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Carrier-Ethernet Acceptance Suite

This document describes Suite to Accept and Approve Carrier class Ethernet nodes such as adapters, hubs, switches, and routers.

Ethernet operators and users may wish to approve specific nodes or stations which will be used as standard equipment on their network. Testing will help operators to decide which brand and model to use. Often a specific physical medium must also be selected, from among several optical and metallic alternatives, and this medium has to be qualified as well.

Approval and acceptance tests help operators to compare devices from different vendors, with a view to choosing one. Some years ago it was also common that once the equipment was purchased, a series of tests were carried out to every single device to confirm that they were working properly before they were accepted by the buyer. Acceptance and approval tests are defined by laboratories, and carried out by engineers working for the purchasers.

These tests, performed by the purchaser, usually go hand in hand with installation tests performed by the installer. Both types of tests are often defined together, and for this reason the documents where they are described usually refer to them as approval/acceptance/installation tests.

1. Ethernet Testing Suite

This *Ethernet testing suite* is an example of a set of test procedures that can be used to prove that an Ethernet device complies with certain specifications.

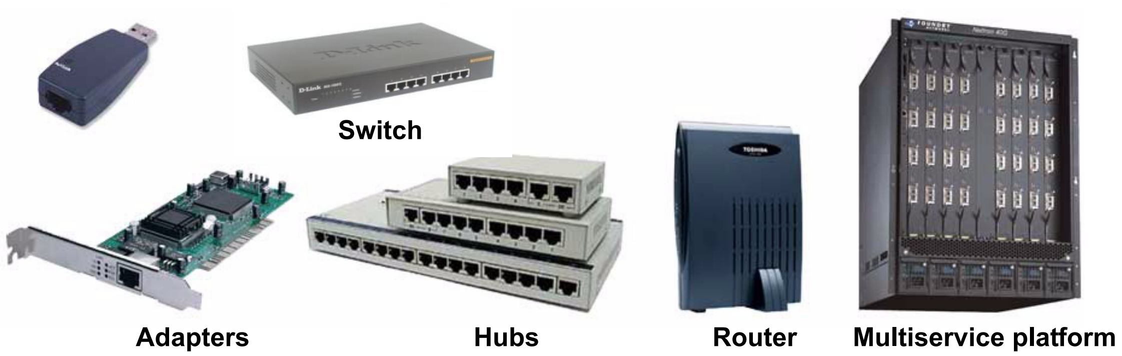

Figure 1. *Ethernet devices to be apporved and accepted.*

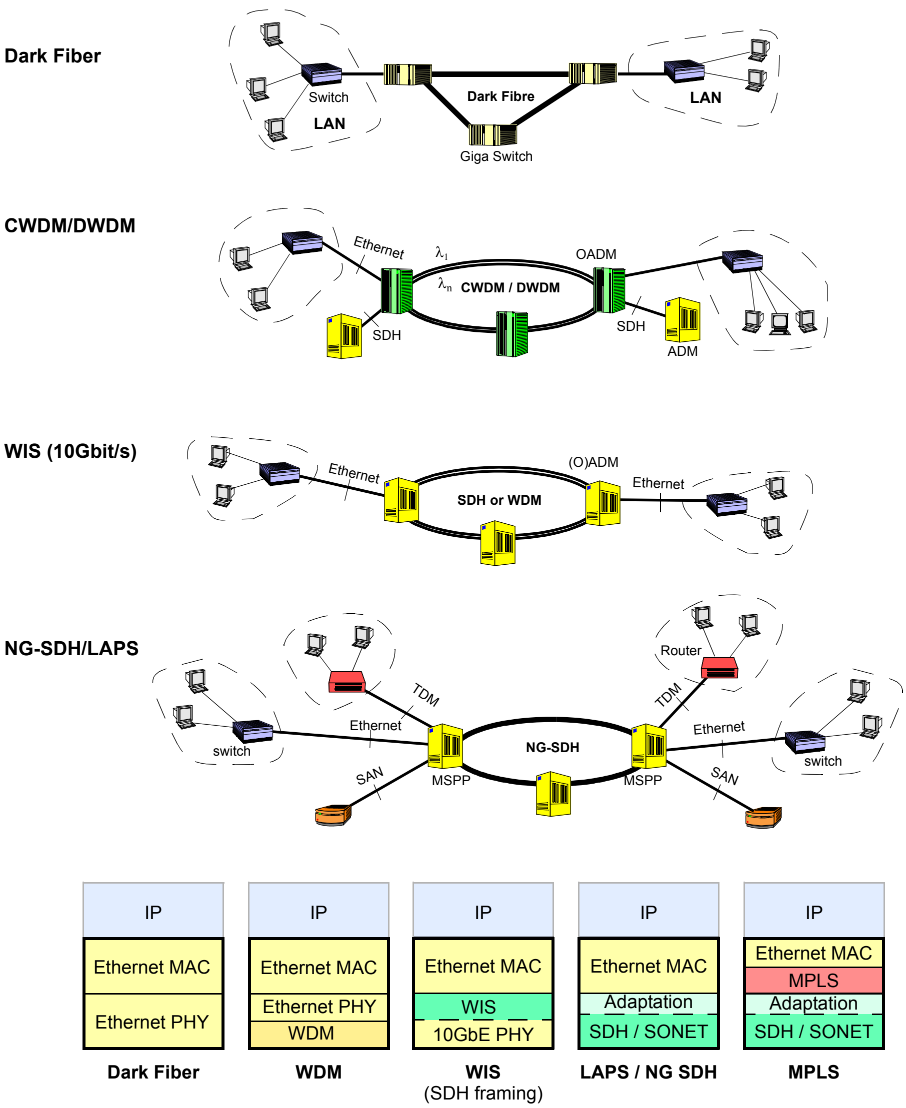

Figure 2. *Carrier Ethernet topologies and protocol towers to be implemented.*

In this book we have basically referred to the IEEE 802.3ab and IEEE 802.3z standards. Nevertheless there are proprietary specifications as well, intended to cover non-standard features that could be eventually included. These procedures can be developed by installers or carriers to facilitate product development and certification by Ethernet equipment suppliers.

Approval and acceptance testing suites are not necessarily methods for demonstrating compliance, because they may be designed to verify certain features only. It may be possible to demonstrate compliance using other procedures. Laboratories of vendors, installers or service providers can use testing suites when auditing or certificating equipment on behalf of the certification authority.

They do not require opening the *Device Under Test* (DUT) to access special test points or to invoke test modes of operation. There are requirements that cannot be verified by black-box techniques, and supplier-proprietary procedures are required to test such requirements. These supplier-proprietary test procedures would be beyond the scope of an acceptance suite of a service provider.

				Encoding			
Standard	**Interface**	**Media Type**	**FDX**	**Data**	**Symbol**	**MFS**	**Distance**
Ethernet IEEE 802.3a-t (clauses1-20) AUI	10BASE-2	One 50 Ohm thin coaxial cable	H	4B/5B	Manchester	64	<185 m
	10BASE-5	One 50 Ohm thick coaxial cable	H	4B/5B	Manchester	64	<500 m
	10Broad36	One 75 Ohm coaxial (CATV)	H	4B/5B	Manchester	64	<3600 m
	10BASE-T	Two pairs of UTP 3 (or better)	H/F	4B/5B	Manchester	64	<100 m
	10BASE-FP	Two optical 62.5 µm MMF passive hub	H	4B/5B	Manchester	64	<1000 m
	10BASE-FL	Two optical 62.5 µm MMF asyn hub	F	4B/5B	Manchester	64	2000 m
	10BASE-FB	Two optical 62.5 µm MMF sync hub	H	4B/5B	Manchester	64	<2000 m
Fast Ethernet IEEE 802.3u (clauses 21-29) MII	100BASE-T4	Four pairs of UTP 3 (or better)	H	8B/6T	MLT3	64	<100 m
	100BASE-T2	Two pairs of UTP 3 (or better)	H/F	PAM5x5	PAM5	64	<100 m
	100BASE-TX	Two pairs of UTP 5 (or better)	H/F	4B/5B	MLT3	64	<100 m
	100BASE-TX	Two pairs of STP cables	F	4B/5B	MLT3	64	200 m
	100BASE-FX	Two optical 62.5 µm MMF	F	4B/5B	NRZI	64	2 km
	100BASE-FX	Two optical 50 µm SMF	F	4B/5B	NRZI	64	40 km
Gigabit Ethernet IEEE 802.3z/ab (clauses 34-42) GMII	1000BASE-CX	Two pairs 150 Ohm STP (twinax)	F	8B/10B	NRZ	416	25 m
	1000BASE-T	Four pair UTP 5 (or better)	H/F	4D-PAM5	PAM5	520	<100 m
	1000BASE-SX	Two 50 µm MMF, 850 nm	F	8B/10B	NRZ	416	500/750 m
	1000BASE-SX	Two 62.5 µm MMF, 850 nm	F	8B/10B	NRZ	416	220/400 m
	1000BASE-LX	Two 50 µm MMF, 1310 nm	F	8B/10B	NRZ	416	550/2000 m
	1000BASE-LX	Two 62.5 µm MMF, 1310 nm	F	8B/10B	NRZ	416	550/1000 m
	1000BASE-LX	Two 8-10 µm SMF,1310 nm	F	8B/10B	NRZ	416	5 km
	1000BASE-ZX	Two 8-10 µm SMF, 1310 nm	F	8B/10B	NRZ	416	80 km
10GEthernet IEEE 802.3ae (clause 48-53) XGMII	10GBASE-SR	Two 50 µm MMF, 850 nm	F	64B/66B	NRZ	N/A	2 ~ 300 m
	10GBASE-SW	Two 62.5 µm MMF, 850 nm	F	64B/66B	NRZ	N/A	2 ~ 33 m
	10GBASE-LX4	Two 50 µm MMF, 4 x DWM signal	F	8B/10B	NRZ	N/A	300 m
	10GBASE-LX4	Two 62.5 µm MMF, 4 x DWM signal	F	8B/10B	NRZ	N/A	300 m
	10GBASE-LX4	Two 8 ~ 10 µm SMF, 1310 nm, 4 x DWM signal	F	8B/10B	NRZ	N/A	10 km
	10GBASE-LR	Two 8 ~ 10 µm SMF, 1310 nm	F	64B/66B	NRZ	N/A	10 km
	10GBASE-LW	Two 8 ~ 10 µm SMF, 1310 nm	F	64B/66B	NRZ	N/A	10 km
	10GBASE-ER	Two 8 ~ 10 µm SMF, 1550 nm	F	64B/66B	NRZ	N/A	2 ~ 40 km
	10GBASE-EW	Two 8 ~ 10 µm SMF, 1550 nm	F	64B/66B	NRZ	N/A	2 ~ 40 km

Table 2. *IEEE 802.3 Ethernet Interfaces*

Any testing suite has to be structured and adapted to the device features and communication layers. A hub is different to a router, because hubs do not have the IP functionalities that routers have, and this is why routers require an additional series of testing procedures. In the following test we have addressed only common features of a generic gigabit device, intentionally excluding half-duplex mode and STP cabling, because it is unlikely to find them on the market.

3. Physical Interfaces Test

This is probably the first test to be performed, the verification of operating ranges of transmitters and receivers, and data pulse shapes of both electrical and optical interfaces.

Optical Interfaces

Testing optical interfaces is more important than analyzing their electrical equivalents, because optical components are more prone to damage and contamination. The following tests can detect most failures:

- *Transmission power* – An optical power meter is needed for testing transmission power. This test is used to measure the output power of the device's transmit laser or LED.
- *Receiver sensitivity* – When optical power falls below a certain limit, the level of noise above the signal starts to become significant, causing errors. Optical sensitivity testing is key in evaluating the quality of optical receivers. The values for sensitivity are specified by the IEEE.

- *Spectral density* **–** Spectral density tests are quite sophisticated, and they require an optical spectrum analyzer. The result is compared with the acceptance mask for the signal.
- *Eye mask* – An eye mask test uses an optical communications analyzer to check transmit port compliance with industry standards. The eye mask can verify characteristics such as jitter, data rate and optical overload (ver Figure 3.).

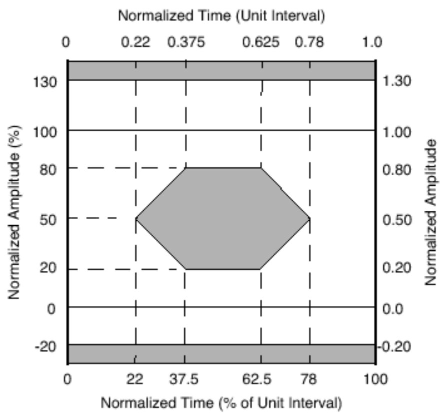

Figure 3. *Transmitter eye mask definition.*

- *Extinction ratio* – Extinction ratio test determines the ratio of optical power for a logical 1 versus a logical 0. The ratio must be large enough to ensure that the detector circuits can differentiate a high data bit from a low data bit.
- *Detecting optical overload* – The optical receiver has a limit for the maximum power it can receive. The purpose of optical overload testing is to check that this limit is adhered to. If it is not, optical saturation or *overload* occurs, which makes it impossible to detect the pulses.
- *Jitter tolerance* – Nodes must tolerate a certain amount of jitter in their inputs without losing synchronization or introducing errors. Jitter tolerance tests are used to measure how much jitter nodes can tolerate. The maximum jitter amplitude that nodes must be able to tolerate is specified by the IEEE (ver Figure 4.).

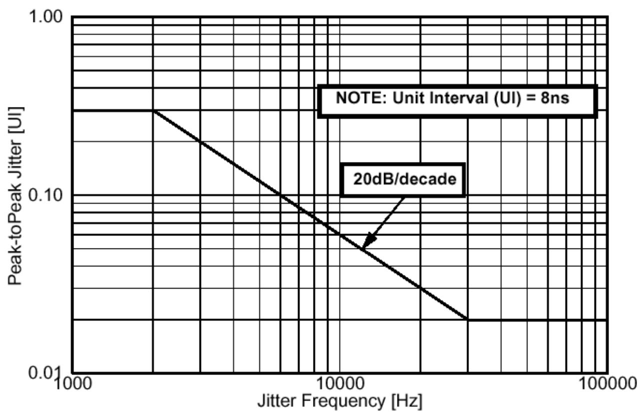

Figure 4. *Jitter tolerance for GbE.*

Electrical Interfaces

Tests based on the Gigabit Ethernet specifications may include:

- *Transmitter electrical specifications* – In transmitter tests various attributes of the electrical transmitter are verified including differential amplitude, skew, and rise and fall times.
- *Receiver electrical specifications* – Receiver tests measure the maximum input and sensitivity, input impedance and jitter.
- *Peak differential output voltage and Level accuracy* – Voltage measurements are made at precise points in the output data stream, using predefined test setups.
- *Maximum output droop* – In receiver maximum output droop testing pairs of points on particular pulses are measured and compared, to ensure that excessive droop is not present, and to verify the receiver's ability to exceed certain levels of voltage droop.
- *Differential output templates* – These measurements look at various positions within a data stream to check that a standard waveform falls within a standard template defined by the IEEE.
- *Return Loss (RL)* – These tests measure the return loss for both the RX and TX ports.

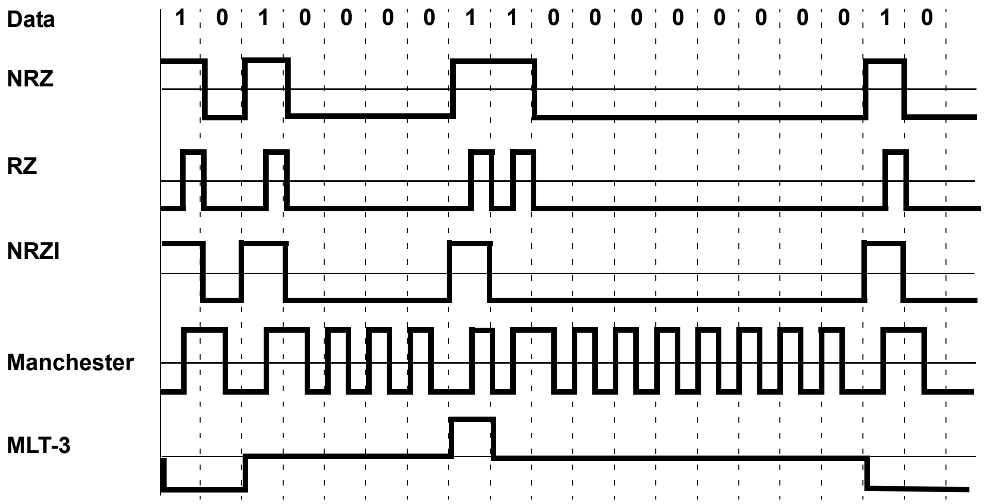

Figure 5. *Symbol encoding schemes used in Ethernet to be checked.*

Measuring Frequency

Low-quality synchronization sources that deviate from the nominal value of the signal they supply, or badly synchronized clock recovery circuits can give rise to problems in the operation of NEs. For this reason, it is necessary to measure the frequency of the line signal at all hierarchical levels, and check its deviations.

The GbE tester needs to be capable of measuring the frequency of the signals received, and, in some cases, the associated line codes as well. The frequency of the signal is usually given in Hz, and its deviation relative to the nominal hierarchical value in ppm. This shows whether the frequency measured is inside or outside the range defined.

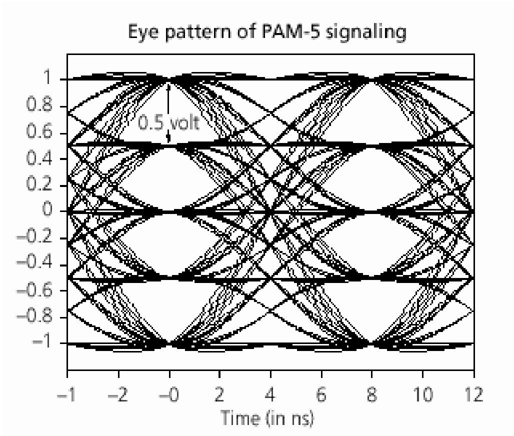

Figure 6. *Eye pattern of PAM-5 signaling.*

4. Jitter Test

Line jitter occurs when bits on a link are received either earlier or later than expected, causing sampling at a non-optimum instant and increasing the probability of bit errors and slips.

Line jitter should not be confused with *frame jitter*. Frame jitter is a quantity-related with the delay variation of frames delivered between the same transmitter and receiver along the network. It depends on queing times in the intermediate nodes as well as on the route followed by the frames.

Phase Fluctuation and Jitter

In terms of time, the *phase* of a signal can be defined as the function that provides the position of any significant instant of this signal relative to its origin in time. A significant instant is defined arbitrarily; for instance, it may be a trailing edge, or a leading edge if the signal is a square wave.

In digital communications, phase is related to clock signals. Every data signal has an associated clock signal that makes it possible to determine, on reception, when to read the value of the bits this signal is made up of. Clocks can be generated by the receiver, obtained from a high-quality timing source, or derived from the data signal. Phase fluctuation is an impairment of the data signal due to a (time-dependent) offset of this signal regarding its clock (see Figure 7.).

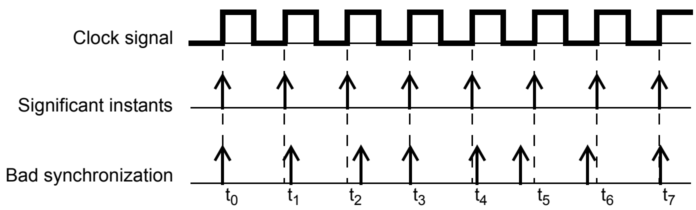

Figure 7. *Phase error of a signal in relation to its ideal frequency*

If the clock signal is generated by the receiver or obtained from a high-quality timing source, phase fluctuation is always a potential cause of problems, but if the clock is derived by the data signal, as is the case of Ethernet, then only phase fluctuation above a certain frequency needs to be considered.

In Ethernet, the clock signal is recovered from the data signal with the help of a *Phase-Locked Loop* (PLL) that is frequency-sensitive. A PPL can track low-frequency phase fluctuations on the data signal, and only high-frequency fluctuation can cause sampling errors. This high-frequency phase fluctuation is known as *line jitter* or just jitter.

Jitter Measurement

The main causes of line jitter in Ethernet networks are the following:

- *Random phase noise* in the clock circuits caused by random movement of the current carriers. This impairment is independent of the data signal.
- *Pattern-dependent jitter* due to limitations of the receiver PLL. Ideally, the clock can be embedded in the data signal and recovered transparently by the reveiver PLL, but in real situations the clock signal is different for every possible data signal. This type of jitter is accumulative, which means that it increases together with the increase in the number of repeaters looked at.

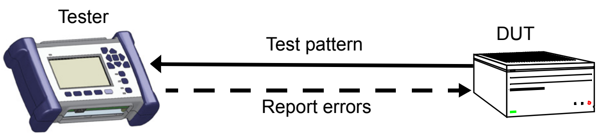

Figure 8. *Jitter measurement of an Ethernet node. The DUT generates a test pattern. The tester measures the amplitude of the jitter generated by the DUT or just the transmission errors due to the presence of jitter. It optionally reports results to the DUT.*

Pattern-dependent jitter makes the test signal important when testing jitter. The IEEE defines test patterns to measure jitter. Each pattern has a different purpose, but the measurement is always performed in the same way. A predictable signal is injected by the transmitter that is being tested, and pattern errors are detected by the tester.

The patterns are given to test GbE-level signals only. The reason is that it is easier for jitter to damage a high bit rate signal, because synchronization constraints are more exigent for them.

Table 5.
Deterministic patterns to test jitter

Test pattern	*Bit sequence*	*Code-group*	*Purpose*
High-frequency	10101010101010101010101...	D21.5	Test random jitter at a BER of 10-12 and test the assymetry of transition times
Low-frequency	1111100000111110000011...	K28.7	Test low frequency random jitter and PLL tracking errors
Mixed frequency	1111101011000001010011...	K28.5	Test combined random jitter and deterministic jitter

The IEEE defines deterministic and random test patterns. In fact, all the test patterns are deterministic, but the patterns classified as random have a more complex structure than the rest. *Deterministic test patterns* are obtained by looped transmission of a specific 8B/10B code group (see Table 5.), whereas *random test patterns* are streams of identical packets separated by a minimum *Inter-Packet Gap* (IPG) and encapsulated in the usual way (see Figure 9.).

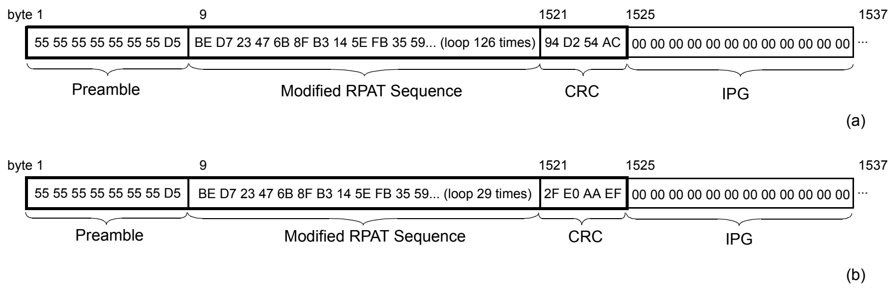

Figure 9. *Random patterns to test jitter, (a) long continuous random test pattern, (b) short continuous random test pattern.*

6. 1000BASE-T PMA TESTING

These tests should determine if a product conforms to IEEE 802.3 (ver Figure 10.). For testing *Physical Medium Attachment* (PMA) electrical characteristics, the standard defines a number of tests:

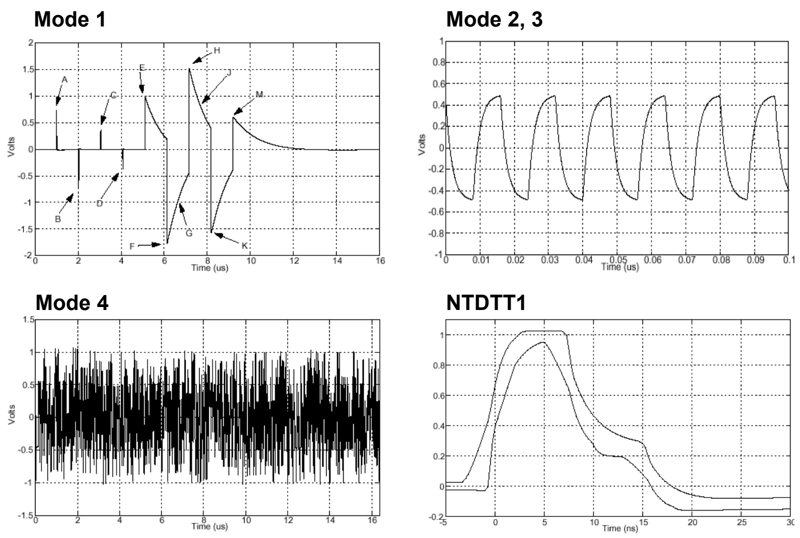

Figure 10. *1000BASE-T PMA test. Example of transmitter test modes of 1, 2, 3 and 4 waveforms. Bottom right, the Normalized Time-Domain Transmit Template (NTDTT).*

- *Peak differential output voltage and level accuracy* – to verify that the value of the wave form falls within the specified range.
- *Maximum output droop* – to verify that the transmitted signal decays according to the specification, but not faster.
- *Differential output templates* – to verify that output falls within the time domain template.
- *MDI return loss* – to measure the RL at the MDI for all four channels.

7. 1000BASE-X PCS TESTING

The PCS functions include the PCS transmit and receive, Carrier sense, Synchronization and Auto-Negotiation.

Synchronization Check

Synchronization ensures the alignment of multicode-group ordered sets to *n*-numbered code group boundaries. Synchronization is acquired by the detection of three ordered sets containing commas in their leftmost bit positions without intervening in valid code group errors (ver Figure 11.).

The DUT should be able to maintain synchronization while sending frames, and for a specific set of invalid code group sequences.

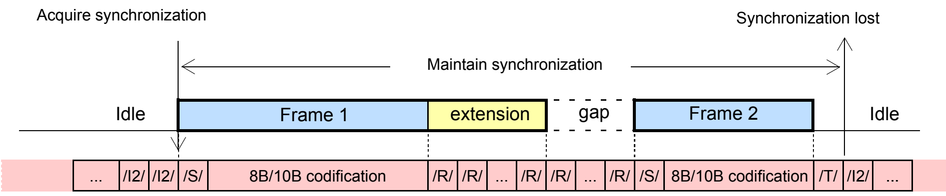

Figure 11. *In the line coding for 1000BASE-X, code-words are used to encapsulate the frame to unambiguously distinguish data from control information.*

PCS Transmission

The *Physical Coding Sublayer* (PCS) uses a transmission code to improve the transmission characteristics of the information to be transferred across the link (ver Figure 11.). Some tests can be performed to verify that the DUT transmits information correctly:

- *8B/10B conversion* – each 8-bit data octet is mapped into 10-bit symbols (see Paragraph 2.3.1.1)
- *Frame encapsulation* – The Ethernet frame is encoded using the 8B/10B code rules. However, control groups are also required for the line code: */S/* indicates the start of a packet, */T/* and */R/* frame termination, */I1/* and */I2/* inter-frame gaps, etc. (see Paragraph 2.3.1.2)

PCS Reception

At the receiver side, the inverse functions should be implemented including 8B/10B decoding, detecting end of packet, or the reception of */C/* during IDLE.

8. AUTO-NEGOTIATION

Many early implementations of the *auto-negotiation feature* are not compliant with the final standard. Some may be fixed with driver updates, while others require new hardware. For example, many Ethernet products older than 1997 do not support auto-negotiation. This has created a situation where the new standard-compliant products appear to be causing problems, when in fact it is the older, non-compliant hardware that cannot take advantage of this new valuable feature.

Auto-negotiation varies depending on the standard. 10/100/1000BASE-T are potentially able to establish links between them, after a successful auto-negotiation process has finished and common parameters have been agreed. 1000BASE-X also has auto-negotiation capabilities, but reduced to the flow control mechanism only.

The following tests are intended to verify the capacity of the DUT to manage the auto-negotiation protocol according to the IEEE 802.3.

10/100/1000BASE-T Auto-Negotiation

Enable/Disable

If the auto-negotiation function of the DUT is enabled, the device should always send auto-negotiation messages (ver Figure 10.) as soon as it is connected to a link and before it reaches its final stage, which could be 'link established' or 'impossible to establish link'. After this stage these messages should cease. If the link is broken and reconnected, the DUT must restart the process.

It is possible to disable the auto-negotiation feature in some devices. If this is done, the DUT should not send any auto-negotiation messages at all.

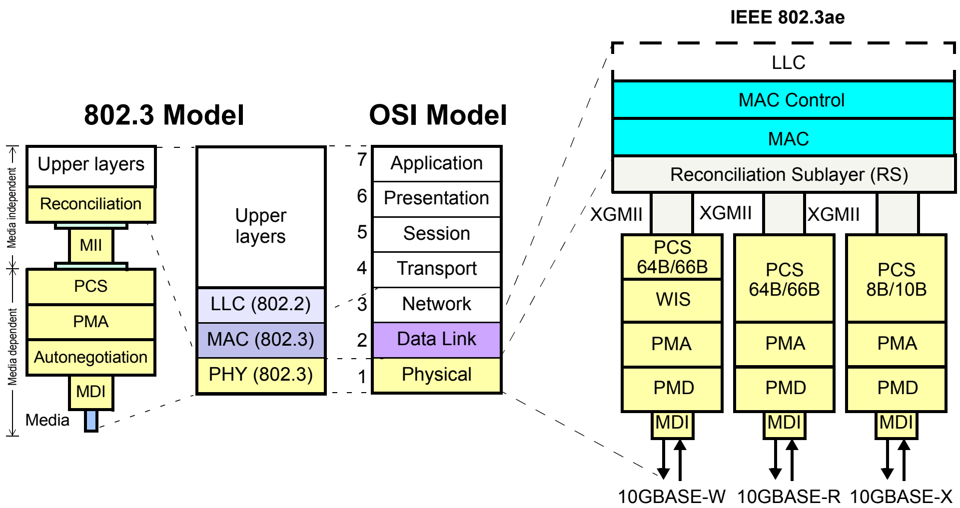

Figure 13 Ethernet layers, 802.3 model compared with OSI. MII and Autonegotiation are optional.
Layered model of IEEE 802.3ae 10 Gigabit Ethernet.

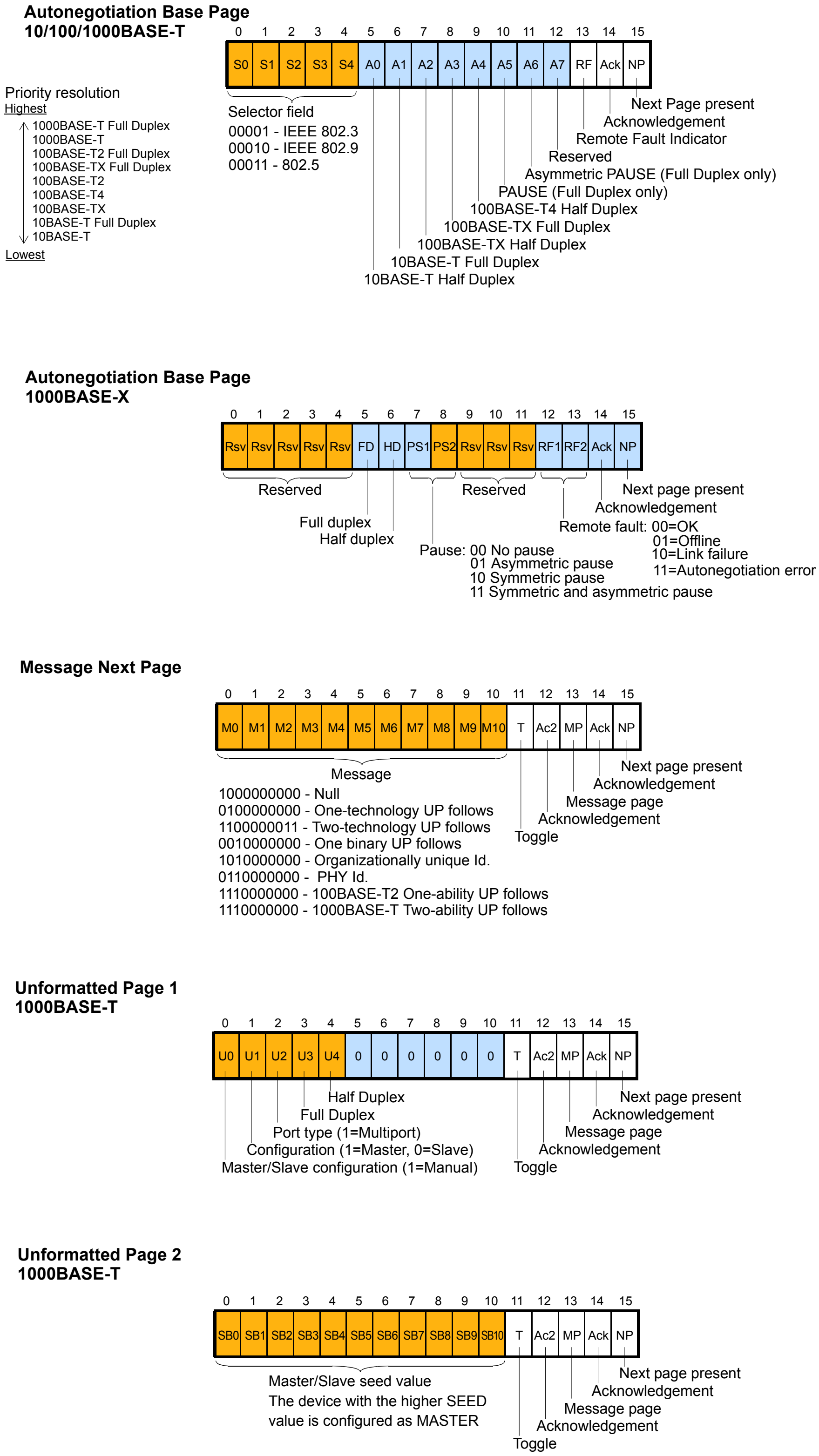

Figure 12. *Autonegotiation messages. On link initialisation, the two stations send 16-bit page messages to their partners. The interchange can consist of many pages in addition to the base page. Scope: 10/100BASE-T autonegotiation: only 10/1000 Mbit/s systems using UTP and RJ-45. 1000BASE-X autonegotiation: media equivalent systems at 1000 Mbit/s. 1000BASE-T autonegotiation: negotiable 10/100/1000 Mbit/s using UTP and RJ-45*

Base Page

The first action the auto-negotiation protocol must take is to declare itself to advertise the abilities of the device by means of a especial message known as *base page* (ver Figure 10.). The message must reflect the exact speed, duplex mode and flow control features of the DUT. Naturally, a device should not advertise abilities it does not have.

Priority Resolution

When both devices attached to a link have sent the base page (if auto-negotiation is enabled), they must proceed to the resolution of speed, duplex, pause mode, and master/slave:

- *Speed resolution* – The DUT must select the highest bit rate that both devices can manage. The top–down priority list is, obviously: 1 Gbit/s, 100 Mbit/s, and 10 Mbit/s.
- *Duplex mode* – The DUT must select full duplex (FDX) if both devices support it, and if not, half-duplex mode is used.
- *Pause mode* – If FDX has been resolved, the devices must also agree the flow control scheme or Pause protocol support. Transmit (Tx) and Receive (Rx) capabilities can be independent, and this way we can get up to four combinations per Tx/Rx pair. The possibilities are: a) Enabled Tx and Rx; b) Disabled Tx and Rx, c) Enabled Tx, disabled Rx; d) Disabled Tx, enabled Rx.
- *Master–Slave* – In 1000BASE-T, one device must be declared master; the other one will be the slave. To decide which one is the master, the top–down priorities are: manual configuration, multiport and single port. If both are multiport or single port, it is necessary to send unformatted page 2, and the device with the highest seed value will be declared master (ver Figure 11.). Faulty situations occur when both devices are manually configured to be either master or slave.

1000BASE-X Auto-Negotiation

The 1000BASE-X auto-negotiation mechanism is gigabit-specific. This means that it is not possible to negotiate bit rate, but duplex operation, flow control and similar capabilities. This mechanism cannot resolve any improper configurations of wavelength of fiber optics. If that should happen, the link just wouldn't work.

1000BASE-X has a set of 8B/10B codes to make sure that auto-negotiation messages are not interpreted as data frames.

Enable/Disable

If the DUT's auto-negotiation feature is enabled, it should always send auto-negotiation messages (ver Figure 10.) as soon as it is connected to a link and before it reaches its final stage, which could be 'link established' or 'impossible to establish link'. After this stage, the messages should cease. If the link is broken and reconnected, the DUT must restart the process.

It is possible to disable the auto-negotiation feature in some devices. In that case, logically, the DUT should not send any auto-negotiation messages.

Base Page

The first action the auto-negotiation protocol must take is to declare itself to advertise the abilities of the device by means of a base page (ver Figure 12.). The message must reflect the exact speed, duplex mode and flow control features of the DUT.

Priority Resolution

When both devices attached to the link have sent the base page (if auto-negotiation is enabled) they must proceed to the resolution of speed, duplex, pause mode, and master/slave:

- *Duplex mode* – (see Full Duplex Verification on page 14).
- *Pause mode* – (see Flow Control Test on page 16).
- *Remote Fault (RF)* – If the RF feature is supported, it is used to indicate error conditions to the link partner. Any indication other than ‘No error’ can make the link non-operational. If a problem is detected, a device can use an RF to inform its partner about the problem.

9. MAC LAYER TESTING

The MAC is the data link sublayer in ch (see Flow Control Test on page 16)arge of transferring data to and from the physical layer. It can be considered as the core of all Ethernet versions, and it is essential for normal operation.

A number of benchmarking tests can be performed to accept a specific Ethernet device. However, many of the new Ethernet installations are full duplex only, to avoid collisions and to increase throughput. In this case, the MAC layer is much simpler, because it has to manage the CSMA/CD protocol needed when the physical media is shared by two or more stations.

The majority of gigabit installations use full duplex only, which is also why we have not considered half duplex verification in the following test.

Frame Error Management

When frames are detected by an Ethernet node, the complete frame is immediately dropped. This is one of the peculiarities of Ethernet. We can carry on generating special test traffic, and then analyzing how the DUT manages frames.

Receiving Frames

- *Preamble errors* – This field is used to allow synchronization with the received frame’s timing. An invalid preamble should not interfere with the reception of a correct MAC frame, and the DUT should be able to get the packet.

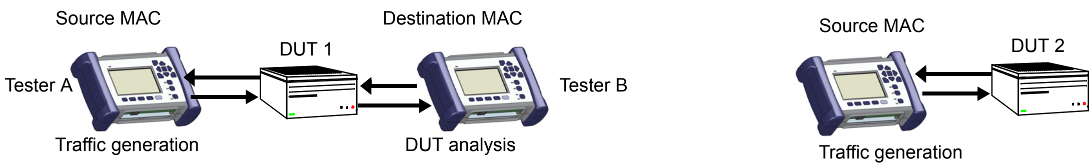

Figure 14. *MAC frames analysis. At left, tester A generates a special frame to test how the DUT works. Tester B should check if DUT1 forwards or drops every single frame. While DUT1 could be a hub or a router, the right side testing fixture is for end stations, such as a server or a PCs, and it would require DUT2 to offer a view on the Ethernet traffic.*

- *SDF errors* – This field is the sequence *10101011*. It immediately follows the preamble pattern and indicates the start of a frame. Any frame with an invalid SDF should be discarded.
- *Source and Destination address* – This field is 48 bits in length; 16-bit addresses are rejected. End stations should discard any unicast frames with address different to the own.
- *Type/Length errors* – If the value of this field is greater than or equal to 1536, that indicates a Type client protocol. If the value is less than or equal to 1500,
it indicates the number of MAC client data octets contained in the LLC-Pad field. If the length is less than the data field, the rest is considered a pad and removed. If the length is greater, there is an error, and the frame must be dropped. An additional difficulty is presented by the DUT supporting proprietary jumbo frames, which can have a size up to 9000 bytes.
- *Fragments of frames* – Any frame which is less than 512 in full-duplex Gigabit Ethernet is illegal and must be dropped by the DUT.
- *Runts* are fragments with a valid CRC. The DUT should drop them.
- *Jabber frames* are described most often as a frame greater than the maximum of 1518 bytes, with a bad CRC. The DUT should discard all of them.
- *FCS error* – This field is a CRC, generated from an algorithm, and it is derived from the data in the frame. If the frame is altered between the source and the destination, the receiving station will recognize that the CRC does not match the contents of the packet. The frame must be dropped by the DUT.

Transmitting Frames

Acceptance tests should also verify that the DUT can properly encapsulate client information in MAC frames. This information includes headers, such as preamble and SDH, source and destination addresses.

It would also be convenient to verify that the DUT calculates the frame length, padding and FCS fields correctly. The inter-frame gap, which must be at least 96 bytes, would require additional verification.

Full Duplex Verification

Full-duplex operation ignores the CSMA-CD protocol and implements a point-to-point Ethernet connection between two devices. In a full-duplex network there are no collisions, and end stations at opposite ends of a full-duplex Ethernet link may transmit simultaneously.

- *No frame collisions* **–** Collisions cannot occur, and the DUT should be able to transmit and receive simultaneously, without observing any collisions or jam signals.
- *Carrier Sense (CS) holdover* **–** The CS is a physical signal used to take up the media during transmission. In half duplex it has to be held over CS after sending the frame to allow transmission by other stations. However, in full duplex the MAC layer does not have to defer the CS because the channel is devoted to it.
- *No frame extensions* **–** Frame extensions ensuring a minimum size in Gigabit Ethernet are not needed anymore. Minimum size was a requirement to guarantee that collisions wouldn't happen while transmitting.
- *No frame bursting* – In half duplex a station is allowed to send multiple frames to avoid collisions and improve efficiency (see Paragraph 1.5.2). Without collisions the DUT should not use the frame bursting technique.

10. Physical-Layer Interoperability Test

Physical-layer interoperability tests ensure that the DUT is able to establish a link and exchange packets with a device of similar characteristics. At the physical layer, the GBIC transceiver must be of good quality, the type of cable must be appropriate, and the configuration must be correct. The integrity of the physical layer is key to getting good performance.

Link Establishment

A *link establishment test* checks if the DUT is able to establish a link at the optimal bit rate. Many Ethernet products have auto-negotiation capability, and others have manual configuration or nothing at all. In any case, they should be able to detect the link speed of the partner device. Once the link has been successfully established, the DUT should be able to recover after it has been disconnected and connected again.

Another interesting test is to verify that the manually configured devices can establish a link with remote stations with the same manual configuration and with a station with compliant auto-negotiation features. Furthermore, it should be verified that a DUT with an optical layer should not establish any links if the partner station has a similar, but not the same, wavelength.

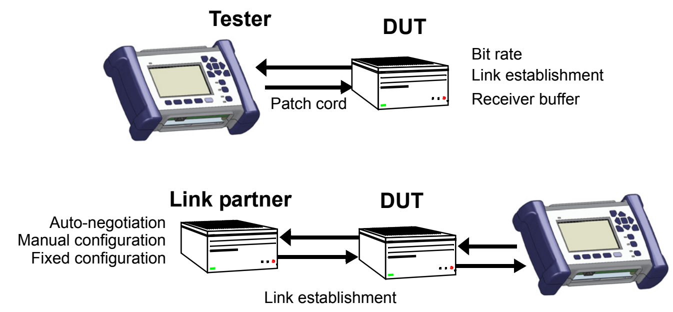

Figure 15. *Acceptance test begins by verifying physical layer interoperability.*

Frame Error Ratio

The *frame error ratio test* determines the percentage of error-free frames that the DUT can generate. The ratio must be below a threshold which will depend on parameters such as bit rate, type of traffic to transport or SLA to achieve. The test can be performed according to the RFC 2544 (see Paragraph 5.3.3).

Receiver Buffer Test

A *receiver buffer test* determines the buffer management ability of the DUT under heavy traffic conditions. When frames start to be dropped, the overload level has been achieved. The test can be performed according to the back-to-back test of the RFC 2544 (see Paragraph 5.3.4)

11. Flow Control Test

The f*low control protocol*, which can be implemented in full-duplex systems, is based on a short packet known as the *Pause frame* (ver Figure 16.). This frame provides a mechanism whereby a congested receiver can ask the transmitter to stop the transmission (see Paragraph 1.6.1).

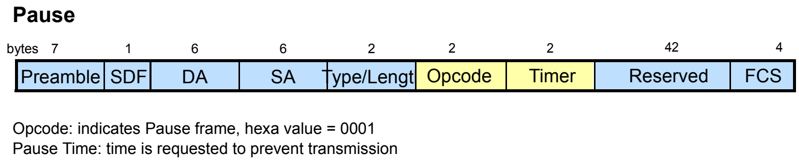

Figure 16. *Pause frame, used for the flow control protocol. The unit of pause time equals to 512 bits. If pause time is 0, transmission should be stopped.*

The DUT may be able to work in several flow control modes, such as *Symmetric Flow Control* (SFC), *Asymmetric Flow Control* (AFC), and no flow control at all. The SFC means that Pause frames may flow in either direction. The AFC means that Pause frames may only flow in one direction, whether that direction is; towards or away from the local device. No flow control means that Pause frames are not allowed.

We can verify how the DUT manages the flow control by analyzing the Pause frame:

- Send a Pause frame with a valid pause time value. The DUT will stop sending frames until the countdown value reaches zero.
- Send a Pause frame with a pause time equal to zero. The DUT should resume sending frames, if it were previously stopped, otherwise it shall continue normal operation.
- MAC control frame reception and handling, to verify that the DUT rejects invalid MAC control Pause frames.
- Receive MAC Control Pause frames of incorrect size. This is to determine how the DUT handles Pause frames that are of incorrect size.
- Pause frame transmission. To verify that the DUT transmits properly encapsulated Pause frames.

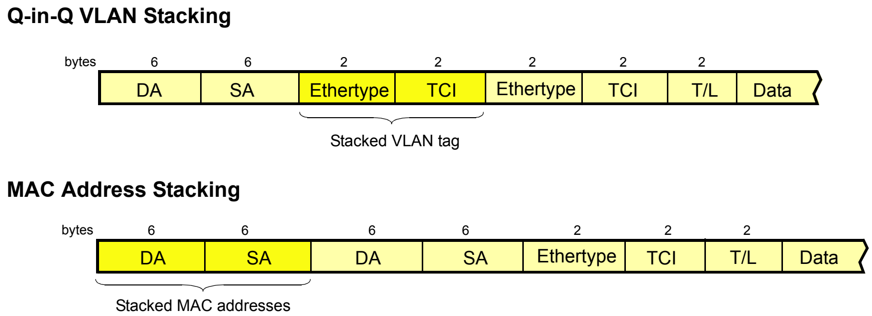

Figure 17. *Ethernet framings for Carrier Class Ethernet*

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