10 Mb/s Single Twisted Pair Ethernet
10BASE-T1L Auto-Negotiation

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Timing Values

- The following table shows possible timer values for a 625 kBit/s communication (a bit time is t_{bit} = 1600 ns, the maximum link segment delay time is t_{dly} = 8834 ns, blue are the numbers, which have changed or are new compared to the D1.2 draft):

Timer	Min	Max	Unit	Remarks
blind_timer	17668	20868	ns	2 x t_{dly} → 2 x t_{dly} + 2 x t_{bit}
break_link_timer	300	305	µs	Time to disable PHY and release the bidirectional data lines for auto-negotiation.
clock_detect_max_timer	1680	2000	ns	5 – 25 % more than time T2 (t_{bit})
clock_detect_min_timer	1200	1520	ns	5 – 25 % less than time T2 (t_{bit})
data_detect_max_timer	880	1200	ns	10 – 50 % more than time T3 (t_{bit} / 2)
data_detect_min_timer	400	720	ns	10 – 50 % less than time T3 (t_{bit} / 2)
interval_timer	799.96	800.04	ns	800 ns ± 0.005 % (t_{bit} / 2)
link_fail_inhibit_timer [10BASE_T1L]	3030	3090	ms	3060 ms ± 30 ms (3030 ms is the maximum time for link training of a 10BASE-T1L PHY)
page_test_max_timer	128000	131200	ns	80 t_{bit} → 82 t_{bit} (a nominal DME frame is 78 bit long)
receive_DME_timer	145668	148868	ns	page_test_max_timer + 2 x t_{dly}
rx_wait_timer	300	340	µs	Time after which at least a new DME frame has to be received before going into receive IDLE state (time to handle the half-duplex state diagram plus headroom).
silent_timer	20868	24068	ns	2 x t_{dly} + 2 x t_{bit} → 2 x t_{dly} + 4 x t_{bit}

- backoff_timer:

  if T[4] bit is 1 then the duration is set as (145668 ns to 148868 ns) + (random integer from 0 to 15) x (20868 ns to 24068 ns)

  (this is equal to: receive_DME_timer + (random integer from 0 to 15) x silent_timer)

  if T[4] bit is 0 then the duration is set as (156902 ns to 160102 ns) + (random integer from 0 to 15) x (20868 ns to 24068 ns)

  (this is equal to: receive_DME_timer + t_{dly} + 3 t_{bit} / 2 + (random integer from 0 to 15) x silent_timer)

Technology Ability Field

- Clause 98 auto-negotiation supports point-to-point link segments only, no mixing segments, thus there will be **no auto-negotiation for the mixing segment using multidrop PHYs**.
- Clause 98 auto-negotiation provides 27 bits (A0 to A26) within the Technology Ability Field.
- Currently bit A0 is reserved for a 100BASE-T1 PHY and bit A2 is reserved for a 1000BASE-T1 PHY.
- Additionally to these bits the following bits are intended to be defined for a 10BASE-T1S PHY and a 10BASE-T1L PHY:

Technology Ability Field Bit	Description
A1	10BASE-T1S PHY
A26	10BASE-T1L PHY

- This keeps the short distance PHYs together and allows for the long distance PHYs to grow from A26 down to lower bit numbers, if there in future are higher speed PHYs available.
- Master/Slave relationship can be decided identically to the existing Clause 98 auto-negotiation procedure.
- The selector field encoding can also be identical to the existing Clause 98 auto-negotiation.
- Additional abilities, as EEE, transmit signal amplitude, half-/full-duplex, PLCA are negotiated using a next page encoding.

10BASE-T1L Next Page Information

- The following bits in a Next Page (message code field 000 0000 0111) are intended to be defined for a 10BASE-T1L PHY:

10BASE-T1L Ability Bits	Description
U0	EEE advertising: 0 = PHY has no EEE capability 1 = PHY has EEE capability
U1	Increased Transmit/Receive Level: 0 = PHY only supports 1.0 V_{pp} 1 = PHY supports 1.0 V_{pp} and 2.4 V_{pp}
U16:U31	User specific data field

- A further idea is to have a 16 bit user specific data field, which is exchanged during auto-negotiation, to e.g. transmit ability data related to intrinsic safety, device information etc.
- All other bits in the next page shall be zero.

- Add message code description for the next page information to Annex 98C.

10BASE-T1S Next Page Information

- The following bits in a Next Page (message code field 000 0000 1000) are intended to be defined for a 10BASE-T1S PHY:

10BASE-T1S Ability Bits	Description
U0	Full Duplex Support: 0 = PHY does only support half-duplex operation 1 = PHY does support half-duplex and full-duplex operation
U1	PLCA ability advertising: 0 = PHY has no PLCA ability 1 = PHY has PLCA ability
U2	PLCA coordinator ability advertising: 0 = PHY has no PLCA coordinator ability 1 = PHY has PLCA coordinator ability
U16:U31	User specific data field

- For 10BASE-T1S it is still under discussion, if different transmit signal amplitudes should be used or not.
- 10BASE-T1S inherently provides EEE functionality as there is no continuous data transmission.
- All other bits in the next page shall be zero.

- Add message code description for the next page information to Annex 98C.

10BASE-T1L Transmit Level Negotiation

- The default transmit/receive level of a 10BASE-T1L PHY is 1.0 V_{pp}:
  - All 10BASE-T1L PHYs shall support a transmit level of 1.0 V_{pp}.
  - All 10BASE-T1L PHYs shall support a receive level of 1.0 V_{pp}.

- For a 10BASE-T1L PHY a transmit level of 2.4 V_{pp} is optional.
- If a 10BASE-T1L PHY supports a transmit level of 2.4 V_{pp}, it also shall support a receive level of 2.4 V_{pp}.

- During auto-negotiation, only if both 10BASE-T1L PHYs connected to the link segment support a transmit/receive level of 2.4 V_{pp}, the resulting transmit level for both PHYs is set to 2.4 V_{pp}.
- In all other cases, the resulting transmit level for both PHYs is set to 1.0 V_{pp}.

Resulting Transmit Level	**Second PHY 1.0 V_{pp}**	**Second PHY 1.0 V_{pp} / 2.4 V_{pp}**
First PHY 1.0 V_{pp}	1.0 V_{pp}	1.0 V_{pp}
First PHY 1.0 V_{pp} / 2.4 V_{pp}	1.0 V_{pp}	2.4 V_{pp}

10BASE-T1S Half-/Full-Duplex Negotiation

- The default (basic) mode for a 10BASE-T1S PHY is half-duplex:
  - All 10BASE-T1S PHYs shall support half-duplex transmitting.
  - All 10BASE-T1S PHYs shall support half-duplex receiving.

- For a 10BASE-T1S PHY full-duplex mode is optional.
- If a 10BASE-T1S PHY supports full-duplex transmitting, it shall also support full-duplex receiving.

- During auto-negotiation, only if both 10BASE-T1S PHYs support full-duplex mode, full-duplex transmission is activated.
- In all other cases, both PHYs operate in half-duplex mode.

Resulting Mode	Second PHY Half-Duplex	Second PHY Half-/Full-Duplex
First PHY Half-Duplex	Half-Duplex	Half-Duplex
First PHY Half-/Full-Duplex	Half-Duplex	Full-Duplex

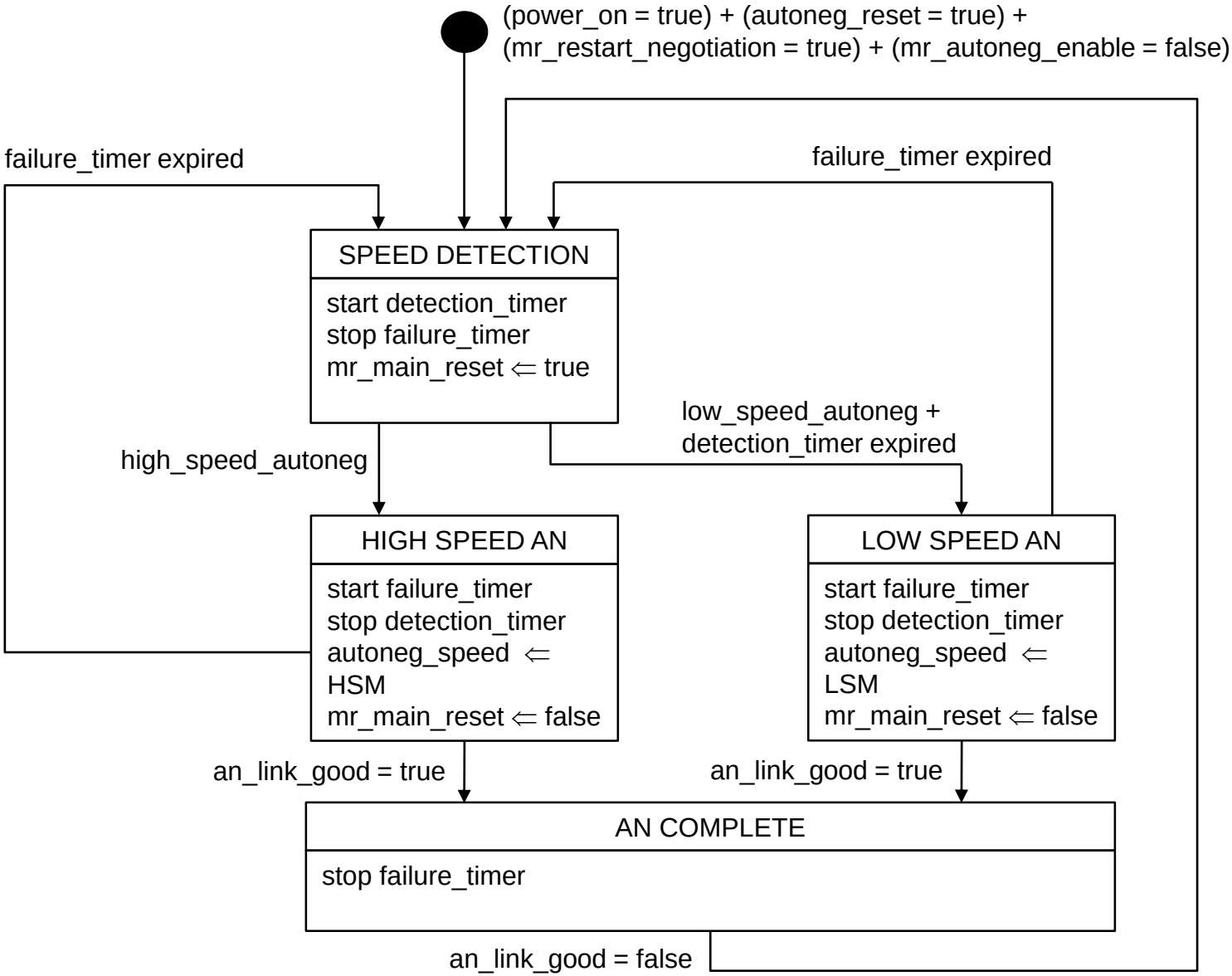
PHY Priority Resolution

- As Clause 98 only supports point-to-point link segments, auto-negotiation for mixing segments will not be supported.
- For a multi-protocol PHY the priority resolution is suggested to be (from highest priority to lowest priority):

  1000BASE-T1
  100BASE-T1
  10BASE-T1S
  10BASE-T1L

- Using the above auto-negotiation priorities, higher communication speeds will be prioritized over lower communication speeds and the more energy efficient short distance PHYs will be prioritized over the more complex and energy hungry long distance PHYs, what is similar to the priority resolution for other Ethernet PHYs.
- Using this priority resolution allows an easy way to select the highest possible speed for short reach applications.
- If a PHY IC supports both, short and long reach PHYs, then negotiating to a short reach PHY type will likely not lead to a reliable communication at longer links segments.
- Therefore for long reach applications using a multi-protocol PHY, this causes the need to select the advertised PHY types during the auto-negotiation process (see BASE-T1 AN advertisement register in Clause 98)
- This allows to block the advertising of the short distance PHY types integrated in a multi-protocol PHY IC during auto-negotiation thus only negotiating between the different long reach PHY types.

Rate Adaption



Rate Adaption

- Modify state machine in figure 98-11 according to the previous slide (remove energy detection state as valid signals are detected by implementation of functions “high_speed_autoneg“ and “low_speed_autoneg“, change variable names so that an interaction with the existing state machines is possible).
- Remove figure 98-12, as only the state machines already existing in Clause 98 are used, if there is single speed auto-negotiation.
- Modify text in clause 98.5.6 for PHYs only supporting one auto-negotiation speed, to use the appropriate timer values and implement the auto-negotiation state machines according to figures 98-7, 98-8, 98-9 and 98-10 without any further change.

- Set auto-negotiation speed detection timer (detection_timer) value to 2.5 ms + random value between (0 to 15) * 0.5 ms.
- Set auto-negotiation failure timer (failure_timer) value to 100 ms ± 1 ms.

- Add additional reset signal (“autoneg_reset”), which is triggered by the management entity, if dual speed auto-negotiation is being used, to restart the auto-negotiation process as replacement signal for “mr_main_reset” of the state machines described in figures 98-7, 98-8, 98-9 and 98-10, as the signal “mr_main_reset” is triggered by the speed selection state machine in figure 98-11, when supporting two different auto-negotiation speeds.

- Use array based timers in the original auto-negotiation state machines to allow the selection of the appropriate timer values by variable “autoneg_speed”.

- Add the descriptions for the new relevant variables “power_on“, „mr_restart_negotiation“, „mr_autoneg_enable“, “mr_main_reset“, and “an_link_good“ to the variables section on the speed selection state diagram.

Next Page Descriptions

- Add the following lines to table 98C-1 – Message Code Field values:

Message code	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	M0	Message code description
7	0	0	0	0	0	0	0	0	1	1	1	10BASE-T1L Information
8	0	0	0	0	0	0	0	1	0	0	0	10BASE-T1S Information

Next Page Descriptions

- Add the following Clause to Annex 98C:

98C.5 Message code 7 – 10BASE-T1L Information

The 10BASE-T1L Information message shall consist of a Message Next Page with the message code field 000 0000 0111. Bit U0 (D16) shall contain a one, if the PHY is supporting and advertising Energy Efficient Ethernet ability and it shall contain a zero, if Energy Efficient Ethernet is not supported or not advertised. If both PHYs advertise the ability to support Energy Efficient Ethernet during Auto-Negotiation, then EEE shall be enabled for both PHYs by the management entity, otherwise it shall be disabled for both PHYs. Bit U1 (D17) shall contain a one, if the PHY is supporting and advertising the 2.4 Vpp operating mode and it shall contain a zero, if the 2.4 Vpp operating mode is not supported or not advertised. If both PHYs advertise the ability to support the 2.4 Vpp operating mode, then it shall be enabled for both PHYs by the management entity, otherwise it shall be disabled for both PHYs. Bits U16:U31 (D32:D47) contain a user specific data field, which is transmitted to the remote PHY during Auto-Negotiation Next Page exchange.

Next Page Descriptions

- Add the following Clause to Annex 98C:

98C.6 Message code 8 – 10BASE-T1S Information

The 10BASE-T1S Information message shall consist of a Message Next Page with the message code field 000 0000 1000. Bit U0 (D16) shall contain a one, if the PHY is supporting and advertising full-duplex ability and it shall contain a zero, if full-duplex communication is not supported or not advertised. If both PHYs advertise the ability to support full-duplex communication during Auto-Negotiation, then full-duplex communication shall be enabled for both PHYs by the management entity, otherwise it shall be disabled for both PHYs. Bit U1 (D17) shall contain a one, if the PHY is supporting and advertising PLCA ability and it shall contain a zero, if PLCA not supported or not advertised. Bit U2 (D18) shall contain a one, if the PHY is supporting and advertising PLCA coordinator ability and it shall contain a zero, if PLCA coordinator ability not supported or not advertised. Bits U16:U31 (D32:D47) contain a user specific data field, which is transmitted to the remote PHY during Auto-Negotiation Next Page exchange.

Thank You