow of buffers in network nodes. Furthermore, queuing and policing mechanisms in the network may intentionally drop packets in case of overload or network congestion.

MIS-ORDERED PACKETS

If the performance of a link in the network degrades, the network may have a mechanism that switch traffic to an alternative link. During the switch-over process one or more packets may arrive at the recipient before packets that was sent earlier, whereby packets are mis-ordered.

Figure 3 Packet sequence from original sender

Figure 4: Packet sequence at recipient with a mis-ordered packet

DUPLICATED PACKETS

In rare cases packets may be duplicated, probably due to network equipment failure. As this is an unlikely event, it is not counted by Xena Networks testers. Despite that, this application note will describe what will happen if duplicated packets are received by a Xena tester.

Figure 5: Packet sequence at recipient with a duplicated packet

OTHER PACKET IMPAIRMENTS

In addition to the packet sequence anomalies mentioned in this chapter, the data packets sent through a network will be affected by other impairments like:

- Latency – or delay: It is unavoidable that packets sent through the network are delayed on the way due to the distance between sender and recipient. Longer distance will mean higher delay

- Packet jitter – or Frame Delay Variation: As mentioned above, packets sent through a network will be delayed, but the delay may change slightly from packet to packet. This is the packet jitter.

XENA NETWORKS TESTERS' DETECTION OF PACKET SEQUENCE ANOMALIES

Xena's Layer 2-3 testers – the XenaBay and XenaCompact equipped with the relevant test modules - detect lost packets, mis-ordered packets latency and packet jitter on Ethernet links running up to 100 Gbps. Testing is done with test packets sent from the tester through the network, system or device to be tested. When test packets are received again by the Xena tester it will use them to calculate the many statistics it can present to the user.

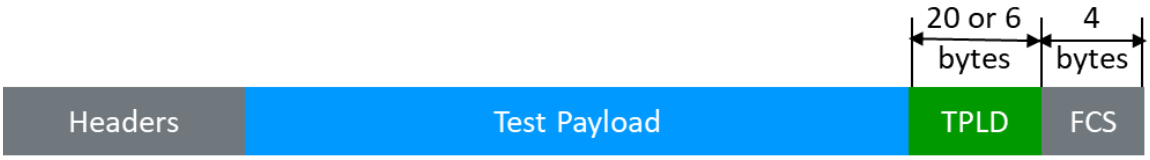

Figure 6: Xena test packet format

After headers (MAC, IP, UDP/TCP etc.) as defined by the user, the Xena test packet includes the test payload, for which the user has several different options. The test payload is followed by a special proprietary data area called the *Test PayLoad Data* (TPLD) which contains various information about the packet. The TPLD is normally 20 bytes long but can in some cases be extended with an extra 2 byte field. Most test modules also support a 6 bytes micro-TPLD, which can be used for sending very short test packets. When the micro-TPLD is used, the Xena testers will not provide information on packet sequence anomalies. Selection of normal TPLD vs. micro-TPLD affects all test packets sent from a port in a Xena test module.

Field	Length	Explanation
Sequence Number	3 bytes	Packet sequence number used for loss and mis-ordering detection
Timestamp	4 bytes	Timestamp value used for latency measurements
Test Payload ID (TID)	2 bytes	Test payload identifier used to identify the sending stream
Payload Integrity Offset	1 byte	Offset in packet from where to calculate payload integrity
First Packet Flag	1 bit	Set if this is the first packet after traffic is started
Checksum Enabled	1 bit	Set if payload integrity checksum is used
<reserved>	10 bits	
Timestamp Decimals	4 bits	Additional decimals for the timestamp
Checksum	8 bytes	Payload integrity checksum
Total TPLD Size	20 bytes	

Table 1: Normal 20 bytes TPLD

Field	Length	Explanation
First Packet Flag	1 bit	Set if this is the first packet after traffic is started
<reserved>	1 bit	
Test Payload ID (TID)	10 bits	Test payload identifier used to identify the sending stream
Timestamp	28 bits	Timestamp value used for latency measurements
Checksum	8 bits	Payload integrity checksum (CRC-8)
Total micro-TPLD Size	6 bytes	

Table 2: 6 bytes micro-TPLD

DETECTION OF SEQUENCE ERRORS AND LOST PACKETS

When the normal TPLD is used, the Xena tester will insert consecutive numbers in the TPLD Sequence Number field. Upon receipt of the test packets the Xena tester will check the TPLD Sequence Number field to identify sequence errors using the following formula:

$$\text{Number of Sequence Errors} = \sum_{n=1}^{n=\text{last packet}} (\text{Sequence\#\_in\_packet}(n) - \text{Sequence\#\_in\_packet}(n\text{-}1) - 1)$$

The result of the sequence error calculation is reported as “Lost Packets” by the Xena tester. The calculation starts when two packets have been received.

As shown in table 1 the packet sequence number in the Xena test packet is a 3 byte 8 (or 24 bit) i.e. the sequence numbers increment by 1 from 0 to 16,777,215. After 16,777,215 sequence number will wrap around and restart at 0. At this point the sequence error calculation would be:

0 – 16,777,215 – 1 = – 16,777,216

This is interpreted by the Xena tester as a “0”. In fact, if any of the individual sequence error calculation results are outside the range – 16,777,216/2 to – 16,777,216/2 (i.e. – 8,388,608 to 8,388,608) the Xena tester will assume it is the result of a sequence number wrap around and will convert the result to “0”.

Figure 7 illustrates the sequence error calculation if there are no problems:

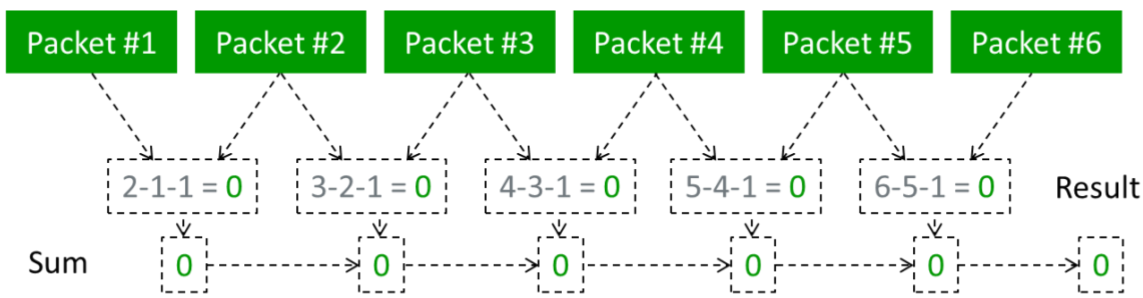

Figure 7: Sequence error calculation if there are no problems

Figure 8 illustrates the sequence error calculation if a packet is lost. As you can see the result of the calculation is that there is 1 Lost Packet:

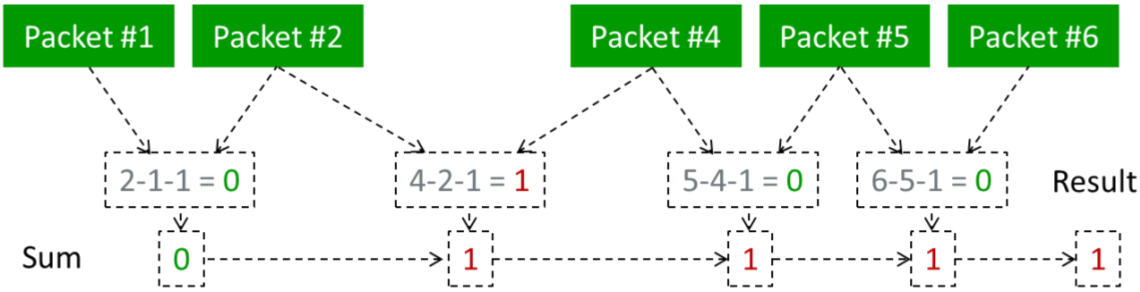

Figure 8: Sequence error calculation if a packet is lost

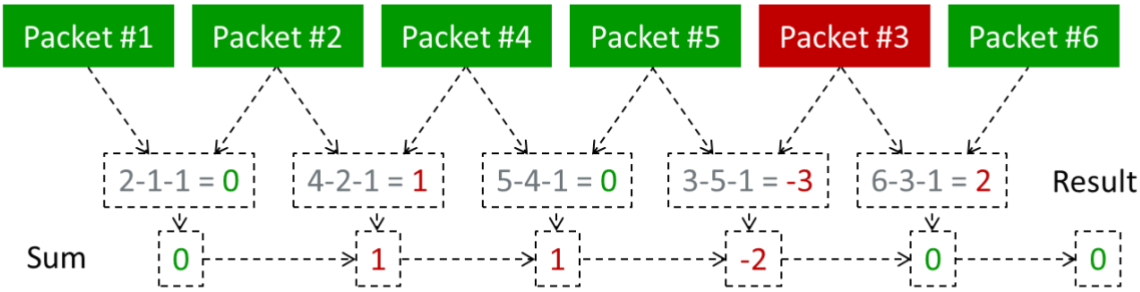

Figure 9: Sequence error calculation if a packet is mis-ordered

Figure 9 illustrates the sequence error calculation if a packet is mis-ordered. As you can see, the final result of the calculation is that there are no Lost Packets. However, until the mis-ordered packet turns up the intermediate calculations will indicate Lost Packets.

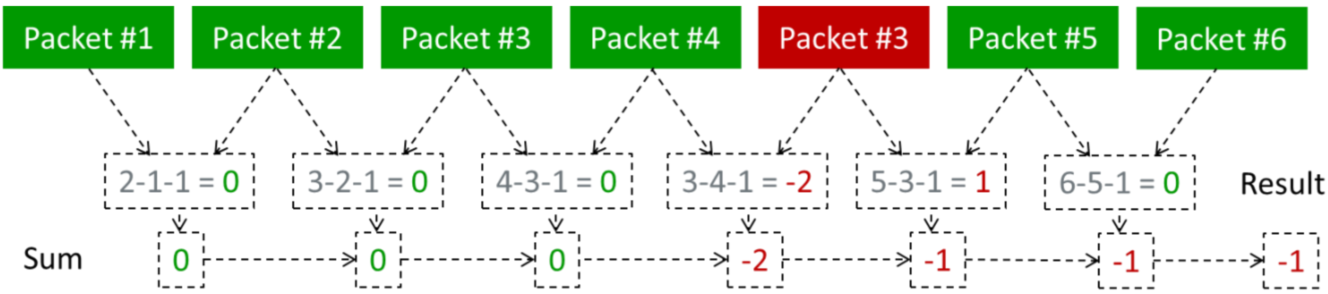

Figure 10: Sequence error calculation if a packet is duplicated

Figure 10 illustrates the sequence error calculation in the unlikely event that a packet is duplicated. As you can see, the final result of the calculation is that there is -1 Lost Packets. This will be indicated by the Xena tester as 16,777,215 i.e. the maximum value of the sequence number.

If 2 consecutive packets have same sequence number, the second is omitted from the from the sequence error calculation and the mis-ordered packets count.

DETECTION OF MIS-ORDERED PACKETS

Mis-ordered packets are detected by looking at the individual results in the sequence error calculation. If the result is negative, the mis-ordered packets counter is incremented by one. However, if the result is less than – 16,777,216/2 (i.e. – 8,388,608) the Xena tester will interpret this as a sequence counter wrap-around and not increment the mis-ordered packets counter.

Figure 11, 12 and 13 illustrates in the “Mis” row how the mis-ordered packets counter is updated for the 3 earlier examples with packet sequence anomalies.

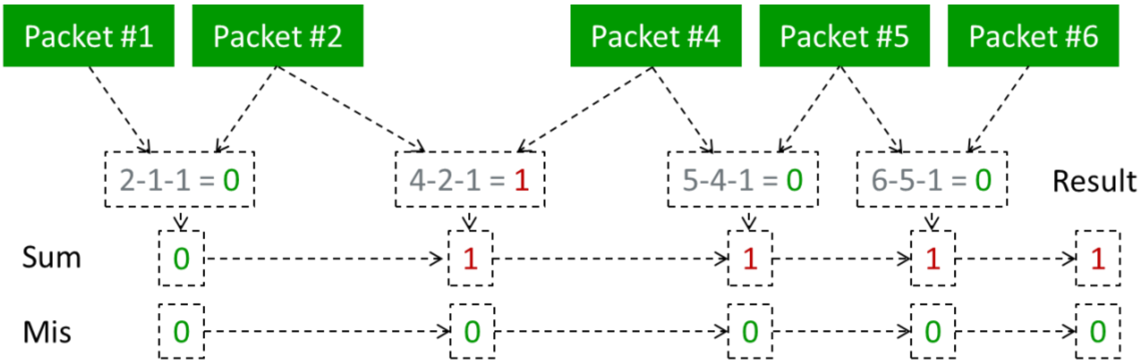

Figure 11: Sequence error and mis-ordered calculations if a packet is lost

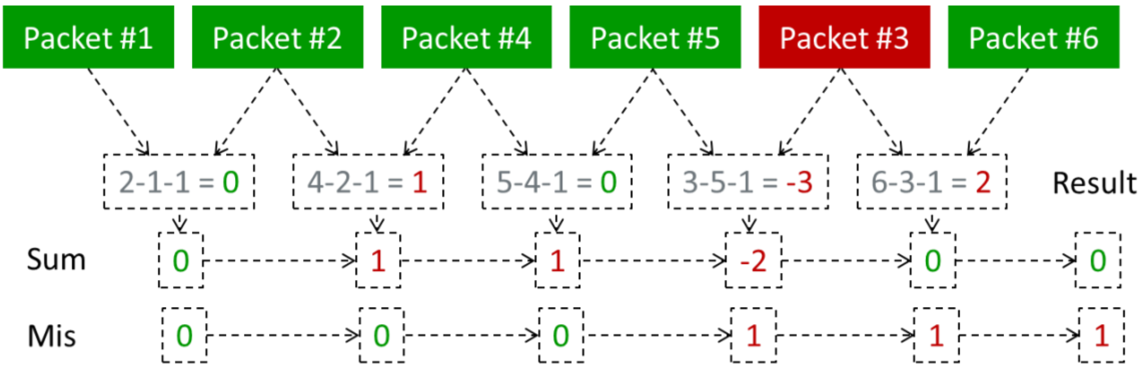

Figure 12: Sequence error and mis-ordered calculations if a packet is mis-ordered

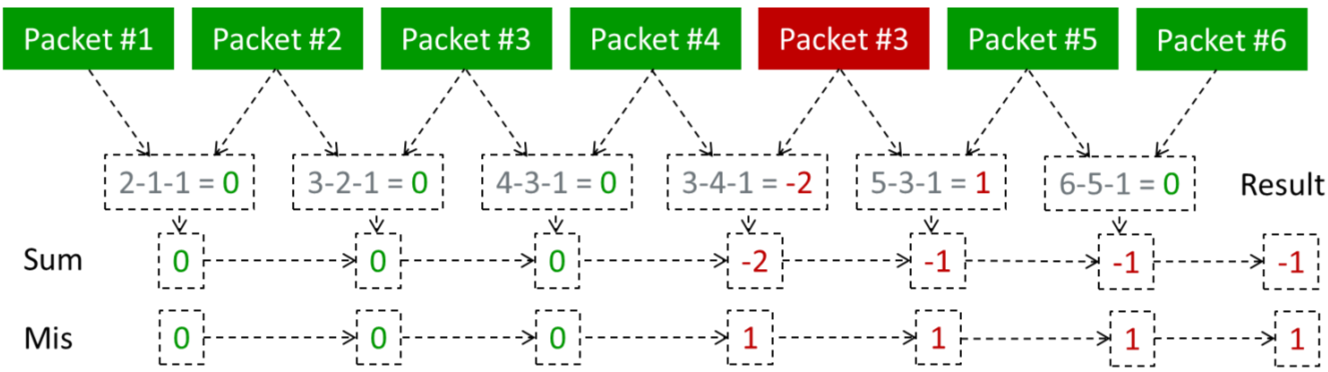

Figure 13: Sequence error and mis-ordered calculations if a packet is duplicated

BER AND PACKET SEQUENCE ANOMALIES

The Bit Error Rate (BER) value provided by Xena testers is estimated based on the assumption that 1 lost packet equals 1 bit error. The estimated BER is calculated as follows by Xena testers (valid from software release 74.2 issued in November 2017):

$$BER = \frac{\text{Lost Packets count}}{8 \times \text{Received Bytes}}$$