To: T10 Technical Committee

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Subject: T10/02-300r2 SAS OOB and DWS state machine updates

This revision incorporates technical changes to the state machines and editorial changes (developed with George Penokie, IBM) to the OOB/phy reset sequence descriptions prior to the state machines.

6 Phy layer

6.1 Encoding (8b/10b)

6.2 Character encoding and decoding

6.3 Bit order

6.4 Out of band (OOB) signals

SATA defines "out of band" (OOB) signals used for phy resets. OOB signals are low-speed signal patterns detected by the phy that do not appear in normal data streams. They consist of defined amounts of idle time followed by bursts (repeated sequences) of ALIGNs. During the burst time, ALIGN or ALIGN(1) primitives are sent repeatedly. During the idle time, the transmitter output shall meet the requirements described in 5.7.5. The signals are differentiated by the length of idle time between the bursts of ALIGNs.

SATA defines two OOB signals: COMINIT/COMRESET and COMWAKE. COMINIT and COMRESET are used in this standard interchangeably. SAS devices identify themselves with an additional SAS-specific OOB signal called COMSAS.

Table 22 defines the timing specifications for OOB signals.

Table 22 — OOB signal timing specifications

Parameter	Minimum	Nominal	Maximum	Comments
Unit interval during OOB (UI(OOB)) [a]	666,600 ps	666,667 ps	666,734 ps	The time basis for ALIGN bursts and idle times used to create OOB signals. Based on 1,5 Gbps clock tolerance.
COMSAS Detect Timeout	13,65 μs			The minimum time a receiver shall allow to detect COMSAS after sending COMSAS. Derived from: UI(OOB) x 512 x 40
[a] This is not the same as UI(OOB) defined in SATA; SAS has tighter clock tolerance.				

Table 23 describes the OOB signal transmitter requirements for the burst time, idle time, and negation times that comprise each OOB signal..

Table 23 — OOB signal transmitter requirements

Signal	Burst time	Idle time	Negation time
COMWAKE	160 UI(OOB)	160 UI(OOB)	280 UI(OOB)
COMINIT/RESET	160 UI(OOB)	480 UI(OOB)	800 UI(OOB)
COMSAS	160 UI(OOB)	1 440 UI(OOB)	2 400 UI(OOB)

To send an OOB signal, a transmitter shall repeat these steps six times:

1) transmit idle for an idle time; and
2) send an ALIGN burst.

It shall then transmit idle for an OOB signal negation time.

The ALIGNs used in OOB signals are not required to be at generation 1 (G1) rates (1,5 Gbps), as this rate might not be supported in future generations of SAS devices. The ALIGNs are only required to generate an envelope for the detection circuitry, as required for any signaling that may be AC coupled. If G2 ALIGNs are used, the number of ALIGNs doubles compared with G1 ALIGNs.

A SAS transmitter should transmit ALIGNs at the G1 rate to create the burst portion of the OOB signal, but may transmit ALIGNs at its slowest supported rate if it does not support the G1 rate and shall not send them at a rate faster than its slowest supported rate.

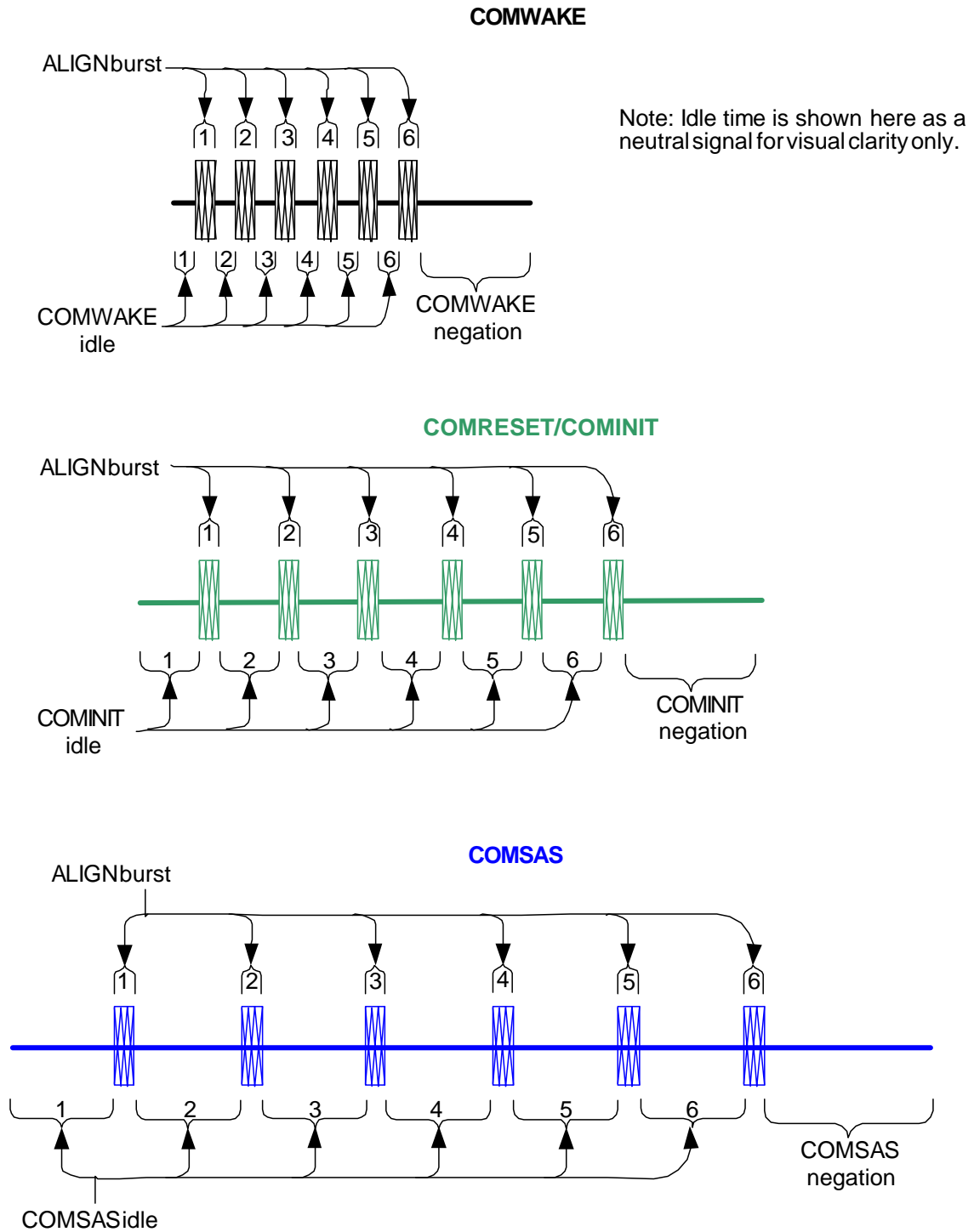Figure 34 describes OOB signal transmission.

COMWAKE

Note: Idle time is shown here as a neutral signal for visual clarity only.

COMRESET/COMINIT

COMSAS

Figure 34 — OOB signal transmission

Table 24 describes the OOB signal receiver requirements for the idle times and negation times. The burst time is not used to distinguish between signals.

Table 24 — OOB signal receiver requirements

Signal	Idle time			Negation time
	may detect	**shall detect**	**shall not detect**	**shall detect**
COMWAKE	55 ns to 175 ns	101,3 ns to 112 ns	< 55 ns or > 175 ns	175 ns
COMINIT/ COMRESET	175 ns to 525 ns	304 ns to 336 ns	< 175 ns or > 525 ns	525 ns
COMSAS	525 ns to 1 575 ns	911,7 ns to 1008 ns	< 525 ns or > 1 575 ns	1 575 ns

A receiver shall detect an OOB signal after receiving four consecutive idle time/ALIGN burst pairs (see figure 35). It is not an error to receive more than six idle time/ALIGN burst pairs. A receiver shall not detect the same OOB signal again until it has detected a different OOB signal (e.g., if the idle time changes) or has detected lack of transitions for a time greater then the proceeding idle time (i.e., a COMINIT negation time for a COMINIT idle time or a COMSAS negation time for a COMSAS idle time).

A SAS receiver shall detect OOB signals comprised of ALIGNs transmitted at any rate up to its highest supported rate. This includes rates below its lowest supported rates. For example, a SAS receiver supporting only 3,0 Gbps needs to detect 1,5 Gbps based ALIGNs to interoperate with a SAS transmitter supporting both 1,5 Gbps and 3,0 Gbps.

Figure 35 describes SAS OOB signal detection. The COMWAKE Detected, COMWAKE Completed, COMINIT Detected, COMINIT Completed, COMSAS Detected, and COMSAS Completed parameters are sent to the SAS phy (SP) state machine to indicate that an OOB signal has been partially or fully detected.
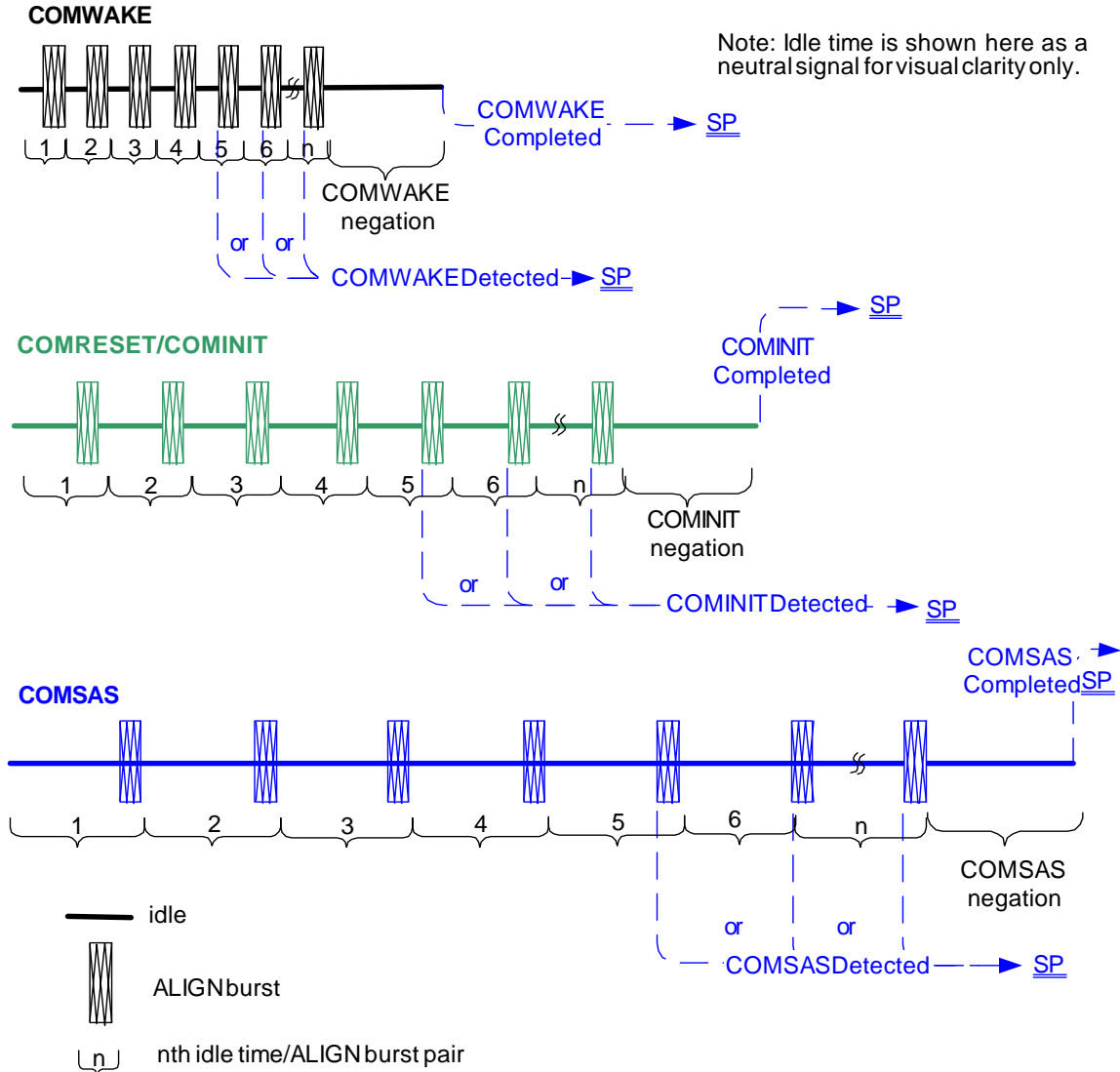

Figure 35 — OOB signal detection

Expanders shall not pass OOB signals. An expander device shall run the link reset sequence independently on each physical link (initiator phy to expander phy, expander phy to expander phy, or expander phy to target phy).

6.5 Phy reset sequences

6.5.1 Overview

The phy reset sequence consists of an OOB sequence and a speed negotiation sequence.

The SAS phy reset sequence shall only affect the phy, not the port or device containing the phy or other phys in the same port or device.

After a HARD_RESET, a device should start the phy reset sequence within 250 ms.

6.5.2 SATA phy reset sequence

6.5.2.1 SATA OOB sequence

Figure 36 depicts the SATA OOB sequence between a SATA initiator device (i.e., SATA host) and target device (i.e, SATA device). The SATA OOB sequence is defined by SATA; see SATA for detailed requirements.
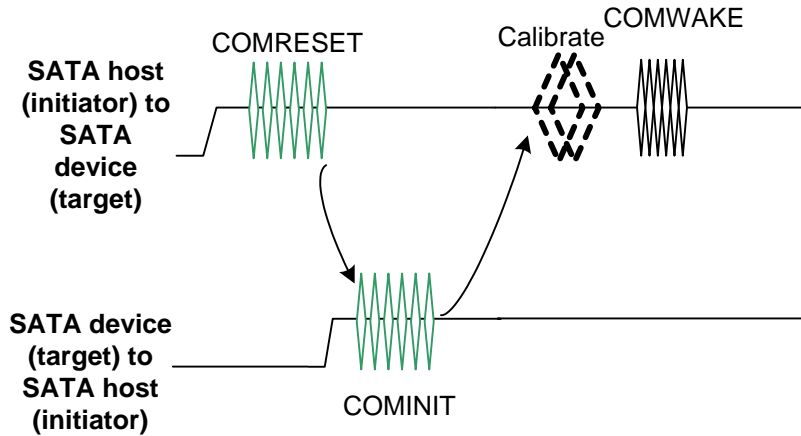

Figure 36 — SATA OOB sequence (informative)

6.5.2.2 SATA speed negotiation sequence

Figure 37 depicts the phy reset sequence between a SATA initiator device and target device. The SATA speed negotiation sequence is defined by SATA; see SATA for detailed requirements.
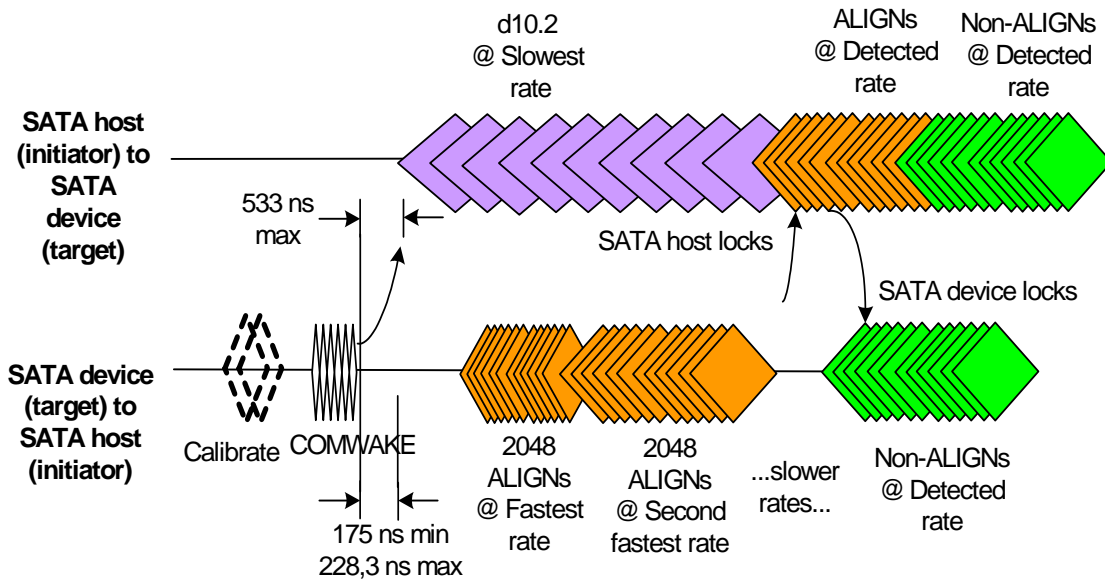

Figure 37 — SATA phy reset sequence (informative)

6.5.3 SAS to SATA phy reset sequence

SAS initiator devices and expander devices may be attached to SATA target devices.

To initiate a phy reset sequence a SAS phy shall:

    1)   transmit a COMINIT; and
    2)   in response to a COMINT, transmit a COMSAS.

The COMSAS identifies the phy as a SAS phy rather than a SATA phy for SAS to SAS attachments.

If a SATA phy is attached to the link it either:

  a) misinterprets the COMSAS to be a COMRESET and responds with a COMINIT; or
  b) ignores the COMSAS and provides no response within the COMSAS Detect Timeout.

Either response indicates to the SAS phy that a SATA phy is attached. As a result the SAS phy shall initiate a SATA reset sequence (i.e., transmit a COMRESET). This is shown in

Figure 38 shows a reset sequence between a SAS phy and a SATA phy (i.e., between an expander device and a SATA target device, or between a SAS initiator device and a SATA target device). The two possible cases are presented. The first case is that a legacy SATA phy misinterprets the COMSAS to be a COMRESET and responds with a COMINIT. The second case is that the SATA phy ignores the COMSAS and provides no response within the COMSAS Detect Timeout. The SAS phy state machine treats these two cases the same, and determines that a SATA phy is attached. The normal SATA reset sequence shall be used thereafter.
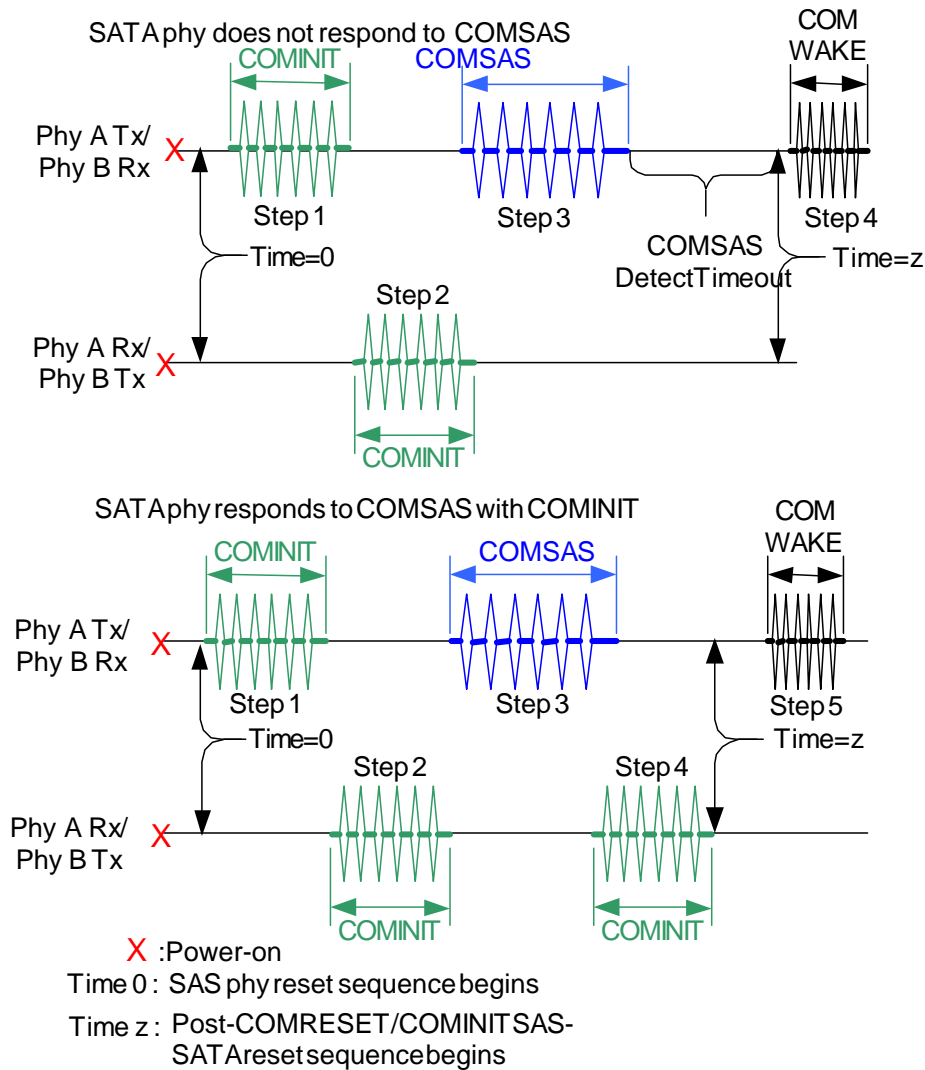

Figure 38 — SAS to SATA OOB sequence

6.5.4 SAS to SAS phy reset sequence

6.5.4.1 SAS OOB sequence

To initiate a SAS OOB sequence a SAS phy shall transmit a COMINIT. If there is no COMINIT or a COMSAS recieved within a hot plug timeout then the SAS phy shall transmit another COMINIT.

On receipt of a COMINIT a SAS phy shall either:

 a) transmit a COMINIT, if the receiving SAS phys has not yet transmitted a COMSAS, followed by a COMSAS; or
 b) transmit a COMSAS, if the receiving SAS phys has transmitted a COMINIT.

After completing the transmission of a COMSAS and the successful receipt a COMSAS the SAS OOB sequence is complete and the SAS speed negotiation sequence begins.

A SAS device shall distinguish between COMINIT and COMSAS and continue with a SAS speed negotiation sequence after completing the SAS OOB sequence.

Figure 39 illustrates several different SAS OOB sequences between a SAS phy A and SAS phy B, with SAS phy A starting the SAS OOB sequence before, after, or at the same time as SAS phy .
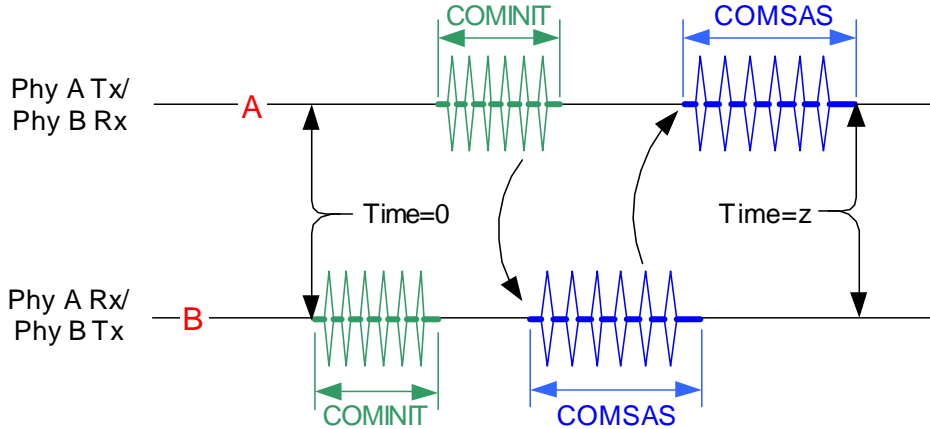
Scenario 1: Both SAS phys start SAS OOB sequence at same time
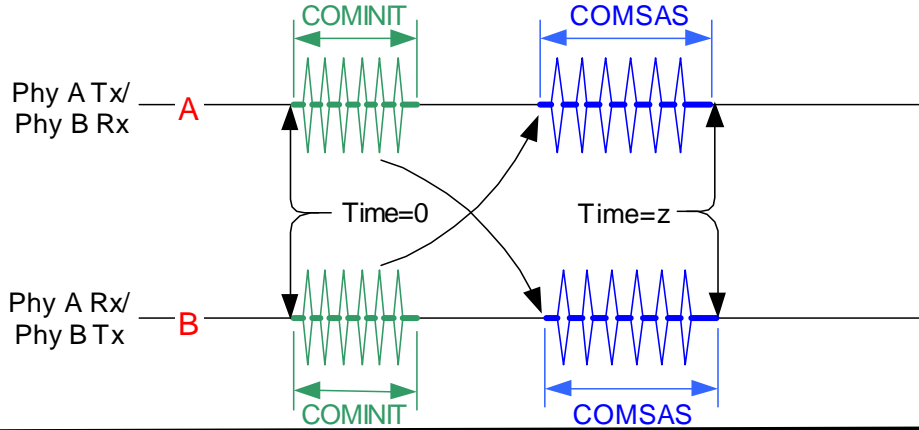
Scenario 2: SAS phy A starts SAS OOB sequence
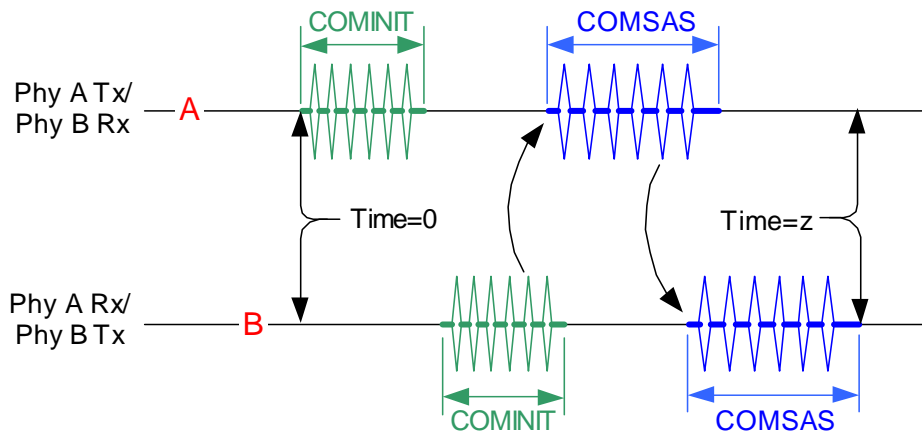
Scenario 3: SAS phy B start SAS OOB sequence

A : SAS A Power-on
B : SAS B Power-on
Time 0: SAS phy reset sequence begins
Time z: SAS speed negotiation sequence begins

Figure 39 — SAS to SAS OOB sequence

6.5.4.2 SAS speed negotiation sequence

The SAS speed negotiation sequence is a peer-to-peer negotiation technique that does not assume initiator device and target device roles like the SATA speed negotiation sequence. The sequence consists of a set of speed negotiation windows for each link rate, starting with 1,5 Gbps, then 3,0 Gbps, then the next rate. The length of the speed negotiation sequence is determined by the number of link rates supported by the phys.

Figure 40 defines the speed negotiation window. The Speed Negotiation Window Time (SNWT) consists of a Rate Change Delay (RCD) plus a Speed Negotiation Transmit Time (SNTT). The Speed Negotiation Lock Time (SNLT) is a subset of the SNTT used by the receiver..
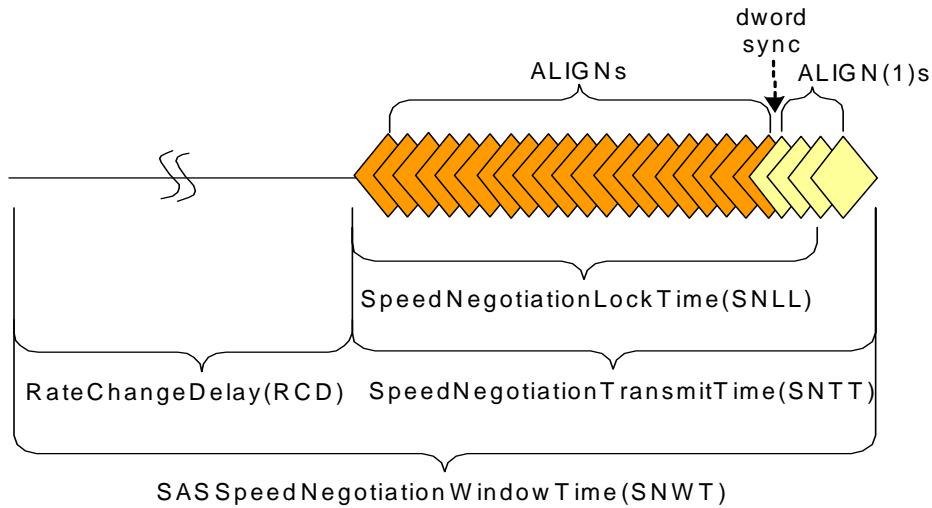

Figure 40 — SAS speed negotiation window

Table 22 defines the timing specifications for the SAS speed negotiation sequence.

Table 25 — SAS speed negotiation sequence timing specifications

Parameter	Minimum	Nominal	Maximum	Comments
Hot-Plug Timeout	10 ms	100 ms	500 ms	How often a device should resend COMINIT to detect if a device has been attached.
Rate Change Delay (RCD)		750 000 UI(OOB)		The time the transmitter shall transmit idle between rates during speed negotiation. Used by the transmitter and receiver to calculate the width of the Speed Negotiation Window.
Speed Negotiation Transmit Time (SNTT) for transmitter		163 480 UI(OOB)		The time during which ALIGN or ALIGN(1) is transmitted at each rate during the speed negotiation sequence. Derived from: UI(OOB) x 4 096 x 40.
Speed Negotiation Transmit Time (SNTT) for receiver	109,22 μs	109,23 μs	109,24 μs	The time during which ALIGN or ALIGN(1) is received at each rate during negotiation. Derived from: UI(OOB) x 4 096 x 40.
Speed Negotiation Lock Time (SNLT) for transmitter		153 600 UI(OOB)		The maximum time during the speed negotiation window for a transmitter to reply with ALIGN(1). Derived from: UI(OOB) x 3 840 x 40
Speed Negotiation Lock Time (SNLT) for receiver	102,39 μs	102,40 μs	102,41 μs	The maximum time during the speed negotiation window for a receiver to detect ALIGN or ALIGN(1) and reply with ALIGN(1). Derived from: UI(OOB) x 3 840 x 40.
Speed Negotiation Window Time (SNWT)	609,166 μs	609,227μs	609,288 μs	The duration of a speed negotiation window. Derived from: RCD + SNTT.
ALIGN Detect Timeout			880 μs	The maximum time during SATA speed negotiation that an initiator phy receiver shall allow for an ALIGN to be received after detecting the COMWAKE negation period.
[a] This is not the same as UI(OOB) defined in SATA; SAS has tighter clock tolerance.				

The speed negotiation window shall consist of the following transmission sequence for each speed negotiation window:

1) a transmission of idle for a Rate Change Delay; and
2) if the phy supports the link rate, a transmission of ALIGNs at that link rate for the remainder of entire speed negotiation window. If the phy does not supports the link rate, transmission of idle for the remainder of entire speed negotiation window.

If the a phy supports the link rate, it shall attempt to synchronize on an incoming series of dwords at that rate for the SNLT. The received dwords may be ALIGNs or ALIGN(1)s. If the phy achieves dword synchronization within the SNLT, it shall change from transmitting ALIGNs to transmitting ALIGN(1)s for the remainder of the SNTT (i.e., the remainder of the SNW). If the device does not achieve dword synchronization within the SNLT, it shall continue transmitting ALIGNs for the remainder of the SNTT (i.e., the remainder of the SNW).

At the end of the SNTT, if a phy is both transmitting and receiving ALIGN(1)s, it shall consider that link rate valid. The phy shall then proceed to the next speed negotiation window. A phy shall participate in all speed negotiation windows:

   a) up to its highest supported link rate plus one; or
   b) until it runs a speed negotiation window that does not detect a valid link rate.

If the phy has detected a valid link rate in the previous speed negotiation window, it shall enter the final speed negotiation window using the highest previously successful link rate.

Figure 41 shows speed negotiation between a SAS phy A that supports G1 thru G3 link rates and a SAS phy B that only supports the G2 link rate. Both phys run the G1 speed negotiation window (supported by phy A but not by phy B, so invalid), the G2 speed negotiation window (valid), and the G3 speed negotiation window (supported by phy A but not by phy B, so invalid), that phy then selects G2 for the final speed eegotiation eindow to establish the negotiated rate.
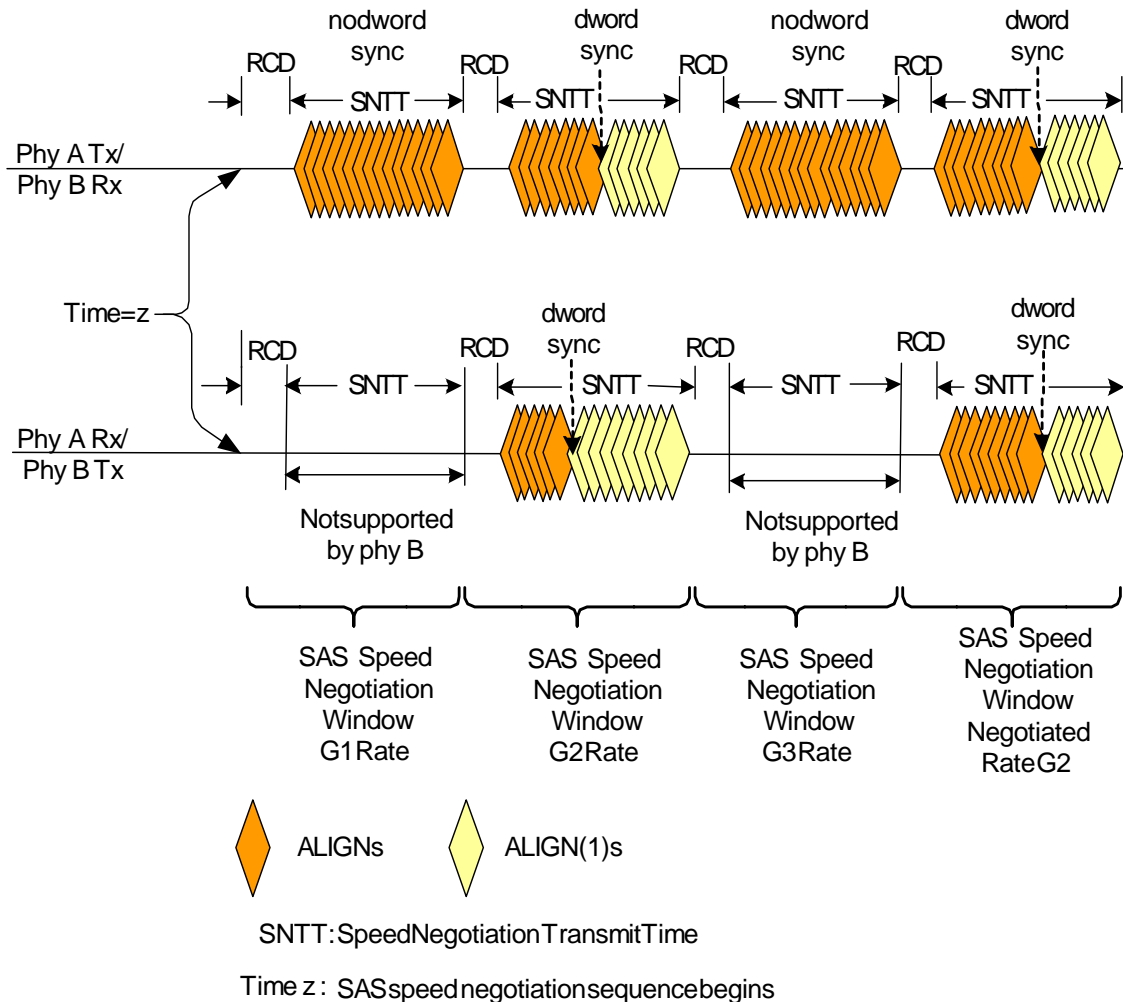

Figure 41 — SAS speed negotiation sequence (phy A: G1, G2, G3, phy B: G2 only)

If the SAS phy's PLLs does not obtain dword synchronization during the final speed negotiation window the SAS phy speed negotiation fails and the phy reset sequence shall be retried. This may be counted and reported in the PHY RESET PROBLEM field in the SMP REPORT PHY ERROR LOG page (see 9.4.4.7) and the REPORT PHY ERROR LOG log page (see 10.1.2.1).

Any time a SAS phy fails speed negotiation, it shall wait the Hot Plug Timeout before attempting a retry.

Figure 42 shows the same speed negotiation sequence as in figure 41, except for some reason, one of the SAS device's PLLs does not obtain dword synchronization during the final speed negotiation window. If this occurs, the handshake is not complete and the OOB sequence shall be retried starting with COMINIT, forcing the phy to retry the whole reset sequence.
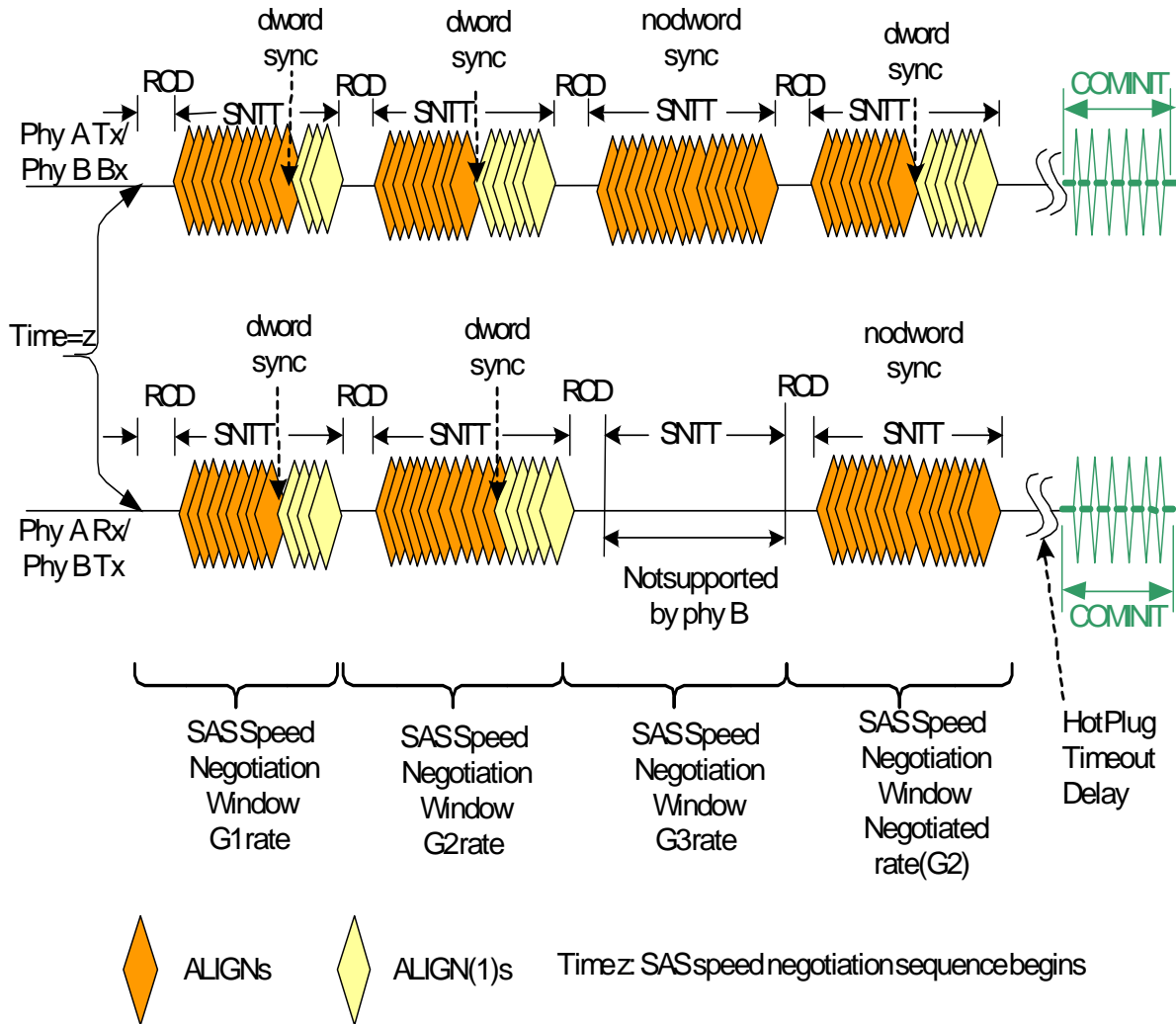
Figure 42 — SAS speed negotiation sequence (phy A: G1, G2, G3, phy B: G1, G2) with failure

For more examples of speed negotiaions between devices that support various speeds see Annex A.

6.6 Phy reset sequence after signal cable insertion

Since SATA and SAS signal cable connectors do not include power lines, it is not possible to detect the physical insertion of the signal cable connector into a receptacle. As a result, SAS phys should periodically transmit a COMINIT sequence if they have not detected a COMINIT sequence within a Hot-Plug Timeout period.

Figure 43 illustrates how two SAS phys complete the phy reset sequence if the phys are not attached at power on. In this scenario, SAS phy B is attached to SAS phy A some time before SAS phy B's second Hot-Plug Timeout occurs. SAS phy B's OOB detection circuitry detects a COMINIT after the attachment, and therefore SAS phy B transmits the COMSAS sequence, since it has both transmitted and received a COMINIT sequence. Upon receiving COMSAS, SAS phy A transmits its own COMSAS sequence, bypassing the normal requirement that COMINIT be both transmitted and received. The SAS speed negotiation process sequence.

A : SAS A Power-on   B : SAS B Power-on

Time y : SAS phy A attached to SAS phy B   Step xA : The SAS OOB sequence at SAS phy A

Time z : SAS phy A and SAS phy B start the   Step xB : The SAS OOB sequence at SAS phy B
         SAS speed negotiation sequence
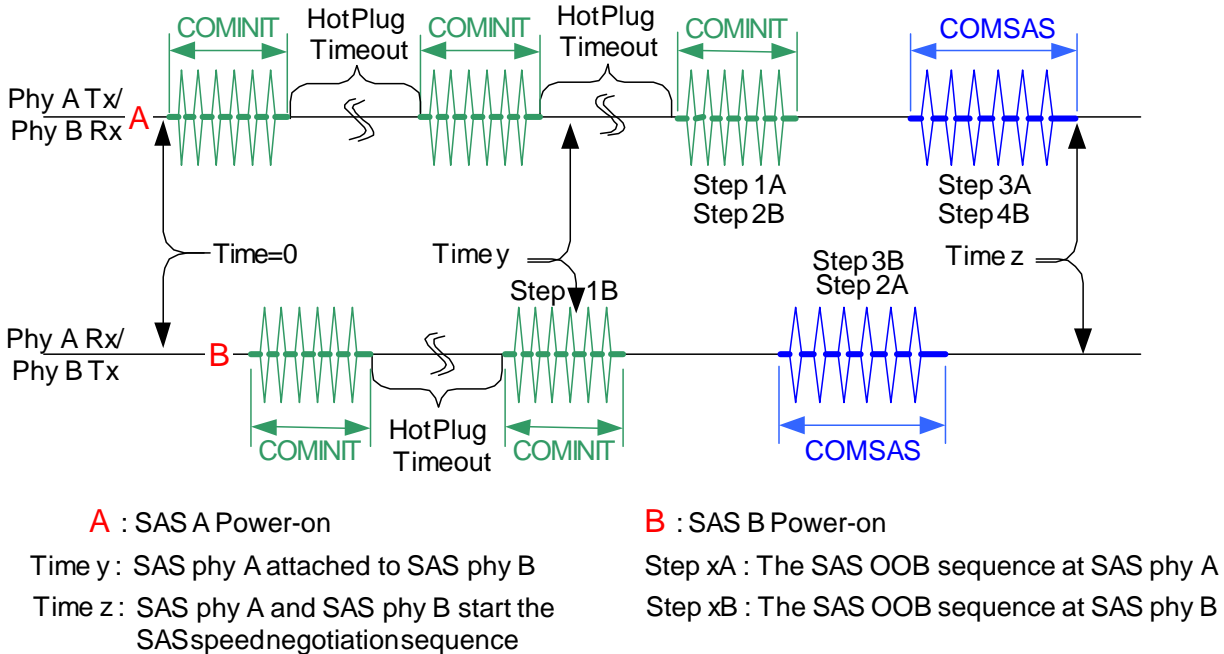
Figure 43 — Hot-plug and the phy reset sequence

6.7 SAS phy (SP) state machine

6.7.1 Overview

The SAS phy (SP) state machine has three sections:

    a) OOB sequence states (SAS);
    b) SAS speed negotiation (SN and PHY) states; and
    c) SATA host emulation (SATA) states.

The SP states are:

    a) SP0:SAS_PowerOn (see 6.7.2.1);
    b) SP1:SAS_Reset (see 6.7.2.2);
    c) SP2:SAS_AwaitCOMX (see 6.7.2.3);
    d) SP3:SAS_AwaitCOMINIT_Sent (see 6.7.2.4);
    e) SP4:SAS_COMSAS (see 6.7.2.5);
    f) SP5:SAS_AwaitCOMSAS_Sent (see 6.7.2.6);
    g) SP6:SAS_AwaitNoCOMSAS (see 6.7.2.7);
    h) SP7:SAS_AwaitCOMSAS (see 6.7.2.8);
    i) SP8:SN_Start (see 6.7.3.1);
    j) SP9:SN_RateNotSupported (see 6.7.3.2);
    k) SP10:SN_AwaitALIGN (see 6.7.4.3);
    l) SP11:SN_AwaitALIGN1 (see 6.7.3.4);
    m) SP12:SN_AwaitSNW (see 6.7.3.5);
    n) SP13:SN_Pass (see 6.7.3.6);

o) SP14 SN_Fail (see 6.7.3.7);
p) SP15:SN_Fallback (see 6.7.3.8);
q) SP16:SN_IncSpeed (see 6.7.3.9);
r) SP17:SN_PHY_Change
s) SP18:PHY_Ready (see 6.7.3.11);
t) SP19:SATA_COMWAKE (see 6.7.4.1);
u) SP20:SATA_AwaitCOMWAKE (see 6.7.4.2);
v) SP21:SATA_AwaitNoCOMWAKE (see 6.7.4.3);
w) SP22:SATA_AwaitALIGN (see 6.7.4.4);
x) SP23:SATA_AdjustSpeed (see 6.7.4.5);
y) SP24:SATA_Transmit_ALIGN (see 6.7.4.6);
z) SP26:SATA_PHY_Ready (see 6.7.4.7);
aa) SP27:SATA_PM_Partial (see 6.7.4.8); and
ab) SP28:SATA_PM_Slumber (see 6.7.4.9).

The SP state machine receives the following requests from the link layer:

a) ResetPhy.

The SP state machine sends no confirmations to the link layer.

The SP state machine sends the following parameters to the DWS state machines:

a) PhyReady(SAS); and
b) PhyReady(SATA).

The SAS phy layer shall maintain the following timers:

a) OOB Timeout timer;
b) Hot Plug Timeout timer;
c) Rate Change Delay (RCD) timer;
d) Speed Negotiation Lock Time (SNLT) timer;
e) Speed Negotiation Window Time (SNWT) timer; and
f) COMSAS Detect Timeout timer.

The SP state machine runs the phy reset sequence. The SP state machine starts in the SP0:SAS_PowerOn state after:

a) A power on event; or
b) Upper protocol layers request a transition to the SP0:SAS_ PowerOn state. The SMP PHY CONTROL function may be used to trigger this transition in devices supporting SMP.

The Dword Synchronization state machine (DWS) sets policy on the operational state of the link by monitoring received errors on the link. Entry into the DWS0:AcquireSync state indicates that the link has lost dword synchronization and needs to re-establish synchronization. The SP state machine shall transition to the SP1:SAS_Reset state.

The DWS state machine is active after power-up and may be monitored by the SP state machine to help determine receipt of ALIGN and ALIGN(1) primitives. The SP state machine actively monitors the DWS state machine in the PhyReady(SATA/SAS) state to determine if it needs to re-run OOB.

6.7.2 OOB sequence states

Figure 44 shows the OOB sequence states, in which the SAS device transmits an initial COMINIT and COMSAS sequences, and awaits to receive a COMINIT and COMSAS sequences back. These states include a prefix of SAS_ in the state name. Once a COMINIT has been detected, the SAS device transmits a COMSAS sequence instead or in place of the normal SATA calibration pattern, and waits to see if the connected device responds with a COMSAS. If the SAS device does not detect a COMSAS sequence within a COMSAS Detect Timeout period, it assumes that a SATA Device is attached, and jumps to the SATA Host

emulation states. Otherwise, a SAS-capable port is attached and the SAS speed negotiation states are entered.
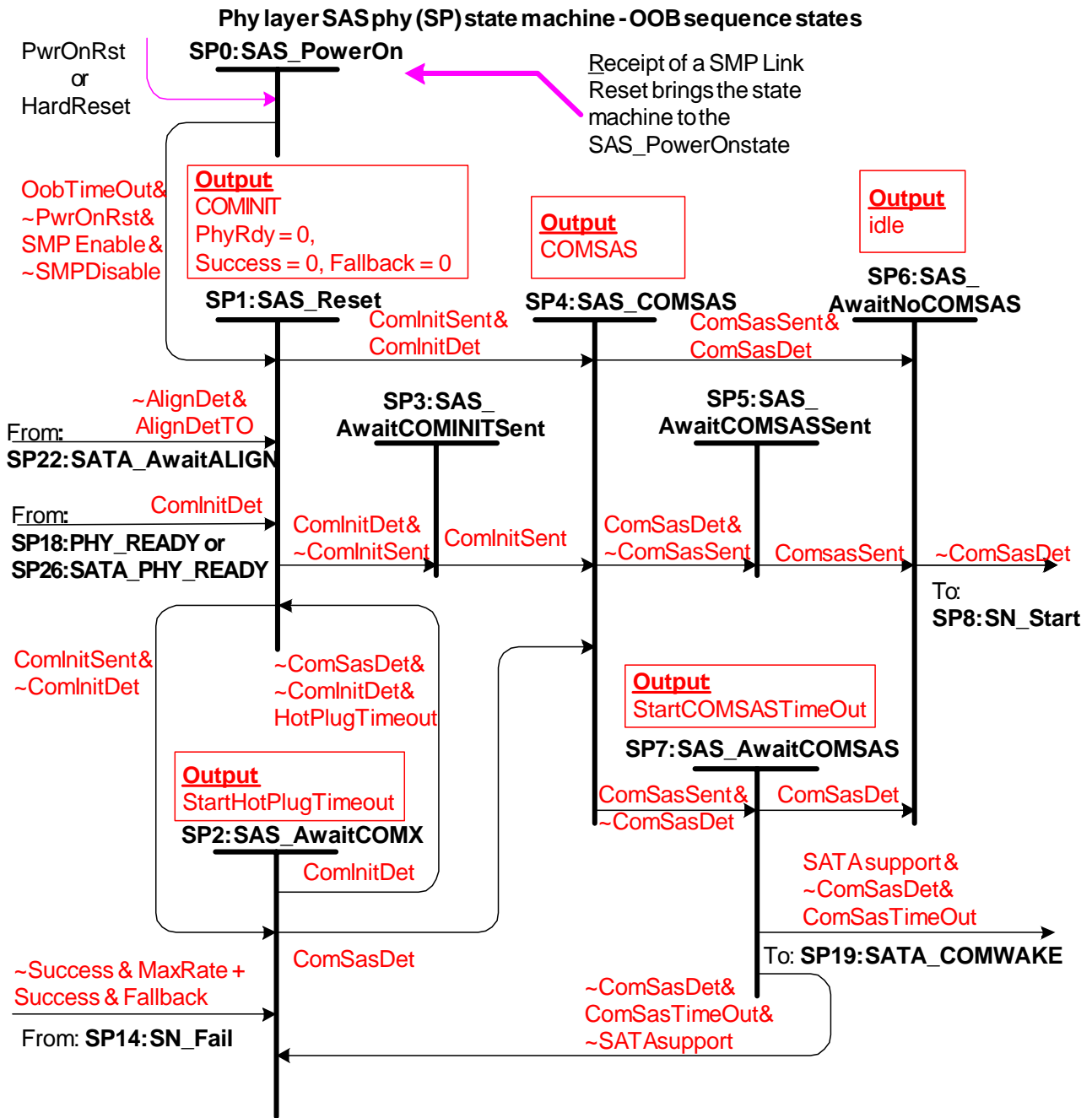

Figure 44 — SAS phy (SP) state machine - OOB sequence states

6.7.2.1 SP0:SAS_PowerOn state

6.7.2.1.1 State description

This state is entered when power on reset (PwrOnRst) is detected, or any of the SMP commands affecting the operating status of the phy are received. This state controls the initial start time value.

6.7.2.1.2 Transition SP0:SAS_PowerOn to SP1:SAS_Reset

This transition occurs at the expiration of this time after (PwrOnRst) is de-asserted or a SMP command is received enabling the phy.

6.7.2.2 SP1:SAS_Reset state

6.7.2.2.1 State description

This state is entered under the following conditions:

  a) from SP0:SAS_PowerOn or from any state when a general reset is requested from the ULP;
  b) from SP18:PHY_Ready or SP26:SATA_PHY_Ready states if COMINIT is detected;
  c) from SP22:SATA_AwaitALIGN if ALIGN primitives are not detected within an ALIGN Detect Timeout period;
  d) from state SP18:PHY_Ready or SP26:SATA_Phy_Ready if dword synchronization is lost. Enable Disable Link Layer(SATA/SAS Disable) are real time indications that dword synchronization has been lost. When asserted, this indicates that a significant problem with the link exists.

The state machine exits this state when it has been determined that a COMINIT burst has been sent or detected.

PhyRdy(SAS/SATA) are cleared to 0 upon entering this state. The Fallback and Success flags are also cleared upon entering this state.

6.7.2.2.2 Transition SP1:SAS_Reset to SP2:SAS_AwaitCOMX

This transition shall occur when a COMINIT has been transmitted but a COMINIT was not detected.

6.7.2.2.3 Transition SP1:SAS_Reset to SP3:SAS_AwaitCOMINITSent

This transition shall occur when a COMINIT has not been completely transmitted but COMINIT was detected.

6.7.2.2.4 Transition SP1:SAS_Reset to SP4:SAS_COMSAS

This transition shall occur when PwrOnRst is de-asserted, a COMINIT has been sent and a COMINIT was detected.

6.7.2.3 SP2:SAS_AwaitCOMX state

6.7.2.3.1 State description

This state is entered when a COMINIT sequence has been sent during state SP0:SAS_RESET and a COMINIT sequence was not detected. Upon entering this state, a Hot-Plug Timeout timer shall be initialized and enabled. The state machine exits this state when it detects a COMINIT, or a COMSAS sequence, or if a Hot-Plug Timeout occurs before any of the OOB signals are detected.

This state is also entered from state SP14:SN_Fail if the there was not a previous successful lock and the max frequency has been attempted or there was a successful lock but the fallback speed failed. The state machine shall wait the Hot Plug timeout delay before attempting the connection again.

This state is also entered if COMSAS has been sent and COMSAS is not detected in the timeout window and a SATA connection is not supported.

6.7.2.3.2 Transition SP2:SAS_AwaitCOMX to SP1:SAS_Reset

This transition shall occur when a Hot-Plug Timeout occurs before any OOB signals are detected.

6.7.2.3.3 Transition SP2:SAS_AwaitCOMX to SP4:SAS_COMSAS

This transition shall occur when a COMINIT has been sent and received or COMSAS sequence is detected. This indicates that a connection has been detected, so the SAS device transmits a COMSAS sequence to inform the other end of the link that it supports SAS protocol.

6.7.2.4 SP3:SAS_AwaitCOMINITSent state

6.7.2.4.1 State description

This state is entered when a COMINIT sequence has been detected but the COMINIT initiated in SP1:SAS_Reset has not been completely sent. The state machine shall wait in this state until the completion of the COMINIT transmission.

6.7.2.4.2 Transition SP3:SAS_AwaitCOMINITSent to SP4:COMSAS

This transition shall occur at the completion of COMINIT transmission being completed.

6.7.2.5 SP4:SAS_COMSAS state

6.7.2.5.1 State description

This state is entered when a COMINIT has been sent and detected. If COMINIT was detected before COMINIT transmission was completed, this state will be entered from the SP3:SAS_AwaitCominitSent state when COMINIT transmission is complete. It can also be entered from SP2:SAS_AwaitCOMX if the full COMINIT handshake is complete or COMSAS has been detected. The state machine remains in this state until the COMSAS sequence is transmitted or detected.

6.7.2.5.2 Transition SP4:SAS_COMSAS to SP5:SAS_AwaitCOMSASSent

This transition shall occur if a COMSAS sequence is detected while COMSAS is still being transmitted. This acknowledges that two SAS ports are connected but COMSAS is not completely sent.

6.7.2.5.3 Transition SP4:SAS_COMSAS to SP6:SAS_AwaitNoCOMSAS

This transition shall occur if a COMSAS has been sent and received. This acknowledges that two SAS ports are connected.

6.7.2.5.4 Transition SP4:SAS_COMSAS to SP7:SAS_AwaitCOMSAS

This transition shall occur if a COMSAS sequence was not detected while COMSAS was being transmitted. It cannot be determined yet if a SAS or SATA port is connected.

6.7.2.6 SP5:SAS_AwaitCOMSASSent state

6.7.2.6.1 State description

This state is entered when a COMSAS sequence is detected in state SP4:SAS_COMSAS but the full COMSAS sequence has not been completely transmitted.

The state machine remains in this state until the entire COMSAS sequence is transmitted, at which point it will transition to SP6:SAS_AwaitNoCOMSAS to insure that the COMSAS sequence being received is complete.

6.7.2.6.2 Transition SP5:SAS_AwaitCOMSASSent to SP6:SAS_AwaitNoCOMSAS

This transition shall occur when the entire COMSAS sequence is transmitted.

6.7.2.7 SP6:SAS_AwaitNoCOMSAS state

6.7.2.7.1 State description

This state is entered when a COMSAS sequence has been both transmitted and detected in state SP4:SAS_COMSAS, state SP5:SAS_AwaitCOMSASSent, or state SP7:SAS_AwaitCOMSAS.

The state machine remains in this state until the end of the COMSAS sequence is detected, at which point the SAS speed negotiation begins.

6.7.2.7.2 Transition SP6:SAS_AwaitNoCOMSAS to SP8:SN_Start

This transition shall occur when the end of the COMSAS sequence is detected.

6.7.2.8 SP7:SAS_AwaitCOMSAS state

6.7.2.8.1 State description

This state is entered when a COMSAS sequence has been transmitted, but a COMSAS has not yet been detected in state SP4:SAS_COMSAS.

Upon entering this state the COMSAS Timeout counter shall be initialized and enabled to count down. The state machine remains in this state until either a COMSAS sequence is detected or a COMSAS Detect Timeout period occurs.

6.7.2.8.2 Transition SP7:SAS_AwaitCOMSAS to SP6:SAS_AwaitNoCOMSAS

This transition shall occur when a COMSAS sequence is detected.

6.7.2.8.3 Transition SP7:SAS_AwaitCOMSAS to SP19:SATA_COMWAKE

SAS devices that support SATA target attach shall transition to this state when a COMSAS sequence is not detected within the COMSAS Detect Timeout period.

6.7.2.8.4 Transition SP7:SAS_AwaitCOMSAS to SAS_AwaitNoCOMX

SAS devices that do not support SATA target attach shall transition to this state when a COMSAS sequence is not detected within the COMSAS Detect Timeout period.

6.7.3 SAS speed negotiation states

Figure 45 shows the SAS Speed Negotiation states, in which the SAS phy has detected that it is attached to a SAS phy, and engages in the SAS speed negotiation procedure. These states are indicated by state names with a prefix of SN or PHY.
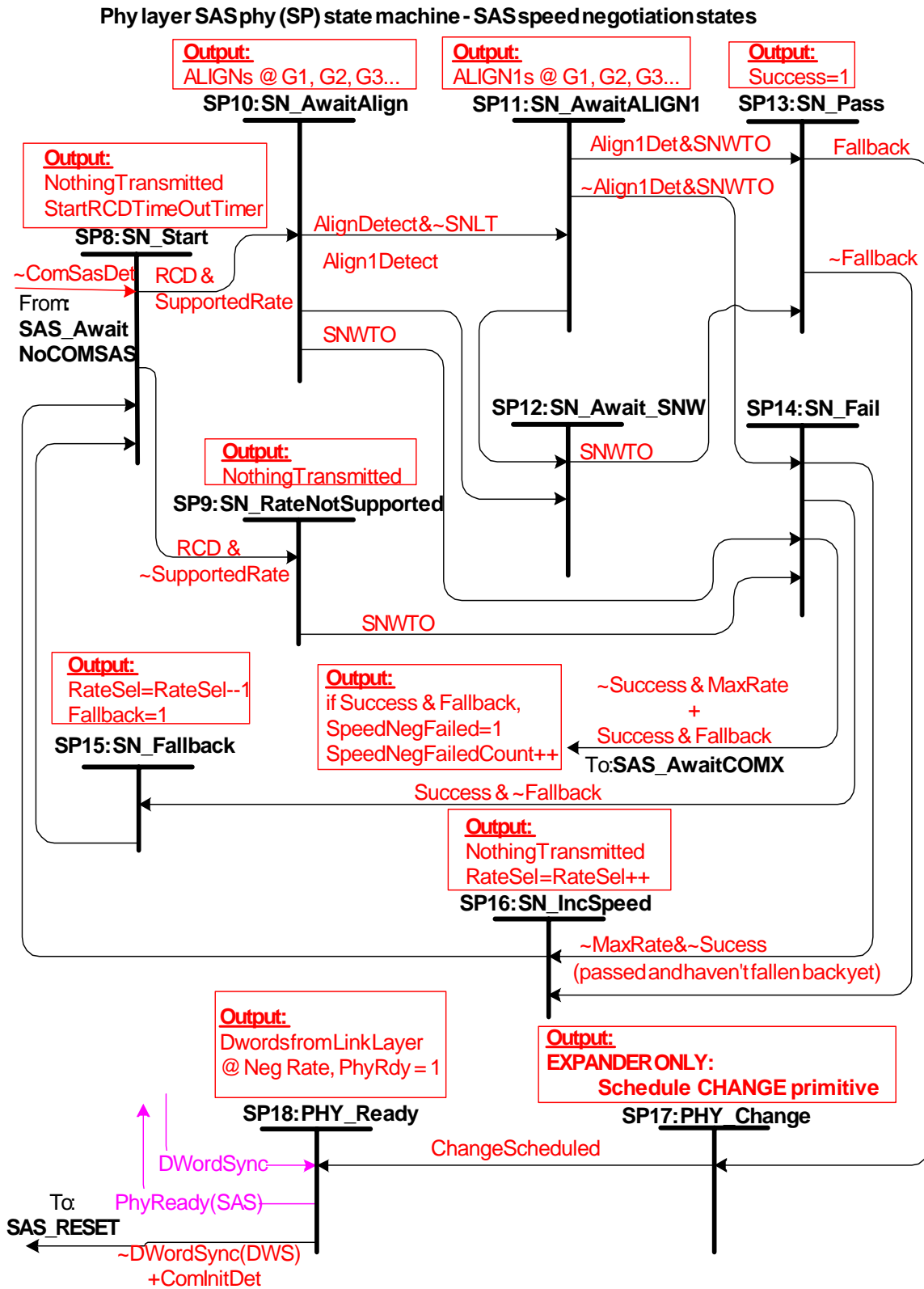
Phy layer SAS phy (SP) state machine - SAS speed negotiation states

Output:
ALIGNs @ G1, G2, G3...
SP10: SN_AwaitAlign

Output:
ALIGN1s @ G1, G2, G3...
SP11: SN_AwaitALIGN1

Output:
Success=1
SP13: SN_Pass

Align1Det&SNWTO

Fallback

Output:
NothingTransmitted
StartRCDTimeOutTimer
SP8: SN_Start

~Align1Det&SNWTO

AlignDetect&~SNLT

~Fallback

~ComSasDet   RCD &
From: SupportedRate
SAS_Await
NoCOMSAS

Align1Detect

SNWTO

SP12: SN_Await_SNW   **SP14: SN_Fail**

SNWTO

Output:
NothingTransmitted
SP9: SN_RateNotSupported

RCD &
~SupportedRate

SNWTO

Output:
RateSel=RateSel--1
Fallback=1

Output:
if Success & Fallback,
SpeedNegFailed=1
SpeedNegFailedCount++

~Success & MaxRate
+
Success & Fallback
To: **SAS_AwaitCOMX**

SP15: SN_Fallback

Success & ~Fallback

Output:
NothingTransmitted
RateSel=RateSel++
SP16: SN_IncSpeed

~MaxRate&~Sucess
(passed and haven't fallen back yet)

Output:
Dwords from LinkLayer
@ Neg Rate, PhyRdy = 1
SP18: PHY_Ready

Output:
EXPANDER ONLY:
Schedule CHANGE primitive
SP17: PHY_Change

ChangeScheduled

DWordSync

To: PhyReady(SAS)
SAS_RESET

~DWordSync(DWS)
+ComInitDet

Figure 45 — SAS phy (SP) state machine - SAS speed negotiation states

6.7.3.1 SP5:SN_Start state

6.7.3.1.1 State description

This state marks the beginning of the SAS speed negotiation process. It is used to transmit idle state in between SAS speed negotiation windows.

This state is entered from state SP6:SAS_AwaitNoCOMSAS after the end of a COMSAS sequence. It can also be entered from states SP16_Inc Speed or SP15:SN_Fallback for another pass, after a SNWT occurs.

Upon entering this state, the Rate Change Delay timer is loaded with an initial value and enabled to count down. This allows time required for a transmitter to switch to either the next higher or next lower supported speed. The state machine remains in this state until a Rate Change Delay has elapsed. During this state idle shall be transmitted.

6.7.3.1.2 Transition SP8:SN_Start to SP10:SN_AwaitAlign

This transition shall occur when the Rate Change Delay timer expires and the current rate is supported.

6.7.3.1.3 Transition SP8:SN_Start to SP9:SN_RateNotSupported

This transition shall occur when the Rate Change Delay timer expires and the current rate is not supported.

6.7.3.2 SP9:SN_RateNotSupported state

6.7.3.2.1 State description

This state is entered after a Rate Change Delay from state SP8:SN_Start when the currently selected rate is not supported. During this state idle shall be transmitted. Upon entering this state the SNWTO counter is loaded and enabled to count down. The state machine exits from this state after the SNWTO counter expires.

6.7.3.2.2 Transition SP9:SN_RateNotSupported to SP14:SN_Fail

This transition shall occur after the SNWTO counter expires.

6.7.3.3 SP10:SN_AwaitAlign state

6.7.3.3.1 State description

The state machine starts transmitting ALIGN characters at the current supported rate (Gen1, Gen2, Gen3…) in this state. Upon entering this state, the Speed Negotiation Window Time (SNWT) timer is loaded and enabled. The state machine exits this state when a SNWT timeout occurs without the pattern synchronization, or if synchronization occurs before the SNLT expires.

6.7.3.3.2 Transition SP10:SN_AwaitAlign to SP11:SN_AwaitALIGN1

This transition shall occur when ALIGNs at the current rate are received and recognized before an SNLT period.

6.7.3.3.3 Transition SP10:SN_AwaitAlign to SP12:SN_AwaitSNW

This transition shall occur when ALIGN(1)s at the current rate are received and recognized before an SNLT period.

6.7.3.3.4 Transition SP10:SN_AwaitAlign to SP14:SN_FAIL

This transition shall occur at the end of the speed negotiation window and dword synchronization had not been obtained within the SNLT.

6.7.3.4 SP11:SN_AwaitALIGN1 state

6.7.3.4.1 State description

This state is entered from state SP10:SN_AwaitAlign if the PLL has locked and obtained Dword synchronization and have detected ALIGNs within the SNLT. During this state the ALIGN(1) primitive is transmitted. This state is exited when the SNWTO expires or when ALIGN(1)s are received before the SNW time out.

6.7.3.4.2 Transition SP11:SN_AwaitALIGN1 to SP14:SN_Fail

This transition shall occur if no ALIGN(1)s were detected within an SNWTO period. This indicates that the other device must not have been able to lock at the current rate.

6.7.3.4.3 Transition SP11:SN_AwaitALIGN1 to SP14:SN_ AwaitSNW

This transition shall occur if ALIGN(1)s were detected within the SNWTO period. This indicates that the other device has been able to lock at the current rate.

6.7.3.5 SP12:SN_AwaitSNW state

6.7.3.5.1 State description

This state is entered from state SP10:SN_AwaitAlign or SP11:SN_AwaitAlign1 if the PLL has locked and obtained the appropriate pattern synchronization within an SNLT. During this window the state machine latches the fact that ALIGN(1)s were received, the speed negotiation is successful and now must only wait till the end of the speed negotiation window.

6.7.3.5.2 Transition SP12:SN_AwaitALIGN1 to SP13:SN_Pass

This transition shall occur after the end of the SNWTO.

6.7.3.6 SP13:SN_Pass state

6.7.3.6.1 State description

This state is entered from state SP11:SN_AwaitALIGN1 or SP12:SN_AwaitSNW after an SNWTO occurs. This is a single clock state that set the Success flag, indicating that there was at least one successful speed negotiation.

6.7.3.6.2 Transition SP13:SN_Pass to SP16:SN_IncSpeed

This transition shall occur if the state machine has not fallen back, which means that it has not progressed past the breaking point so the speed is incremented for the next attempt.

6.7.3.6.3 Transition SP13:SN_Pass to SP18:PHY_Change

This transition shall occur if the speed negotiation has completed in an expander device. This is indicated by the Fallback flag. If this flag is set it indicates that the speed negotiation has progressed to where it failed and then had fallen back to the last negotiated speed and then subsequently passed.

6.7.3.6.4 Transition SP13:SN_Pass to SP18:PHY_Ready

This transition shall occur if the speed negotiation has completed in a device other than an expander device. This is indicated by the Fallback flag. If this flag is set it indicates that the speed negotiation has progressed to where it failed and then had fallen back to the last negotiated speed and then subsequently passed.

6.7.3.7 SP14:SN_Fail state

6.7.3.7.1 State description

This state is entered from the SP11:SN_AwaitALIGN state or SP11:SN_AwaitALIGN1 state if ALIGN(1)s are not received indicating that the other end does not support the rate or has NOT locked at this rate.

6.7.3.7.2 Transition SP14:SN_Fail to SP2:SAS_AwaitCOMX

This transition shall occur when the state machine has not been successful, meaning that the max rate has been attempted and there haven't been any successful rate negotiated or when the speed negotiation fails after dropping back to the last working frequency.

6.7.3.7.3 Transition SP14:SN_Fail to SP15:SN_Fallback

This transition shall occur if the speed negotiation has failed and there was a previous success.

6.7.3.7.4 Transition SP14:SN_Fail to SP16:SN_IncSpeed

This transition shall occur if the speed negotiation has not previously passed and the maximum supported rate has not yet been attempted.

6.7.3.8 SP15:SN_Fallback state

6.7.3.8.1 State description

This state is entered from state SP14:SN_Fail after an SNWTO occurs indicating that the current tested speed failed but there was a former success. This is a one clock state that sets the Fallback flag to indicate that the sequence has progressed through a successful negotiation to one that fails and now needs to fall back to the highest mutually supported speed.

6.7.3.8.2 Transition SP15:SN_Fallback to SP8:SN_Start

This transition shall occur on the next clock.

6.7.3.9 SP16:SN_IncSpeed state

This is a one clock state that increments the speed for the next attempt. This state is entered when the transmitter has not reached its maximum supported rate during the SAS speed negotiation process. This can either be when the previous window has failed with no previous successes or passed but the highest supported rate hasn't been tested.

6.7.3.9.1 Transition SP16:SN_IncSpeed state to SP8:SN_Start

This transition shall occur on the next clock with the transmitter set for the next highest rate.

6.7.3.10 SP17:PHY_Change state

6.7.3.10.1 State description

This state is only present in expander devices. This state schedules broadcast of a CHANGE primitive on all other ports in the expander device.

6.7.3.10.2 Transition SP17:PHY_Change to SP18:PHY_Ready

This transition shall occur after scheduling broadcast of the CHANGE primitive.

6.7.3.11 SP18:PHY_Ready state

6.7.3.11.1 State description

This state is entered from state SP13:SN_Pass state (vis SP17:PHY_Change in expander devices) if the Fallback flag is set, which is an indication that the SAS speed negotiation procedure has completed successfully.

This state enables the SAS phy dword synchronization state machine (DWS) to provide rule checking for dword synchronization and determination of link failure. The input from DWS to indicate that Dword Synchronization is Acquired (DWordSync) and is used in the SP:18:Phy Ready and the SP26:SATA_Phy Ready states to determine if it is necessary to re-run OOB. Until this time, the DWS input is ignored.

The state machine remains in this state until a COMINIT sequence is detected or loss of DWordSync.. PhyReady(SAS) is set to one to indicate that the link has been brought up successfully in SAS mode. While in this state, the PhyRdy(SAS) signal to the link layer shall be set to one and dwords from the link layer are transmitted at the negotiated rate

6.7.3.11.2 Transition SP18:PHY_Ready to SP1:SAS_Reset

This transition shall occur if DWordSync is de-asserted by the DWS state machine or a COMINIT is detected. This is an indication that a device has been unplugged from the port or reset from the link.

6.7.4 SATA host emulation states

Figure 46 shows the SATA Host emulation states, in which the SAS device has detected that it is attached to a SATA target and behaves as if it were a SATA host as far as OOB is concerned, initiating the speed negotiation. These states are indicated by state names with a prefix of SATA_. During SATA Host emulation, the SAS device transmits a COMWAKE sequence and then waits to receive a COMWAKE. Once the COMWAKE sequence is detected, the SAS device follows the speed negotiation sequence defined in the SATA 1.0 specification.

SAS initiator devices, target devices and expander devices should use similar state machines to the one defined in this specification, with the exception that SAS initiators should implement the SATA Host emulation power management states. The power management states that are defined in this specification are for SAS

initiators that intend to attach directly to SATA targets. For SAS-only initiators, these states are not needed. The power management states are prefixed with PM.

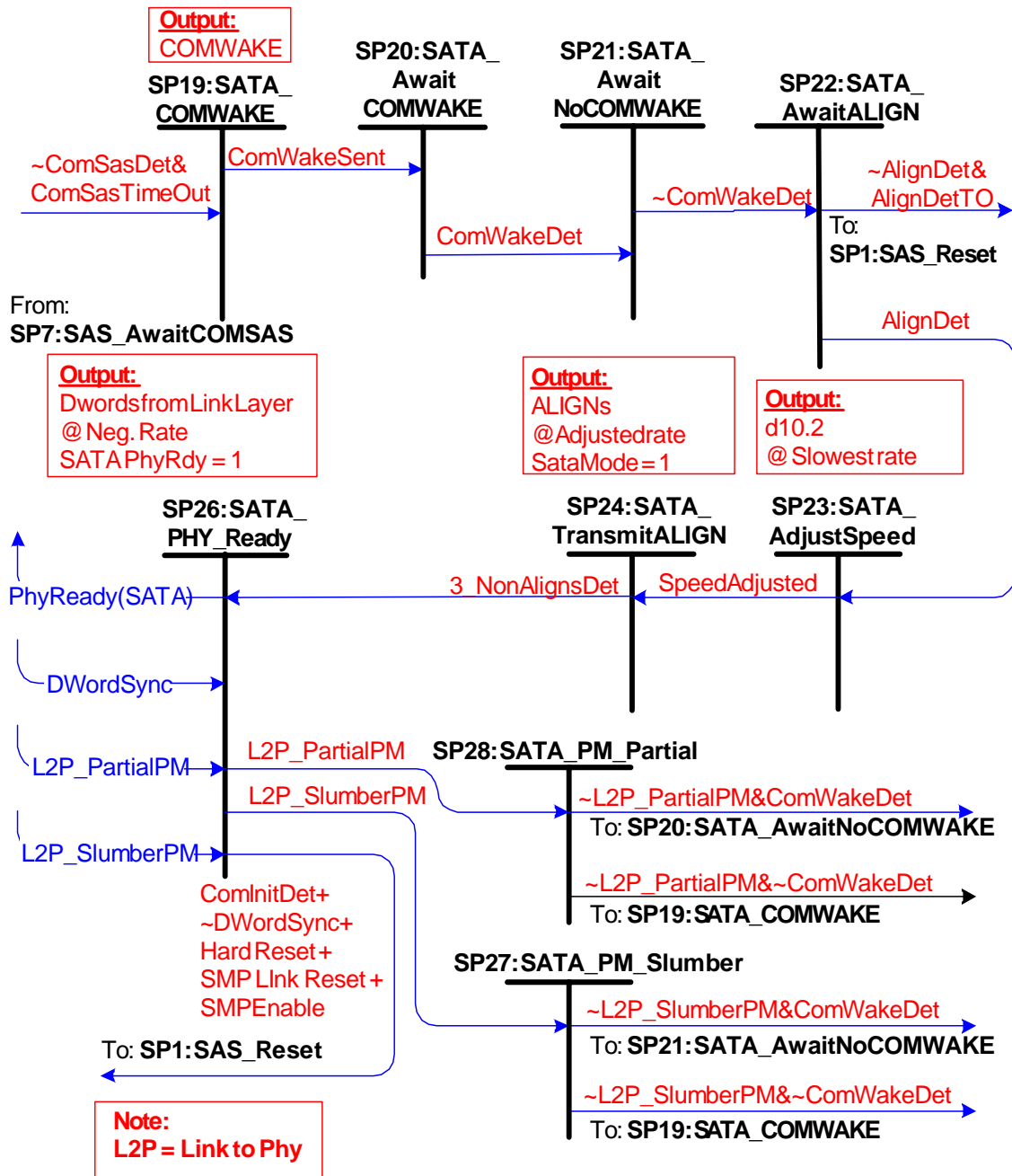**Phy layer SAS phy (SP) state machine - SATA host emulation states**

Figure 46 — SAS phy (SP) state machine - SATA host emulation states

6.7.4.1 SP19:SATA_COMWAKE state

6.7.4.1.1 State description

This is the first state of the SATA Host Emulation states. This state is entered from state SP7:SAS_AwaitCOMSAS when a COMSAS is not detected within a COMSAS Detect Timeout period. The state machine remains in this state until a COMWAKE sequence has been transmitted.

6.7.4.1.2 Transition SP19:SATA_COMWAKE to SP20:SATA_AwaitCOMWAKE

This transition shall occur when the COMWAKE sequence has been transmitted.

6.7.4.2 SP20:SATA_AwaitCOMWAKE state

6.7.4.2.1 State description

This state is entered when a COMWAKE sequence has been sent during state SP19:SATA_COMWAKE. The state machine remains in this state until a COMWAKE sequence has been detected.

6.7.4.2.2 Transition SP20:SATA_AwaitCOMWAKE to SP21:SATA_AawitNoCOMWAKE

This transition shall occur when a COMWAKE sequence is detected.

6.7.4.3 SP21:SATA_AwaitNoCOMWAKE state

6.7.4.3.1 State description

This state is entered when a COMWAKE sequence is detected in state SATA_AwaitCOMX. The state machine remains in this state until the end of the COMWAKE sequence is detected.

6.7.4.3.2 Transition SP21:SATA_AwaitNoCOMWAKE to SP22:SATA_AwaitALIGN

This transition shall occur when the end of the COMWAKE sequence has been detected.

6.7.4.4 SP22:SATA_AwaitALIGN state

6.7.4.4.1 State description

This state is entered from state SP21:SATA_AwaitNoCOMWAKE after the end of a COMWAKE sequence has been detected. While in this state, the SAS device is transmitting D10.2 characters at its slowest supported transmit speed. The state machine remains in this state until either an ALIGN primitive is detected at any of its supported rates, or 880 µs (32K Gen1 dwords) have elapsed without detecting any ALIGN primitives.

The SAS device shall start transmitting D10.2 characters no later than 20 Gen1 dwords (533 ns) after COMWAKE was de-asserted.

6.7.4.4.2 Transition SP22:SATA_AwaitALIGN to SP23:SATA_AdjustSpeed

This transition shall occur when the SAS device detects an ALIGN primitive at any of its supported rates.

6.7.4.4.3 Transition SP22:SATA_AwaitALIGN to SP1:SAS_Reset

This transition shall occur when the SAS device does not detect any ALIGN primitives within 880 µs (32K Gen1 dwords).

6.7.4.5 SP23:SATA_AdjustSpeed state

6.7.4.5.1 State description

This state is entered from state SP22:SATA_AwaitALIGN when the SAS device detects an ALIGN primitive at any of its supported rates. During this state, the SAS device's PHY transmitter circuitry adjusts to the same rate of the ALIGN primitives that were detected by the receiver circuitry. The state machine remains in this state until the transmitter rate has been adjusted appropriately.

6.7.4.5.2 Transition SP23:SATA_AdjustSpeed to SP24:SATA_TransmitALIGN

This transition shall occur when the transmitter rate has been adjusted to the rate of the received ALIGN primitives.

6.7.4.6 SP24:SATA_TransmitALIGN state

6.7.4.6.1 State description

This state is entered from state SP23:SATA_AdjustSpeed after the transmitter rate has been adjusted to the rate of the received ALIGN primitives. While in this state the SAS device transmits ALIGN primitives at the adjusted rate until the receiver circuitry detects three back-to-back non-ALIGN primitives, at which point the state machine transitions to state SP26:SATA_PHY_Ready.

6.7.4.6.2 Transition SP24:SATA_TransmitALIGN to SP26:SATA_PHY_Ready

This transition shall occur when the SAS device's receiver circuitry detects three back-to-back non-ALIGN primitives signaling the completion of a SATA speed negotiation.

6.7.4.7 SP26:SATA_PHY_Ready state

6.7.4.7.1 State description

This state is entered from state SP25:SATA_TransmitAlign. This state enables the SAS phy dword synchronization state machine (DWS) to provide rule checking for dword synchronization and determination of link failure. The input from DWS to indicate that Dword Synchronization is Acquired (DWordSync) and is used in the SP:18:Phy Ready and the SP26:SATA_Phy Ready states to determine if it is necessary to re-run OOB. Until this time the DWS input is ignored.

The state machine remains in this state until a COMINIT sequence is detected or loss of DWordSync.. PhyRdy(SATA) is set to one to indicate that the link has been brought up successfully in SATA mode. While in this state, the PhyRdy(SATA) signal to the link layer shall be set to one and dwords from the link layer are transmitted at the negotiated rate

6.7.4.7.2 Transition SP26:SATA_PHY_Ready to SP1:Reset

This transition shall occur when a COMINIT sequence is detected or loss of DWordSync from the DWS state machine indicating that the incoming signal is not compliant with the encoding defined for SAS/SATA.

6.7.4.8 SP27:SATA_PM_Partial state

6.7.4.8.1 State description

This state is entered from SP26:SATA_PHY_Ready if L2P_PartialPM is received from the link layer. Exit from this state is driven from receipt of COMWAKE or de-assertion of the partial signal.

The phy shall remember if COMWAKE was detected during SP27:SATA_PM_Partial to determine if the wakeup request was originated from the host or the phy.

6.7.4.8.2 Transition SP27:SATA_PM_Partial to SP21:SATA_AwaitNoCOMWAKE

This transition shall occur when the receiver circuitry detects COMWAKE.

6.7.4.8.3 Transition SP27:SATA_PM_Partial to SP20:SATA_COMWAKE

This transition shall occur if the link layer de-asserts the slumber signal to the PHY interface.

6.7.4.9 SP28:SATA_PM_Slumber state

6.7.4.9.1 State description

This state is entered from SP26:SATA_PHY_Ready since the device is operating in SATA mode and L2P_SlumberPM is received from the link layer. Exit from this state is driven from receipt of COMWAKE or de-assertion of the slumber signal.

The phy shall remember if COMWAKE was detected during SP28:SATA_PM_Slumber to determine if the wakeup request was originated from the link layer or the phy.

6.7.4.9.2 Transition SP28:SATA_PM_Slumber to SP21:SATA_AwaitNoCOMWAKE

This transition shall occur when the receiver circuitry detects COMWAKE from the device at the other end of the link. This transition should not occur until the phy interface is recovered from Slumber mode and is ready to initiate communications.

6.7.4.9.3 Transition SP28:SATA_PM_Slumber to SP20:SATA_COMWAKE

This transition shall occur if the link layer de-asserts the slumber signal to the PHY interface.

6.8 SAS phy dword synchronization (DWS) state machine

6.8.1 Overview

Each SAS phy includes a SAS phy dword synchronization state machine (DWS). The DWS state machine establishes the same dword boundaries at the receiver as at the attached transmitter. The DWS state machine requires an error free string of dwords to obtain synchronization. The DWS state machine tolerates invalid dwords as defined in the state machine before losing dword synchronization. While not in dword synchronization, information received is invalid and not passed to the SAS link layer state machine.

A SAS receiver monitors and decodes the incoming data stream and forces K28.5 characters into the first byte position to effectively perform dword alignment. The receiver continues to reestablish dword alignment by forcing received K28.5 characters into the first byte position until a valid SAS primitive is detected. The resultant primitives, dwords and valid dword indicators (encoding error indicators, etc) are sent to the Dword synchronization state machine to enable the state machine to determine the dword synchronization policy.

The DWS state machine contains the following states:

- a) DWS0:AcquireSync;
- b) DWS1:Valid1;
- c) DWS2:Valid2;
- d) DWS3:SyncAcquired;
- e) DWS4:Lost1;
- f) DWS5:Lost1Recovered;
- g) DWS6:Lost2;
- h) DWS7:Lost2Recovered;
- i) DWS8:Lost3; and
- j) DWS9:Lost3Recovered.

The state machine shall start in the DWS0:AcquireSync state after power on.

The DWS state machine receives no requests from the link layer.

The DWS state machine sends the following confirmations to the link layer:

- a) Enable Disable Link Layer(SAS Enable);
- b) Enable Disable Link Layer(SATA Enable);
- c) Enable Disable Link Layer(SAS Disable); and
- d) Enable Disable Link Layer(SATA Disable).

The DWS state machine receives the following parameters from the SP state machine:

- a) PhyReady(SAS); and
- b) PhyReady(SATA).
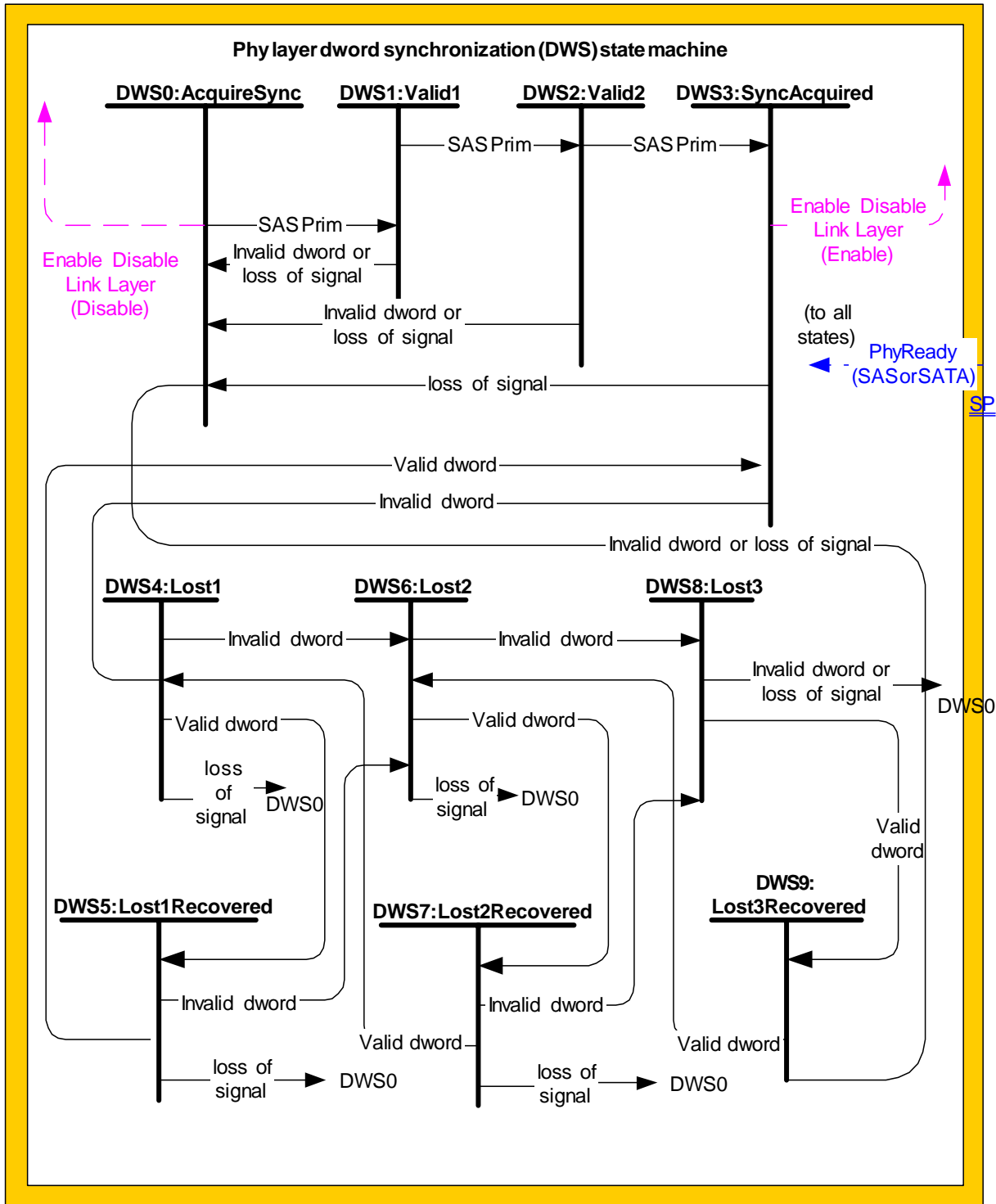
Figure 47 shows the DWS state machine.

Figure 47 — Dword synchronization state machine

6.8.2 DWS0:AcquireSync state

6.8.2.1 State description

Upon Power Up or loss of previous synchronization, this state is entered. On entry into this state, the Enable Disable Link Layer(SAS Disable) or Enable Disable Link Layer(SATA Disable) confirmation is sent to the link layer qualified by the PhyReady parameter from the SP state machine.

The receiver monitors the signal received and forces the first K28.5 it detects character into the first byte position for possible dword alignment.

When the requirements for dword synchronization are met and the DWS state machine enters the DWS3:SyncAcquired state the Enable Disable Link Layer(SATA Enable or SAS Enable) will be output. These signals will be qualified with the phy initialization state machine output PhyReady(SATA or SAS) and presented to the link layer. The link layer uses this qualified version to enable/disable operation. The phy initialization state machine uses the unqualified version of the Enable Disable Link Layer to determine whether to re-run OOB. The unqualified signal will be monitored only in the PhyReady(SATA or SAS) states and not in the other OOB and speed negotiation states. Upon receipt of the Enable Disable Link Layer (SATA Disable) or Enable Disable Link Layer (SAS Disable), the phy initialization state machine re-runs OOB.

6.8.2.2 Transition DWS0:AcquireSync to DWS1:Valid1

This transition shall occur when a valid SAS primitive is detected. This indicates the present dword alignment is valid for this dword.

6.8.3 DWS1:Valid1 state

6.8.3.1 State description

The receiver monitors information received until a valid SAS primitive, an invalid dword, or a loss of signal is detected.

6.8.3.2 Transition DWS1:Valid1 to DWS2:Valid2

This transition shall occur when a valid SAS primitive is detected. This indicates the present dword alignment is valid for this word.

6.8.3.3 Transition DWS1:Valid1 to DWS0:AcquireSync

This transition shall occur when an invalid dword or a loss of signal is detected. A new attempt at word alignment is started.

> Editor's Note 10: PHY WG is investigating whether we should drop "loss of signal" from consideration. Without it, the state machine will still return to DWS0 in 4 dwords.

6.8.4 DWS2:Valid2 state

6.8.4.1 State description

The receiver has detected two valid SAS primitives using the current word alignment. The receiver monitors information received until a valid SAS primitive, an invalid dword, or a loss of signal is detected.

6.8.4.2 Transition DWS2:Valid2 to DWS3:SyncAcquired

This transition shall occur when a valid SAS primitive is detected. This indicates the present dword alignment is valid for this word.

6.8.4.3 Transition DWS2:Valid2 to DWS0:AcquireSync

This transition shall occur when an invalid dword or a loss of signal is detected. A new attempt at word alignment is started.

6.8.5 DWS3:SyncAcquired state

6.8.5.1 State description

The receiver has detected three valid SAS primitives using the current word alignment. The Enable Disable Link Layer(SAS Enable) or Enable Disable Link Layer(SATA Enable) confirmation is sent to the link layer based on the protocol indicated by the PhyReady parameter from the SP state machine. The current SAS primitive is valid for processing. The receiver monitors information received until an invalid dword is received or a loss of signal occurs.

6.8.5.2 Transition DWS3:SyncAcquired to DWS4:Lost1

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see 7.14.13).

6.8.5.3 Transition DWS3:SyncAcquired to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at word alignment is started.

6.8.6 DWS4:Lost1 state

6.8.6.1 State description

The receiver has detected an invalid dword. This is the first state in the process that may result in losing dword synchronization. The receiver monitors information received.

6.8.6.2 Transition DWS4:Lost1 to DWS5:Lost1Recovered

This transition shall occur when a valid dword is detected. This indicates the present dword alignment may still be valid for this dword.

6.8.6.3 Transition DWS4:Lost1 to DWS6:Lost2

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see 7.14.13).

6.8.6.4 Transition DWS4:Lost1 to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at dword alignment is started.

6.8.7 DWS5:Lost1Recovered state

6.8.7.1 State description

The receiver has detected a valid dword after an invalid dword. Dword synchronization may still be valid. The receiver monitors information received for valid dwords, invalid dwords and loss of signal.

6.8.7.2 Transition DWS5:Lost1Recovered to DWS3:SyncAcquired

This transition shall occur when a valid dword is detected. Two valid dwords have been received since the last invalid dword.

6.8.7.3 Transition DWS5:Lost1Recovered to DWS6:Lost2

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see 7.14.13).

6.8.7.4 Transition DWS5:Lost1Recovered to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at dword alignment is started.

6.8.8 DWS6:Lost2 state

6.8.8.1 State description

The receiver has detected an invalid dword without sufficient valid dwords to nullify previous invalid dwords. The receiver monitors information received for valid dwords, invalid dwords and loss of signal.

6.8.8.2 Transition DWS6:Lost2 to DWS7:Lost2Recovered

This transition shall occur when a valid dword is detected. This indicates the present dword alignment is still valid for this dword.

6.8.8.3 Transition DWS6:Lost2 to DWS8:Lost3

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see 7.14.13).

6.8.8.4 Transition DWS6:Lost2 to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at dword alignment is started.

6.8.9 DWS7:Lost2Recovered state

6.8.9.1 State description

The receiver has detected a valid dword after an invalid dword. Dword synchronization may still be valid. The receiver monitors information received for valid dwords, invalid dwords and loss of signal.

6.8.9.2 Transition DWS7:Lost2Recovered to DWS4:Lost1

This transition shall occur when a valid dword is detected. Two valid dwords have been received since the last invalid dword.

6.8.9.3 Transition DWS7:Lost2Recovered to DWS8:Lost3

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see 7.14.13).

6.8.9.4 Transition DWS7:Lost2Recovered to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at dword alignment is started.

6.8.10 DWS8:Lost3 state

6.8.10.1 State description

The receiver has detected an invalid dword without sufficient valid dwords to nullify a previous invalid dwords. The receiver monitors information received for valid dwords, invalid dwords and loss of signal.

6.8.10.2 Transition DWS8:Lost3 to DWS9:Lost3Recovered

This transition shall occur when a valid dword is detected. This indicates the present dword alignment may still valid for this dword.

6.8.10.3 Transition DWS8:Lost3 to DWS0:AcquireSync

This transition shall occur when an invalid dword or loss of signal is detected. If an invalid dword is detected, at least four invalid dwords have been received without sufficient intervening valid dwords to nullify their effect. Dword synchronization is lost; a new attempt at dword alignment is started.

6.8.11 DWS9:Lost3Recovered state

6.8.11.1 State description

The receiver has detected a valid dword after an invalid dword. Dword synchronization may still be valid. The receiver monitors information received for valid dwords, invalid dwords and loss of signal.

6.8.11.2 Transition DWS9:Lost3Recovered to DWS6:Lost2

This transition shall occur when a valid dword is detected. Two valid dwords have been received since the last invalid dword.

6.8.11.3 Transition DWS9:Lost3Recovered to DWS0:AcquireSync

This transition shall occur when an invalid dword or loss of signal is detected. If an invalid dword is detected, at least four invalid dwords have been received without sufficient intervening valid dwords to nullify their effect. Dword synchronization is lost; a new attempt at dword alignment is started.