IEEE 802.3, HSSG – 10 Gigabit Ethernet MINUTES
Study Group Plenary Meeting
January 18 – 20, 2000
Dallas, Texas

Prepared by:
Jeff Warren – Extreme Networks

Administrative:

The meeting convened at 8:25AM, January 18th, 2000. Jonathan Thatcher, the High Speed Study Group Chairman, opened the meeting with a presentation of the agenda, now available at the IEEE web site
http://grouper.ieee.org/groups/802/3/10G_study/public/jan00/index.html.

Jonathan then volunteered Jeff Warren to act as recording secretary for the meeting and went on to review the agenda. A motion to approve the agenda was made by Paul Kolesar, it passed by acclamation.

The next meeting is a plenary meeting and will be held in Albuquerque, NM from March 6th – 10th. This March meeting will be the first official meeting of the 10 GE task force, IEEE 802.3ae. The task force will organize and structure the committee, close the "brainstorming phase", and begin to "down select" PMD options at this meeting.

An e-mail reflector has been set up for the HSSG, stds-802-3-hssg@mail.ieee.org To be added to the reflector, send an e-mail to majordomo@ mail.ieee.org with the following line, subscribe stds-802-3-hssg <your email address>. To send a message to the HSSG reflector use the email address, stds-802-3-hssg@ieee.org

The voting rules can be found at http://grouper.ieee.org/groups/802/3/rules/member.html
The 802.3 patent policy can be found at http://grouper.ieee.org/groups/802/3/patent.html
Mr. Geoff Thompson, the chair of 802.3 reviewed the current patent policy rules with the HSSG group.

Jonathan closed the meeting by stating that the group is transitioning from brainstorming to refining proposals on the table and narrowing down the many PMD options before us. The HSSG meeting was adjourned at 10:10AM on Thursday the 20th of January.

Outline:

	Administrative	Pg. 1
	Meeting Goals & HSSG Objectives	Pg. 2
	802.3ae Standards Timeline	Pg. 3
	Agenda	Pg. 4
	Summary of Presentations	Pg. 5 – Pg. 20
	Action Items & New Business	Pg. 21
	Motions	Pg. 22 – Pg 23
	HSSG PHY Spreadsheet	Pg. 23 – Pg 24

Meeting Goals:

Priority One - Come Together:

- Hari Decision: Add, Kill, Postpone (with plan)
  Results: *The chair communicated his decision that Hari was within the objectives of the group and gave the committee an opportunity to bring forward a motion reversing or modifying this decision. None was offered.*
- Plan for paring down PMD / PHY set
  Results: *Nineteen (19) unique PHY proposals are on the books. A spreadsheet was developed. Votes were taken by 62 individuals in an attempt to rank the proposals. Jonathan encouraged the PMD companies to go back to the office and improve upon the information on the spreadsheet. He told the PMD companies that they needed to work together outside the standards forum to develop consensus.*
- Plan for choosing coding scheme(s)
  Results: *An update of the 64b/66b code was given, however no plan to narrow down the coding decisions.*

Priority Two:

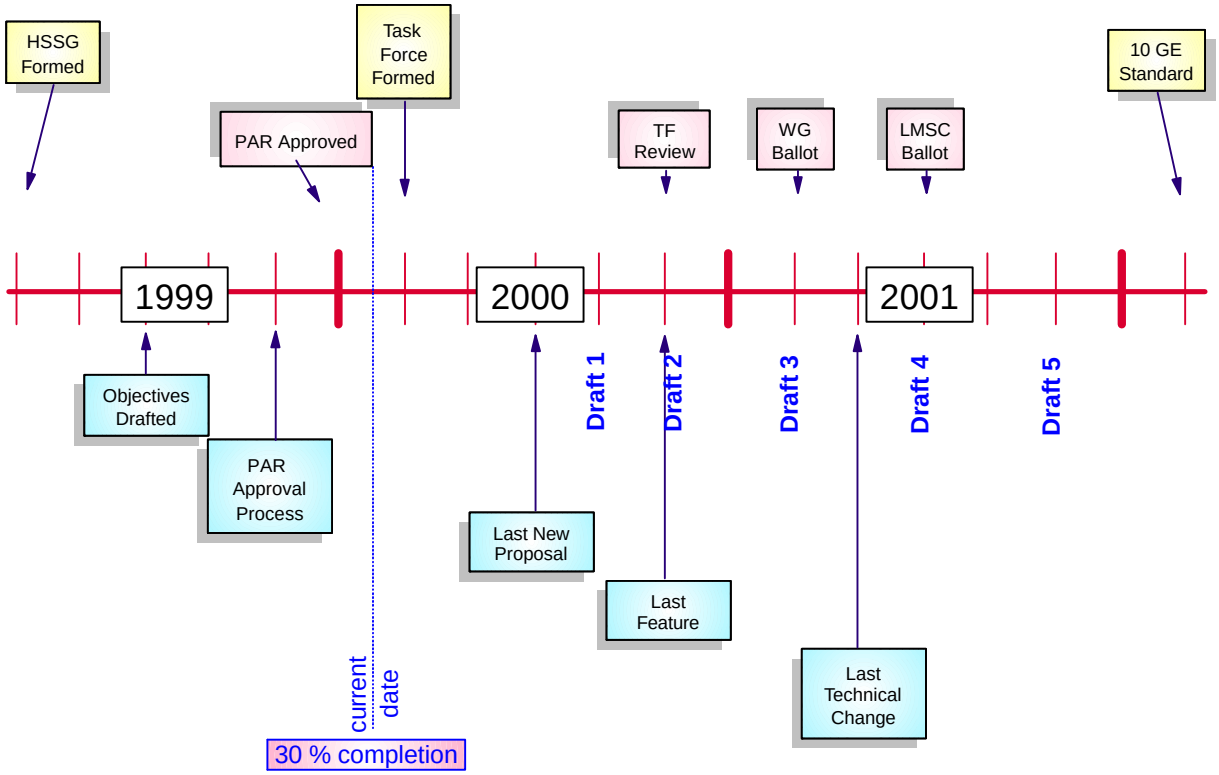
- Recommendation to 802.3 on ITU Letter
  Results: *This was postponed until the March 2000 plenary meeting*
- Plan for Albuquerque Plenary Meeting in March 2000
  Results: *The group will split into two tracks (PMD & everything else). New material gets first priority in scheduling. Joint presentations on proposals that are transitioning to a consensus within a group get the next priority. Then priority will be given to refinements to old subjects that have strong support among multiple vendors. The lowest priority will be presentation on old subjects that do not have strong support from multiple companies.*

HSSG Objectives:

1. Preserve the 802.3/Ethernet frame format at the MAC Client service interface.
2. Meet 802 Functional Requirements, with the possible exception of Hamming Distance.
3. Preserve minimum and maximum FrameSize of current 802.3 Std.
4. Support full-duplex operation only.
5. Support star-wired local area networks using point-to-point links and structured cabling topologies.
6. Specify an optional Media Independent Interface (MII).
7. Support proposed standard P802.3ad (Link Aggregation).
8. Support a speed of 10.000 Gb/s at the MAC/PLS service interface.
9. Define two families of PHYs
   - A LAN PHY, operating at a data rate of 10.000 Gb/s
   - A WAN PHY, operating at a data rate compatible with the payload rate of OC-192c/SDH VC-4-64c

10. Define a mechanism to adapt the MAC/PLS data rate to the data rate of the WAN PHY.
11. Support fiber media selected from the second edition of ISO/IEC 11801 (802.3 to work with SC25/WG3 to develop appropriate specifications for any new fiber media).
12. Provide Physical Layer specifications which support link distances of:
    - At least 100 m over installed MMF
    - At least 300 m over MMF
    - At least 2 km over SMF
    - At least 10 km over SMF
    - At least 40 km over SMF
13. Support fiber media selected from the second edition of ISO/IEC 11801 (802.3 to work with SC25/WG3 to develop appropriate specifications for any new fiber media).

IEEE 802.3ae Standards Timeline:



Agenda:

Speaker		Topic	Time Req	Time Allc	Start Time
Tue, 18 Jan 2000		**Call to Order**			8:30 AM
Jonathan Thatcher	*G*	Opening Business	0:25	0:25	8:30 AM
Roy Bynum	*G*	Transmission Data Reliability	0:30	0:30	8:55 AM
Scott Lowrey	*G*	Status of Optical Internetworking Forum	0:05	0:10	9:25 AM
Steve Swanson	*G*	Status of TIA FO-2.2.1	0:10	0:10	9:35 AM
Tad Szostak	*G*	ISO 11801 MM and SMF back reflection specifications	0:20	0:20	9:45 AM
David W. Martin	*1*	10GE WAN PHY Delineation Performance	0:30	0:30	10:05 AM
		Break	0:25	0:25	10:35 AM
Norival Figueira	*1*	10GE WAN PHY: Physical Coding Sublayer (PCS)	1:00	1:00	11:00 AM
Howard Frazier	*1*	Unified PHY Proposal	0:45	0:45	12:00 PM
		Lunch	1:20	1:20	12:45 PM
Paul Bottorff	*2*	Hari as a Copper PHY	0:20	0:20	2:05 PM
Dae Young Kim	*2*	MB810 applications for HARI interface	0:20	0:20	2:25 PM
		Break	0:25	0:25	2:45 PM
Joel Dedrick	*2*	Sources of Lane to Lane Skew; Alignment Proposal	0:20	0:20	3:10 PM
Rich Taborek	*2*	Hari Update	0:40	0:40	3:30 PM
David W. Martin	*G*	10GE Wan PHY & T1X1.5 EoS (evening timeslot?)	0:30	0:45	4:10 PM
		Adjourn			4:55 PM
Wed, 19 Jan 2000		**Reconvene**			8:30 AM
ChanGoo Lee	*3*	Considerations on MB810 decoder for 10GbE	0:15	0:15	8:30 AM
Heyung Sub Lee	*3*	MB810 Encoding Method with Control Codes	0:20	0:20	8:45 AM
Han Chul Do	*3*	Error Detectability of MB810	0:15	0:15	9:05 AM
Rick Walker	*3*	Update of 64b/66b low-overhead-coding proposal	0:30	0:30	9:20 AM
		Break	0:25	0:25	9:50 AM
Ed Sayre	*2*	Transmission Line Bandwidth Limits for FR4 (Wed a.m.)	1:00	1:00	10:15 AM
Dennis Petrich	*4*	Jitter Measurement?	0:30	0:30	11:15 AM
		Lunch	1:20	1:20	11:45 AM
Vivek Telang	*4*	10GbE over Twisted Pair Copper (Cat6 cable)	0:30	0:30	1:05 PM
Vipal Bhatt	*4*	Update on Serial PMD	0:30	0:30	1:35 PM
Rich Taborek	*4*	MAS/2Wdm PHY Proposal	0:20	0:20	2:05 PM
		Break	0:25	0:25	2:25 PM
Stefan Wurster	*4*	10000LX-4WDM-1.25 and 10000CX-4T-1.25 XCVRs	0:15	0:15	2:50 PM
Eric Grann	*4*	8 Channel VCSEL Transceiver for 10-Gig	0:30	0:30	3:05 PM
Oscar Agazzi	*4*	Simulation Studies for PAM-5 10Gb/s PMD	0:30	0:30	3:35 PM
George Claseman	*G*	Emerging 10GbE Applications (Wed pm)	0:30	0:30	4:05 PM
		Adjourn			4:35 PM
Thur, 20 Jan 2000		**Reconvene**			8:30 AM
Jonathan Thatcher		Motion Madness / Future Planning / Close Meeting	1:30	2:00	8:30 AM
		Break	0:25	0:25	10:30 AM
Jonathan Thatcher		PMD Special Meeting	1:00	1:00	10:55 AM
Jonathan Thatcher		Reserved	3:00	3:00	1:15 PM
		Adjourn			4:15 PM

Presentations:

1. **Opening Business**
   - Presenter: Jonathan Thatcher (World Wide Packets)
   - Time Allocated: 25 minutes
   - Start Time: 8:25AM

2. Information Data Reliability with the XGbE WAN PHY
   - Presenter: Roy Bynum (MCI World Com)
   - Time Allocated: 30 minutes
   - Start Time: 9:27AM
   - Presentation Highlights:
     - Mr. Bynum's stated that 95 % of IP traffic that is transmitted over optical transports is originated from 802.3 based Ethernet IP networks. The Ethernet networks are more reliable than SONET networks, with GE networks exhibiting a data loss of approximately 1% whereas data loss of packet over SONET is approximately 3 percent. An interesting chart that shows POS traffic restoration is limited by multiple layers of handshaking was shown. In this case the optical restoration (e.g. APS switching and restoring the optical signal) took less than 50ms, however the higher layers added another 375ms for just the HDLC/PPP link setup and SONET restoration plus another 500ms to seconds for the TCP/IP setup and application restoration. In comparison to GE Roy felt that the P802.3ae WAN PHY traffic restoration could be as low as 625us. Roy stated that the single biggest slow down in network traffic is due to link aggregation, this prevents IP convergence. The HDLC/PPP protocol is an analog protocol that is 30 years old. EOS is getting rid of this analog element and this means the restoration time improves. In a full digital system the new 10 GE WAN PHY can sync up in 625 microseconds. In addition to improved restoration times, 10 GE WAN gear will also provide deterministic latency and differentiated services through priority queuing.
     - Discussion (Q&A):
       - IP Convergence is required when traffic will not flow across a link that it would normally take. The network is an Internet backbone, or local network. On the topic of convergence, every router in the network is building a topology map, when every router in the network has the same map the network is said to be converged. When a change occurs, convergence occurs again after all routers have the same "new view" of the network. This is specific to routing domains.

3. Optical Internetworking Forum Report

- Presenter: Tom Palkert (AMCC)
- Time Allocated: 10 minutes
- Start Time: 9:46AM
- Presentation Highlights:
  - Mr. Palkert's presentation was a brief update on the OIF. Much of the information was a repeat of the previous OIF update given at the Kauai HSSG meeting. This forum is comprised of three working groups, i.e. architecture, OAM&P, and PLL – physical and link layer. Tom is working within this PLL group which has overlapping activities with this HSSG group, for example the low-cost 10 Gb/s interface and SERDES interface definition. The OIF is considering issues related to the Hari interface, Mr. Hanson from Agilent for example made a recent Hari presentation to the OIF. The OIF has a web site, the URL is: http://www.oiforum.com/
- Discussion (Q&A):
  - The original presentation posted to the web was different from the one presented. How do 12 fibers map into 10GE transmission, there are two channels that map into something else, not specified. Ten channels are used for data. Is there the market timing for this common OIF work that overlaps HSSG? They want to get things moving by July, no formal timing has been established, except to say this is not a standards body, it is an implementer's agreement forum. The OIF is committed to review any material we send their way. The OIF efforts do not directly map into the HSSG, meaning we would not point to their work in our standard.

4. TIA FO-2.2.1 Task Group on Modal Dependence of Bandwidth, 1/00 Status Update

- Presenter: Steve Swanson (Corning)
- Time Allocated: 10 minutes
- Start Time: 9:56AM
- Presentation Highlights:
  - There was an FO-2.2.1 Task Group meeting in December 1999 that started the discussion of 10GE. The bulk of their work is aimed at 62.5 fiber. The short reach (100m & 300m) HSSG objectives apply to this groups work efforts. Both Lucent and Corning have made 10GE serial recommendations for 850 nm using new 50 um fiber. The development issues are fiber, transceiver characterizations followed by system validation. A preliminary timeline tied to this groups timeline has been established, this results in a May 2001 recommendation for system performance.
- Discussion (Q&A):
  - The GE & 10GE standards will benefit from FO-2.2.1 Task Group's work on new 50 um fiber. The recommendations are strictly MMF recommendations, and the receiver side is focused on 850 nm VCSEL technology. This group needs to specify things like encoding schemes that will make their system performance modeling work. The availability of this recommendation showing up in 11801 is relatively premature at this point until this group

decides upon an encoding scheme. They will have to gain consensus internationally; this translates into a lot of political work to be done as opposed to a lot of technical work.

5. ISO/IEC JTC 1/SC 25/ WG 3 reaffirmation of passive F/O connector back reflection values
   - Presenter: Tad Szosltak (3M)
   - Time Allocated: 20 minutes
   - Start Time: 10:05AM
   - Presentation Highlights:
     - Since Tad's pitch is contain on one page it is reproduced here in its entirety.
     - The US TAG to ISO/IEC JTC 1/SC 25/ WG 3 inquired about reaffirmation of the passive F/O connector back reflection values of -20 (multi mode) and -26 dB (single-mode fiber) specified in the ISO-11801-1995 Generic Cabling for Customer Premises Standard
     - **Background:**
       - The IEEE 802.3 HSSG specifies in the PAR-5 criteria support for the fiber media selected from the second edition of ISO/IEC 11801 including work with SC25/WG3 to develop appropriate specifications for any new fiber media
       - ISO/IEC 11801, International Cabling Standard, is going presently through the revision process with completion targeted for end of 2000
       - The reflection values for the optical fiber passive connection's specified in the 1995 edition for both MM and SMF are -20 and -26 dB respectively
       - Preliminary serial PMD proposal for HSSG (e.g. proposal submitted by the Corning, Finisar, IBM, Infineon, Lucent, Mitsubishi, Ortel, Picolite, Sumitomo, Tyco, Gore, and 3M), November '99, specifies the above reflection values in the Preliminary Budget Analysis tables (pg. 7 & 9)
   - Discussion (Q&A):
     - See motion number 3 below.

6. 10GE WAN PHY Delineation Performance
   - Presenter: David Martin (Nortel Networks)
   - Time Allocated: 30 minutes
   - Start Time: 10:33AM
   - Presentation Highlights:
     - Mr. Martin's presentation is a continuation of previous Nortel contributions. This pitch provides additional delineation details on the SONET Framer, encapsulated MAC frames, and pointer processing delineation. Also the pitch includes a recap of the WAN PHY proposal that incorporates new frame delineation statistics presented. The new statistics parameters described were:
       - MTTF - mean time to frame: 254.4us
       - PLF - probability of loss of frame: 9.56x10EE-21
       - MTTFL - mean time to frame loss: 700,000 years
       - PFF - probability of false framing 2.23x10EE-30

        - PRFF - probability of rejecting false frame: 0.9995
    - The three basic step in frame delineation were described. For each step the effects of errors were analyzed. The first step, i.e. finding the SONET frame is accomplished by searching for the A1-to-A2 transition. These A1 & A2 bytes are non-scrambled. The PLF due to errors in these A1 & A2 bytes was graphed. Once the A1-A2 bytes are acquired you can sync on the frame and then locate the H1, 2,3 pointer bytes. The second delineation step, pointer processing used to locate the starting point of the SPE was analyzed. The probability of pointer loss was also graphed and the effects of pointer errors was discussed in great detail, specifically the H1, H2, H3 pointers. The third delineation step encapsulated MAC frames, focused on a discussion of the modified header error control (HEC) check algorithm. This is a four-state algorithm. The normal progression is to hunt for two CRC-16's and transition into the Sync_Correction State. From this state single bit errors can be corrected, however multiple bit errors will cause loss of frame. The probability of false framing is basically equal when you compare the 10 GE 8B/10B PHY with the 10GE WAN PHY. Framer, pointer processing and MAC encapsulation is dominated by the encapsulation loss. Errors in the S, T, and R characters will cause us to lose frame sync. Other things to consider are errors in the payload. When there is an error in the payload we just throw out the frame. If there's an error in the delineation it will take a few frames to reacquire sync. For the WAN PHY we could lose up to 5 frames before re-acquiring sync.
- Discussion (Q&A):
    - The analysis of these probabilities were only done for 500 bytes, this only effects mean time to frame loss, not the probability of frame loss. Small packet sizes were not evaluated. The relevant concern here should be loss of sync when comparing the two PHYs.

7. 10GE WAN PHY: Physical Coding Sublayer

- Presenter: Norival Figueira (Nortel Networks)
- Time Allocated: 1 hour
- Start Time: 11:15AM
- Presentation Highlights:
    - Mr. Figuerira's presentation is tied to the document posting from the NOV99 meeting. The pitch is limited to the PCS for the WAN PHY where MAC packet delineation and scrambling occurs. A functional block diagram for the entire PHY was shown, including the conceptual interface between the PCS and PMA. Station management interface is the same as used by 1 GE. There is a control line per lane, i.e. 4 TXC<3:0>. The data path is 32 bits wide using a DDR 156.25 MHz clock. A new control character "TX_WH" was added to control the effective data rate. Every clock transition is used to clock data, both rising and falling edges of the clock. When the MAC senses the TX_WH asserted it inserts four null characters. There is no requirement for the EOP to be aligned to a particular lane. There is an assumption that the MAC will provide data frame length. A self-synchronous scrambler is used only on the

data octets (1st octet of DA to last octet of FCS); the headers are not scrambled. The purpose of the scrambler is to protect the DC balance and prevent a malicious user from transmitting "killer packets". PCS encapsulation is where HEC is added. The HEC is a straight forward process applied to the 8 octets of modified preamble plus the SFD. The output of the HEC generation bypasses the scrambler. From a high level a proposed strawman for the PCS reference diagram was shown. Idle byte packets are used when there is no data generated by the MAC, these idle byte packets are always 10 bytes in length, so the length field in these idle packets is zero since there is no data. When the PCS locks in on an HEC it has found a MAC packet, and then the length is used to point to the next possible valid location of the next MAC packet. The HUNT state is where we look for the valid HECs, once found transition to the SYNC_Detect state. A subsequent valid HEC moves us to the SYNC_Correct state, where we stay until an incorrect HEC is detected due to single or multiple bit errors. Synchronization is lost when we move back to the HUNT state.

- Discussion (Q&A):
  - The null is only used to reduce the data rate. This pitch rules out preamble shrinkage. A pointer shift in the WAN domain is used to do time domain corrections. SOP should always be word aligned. Flow control is accomplished with the NULL characters. These NULL words can only be inserted in the frame and is always 4 bytes in length, these nulls don't effect idles. The idles from the MAC are converted into idle packets. The PHY FIFO used to control the effective data rate is estimate to be approximately 64 bytes. This proposal relies on a MAC knowing lengths and passing these lengths to the PHY, this will more than likely be dealt with in the standard at the reconciliation layer. This means a store and forward architecture is required so that the MAC can calculate the length of the frame.

8. Unified LAN/WAN PHY Proposal

- Presenter: Howard Frazier (Cisco Systems)
- Time Allocated: 45 minutes
- Start Time: 12:03PM
- Presentation Highlights:
  - Mr. Frazier started his presentation with a review of his LAN/WAN Bridging model originally presented in September of 1999. Howard pointed out some objections to this two PHY proposal, i.e. requiring different PMDs for each PHY type, and rate adaptation for WAN PHY. A quick review of the Hari interfaces occurred next. This brought about Hari with its serial interface, more objections surfaced. Now stepping back and thinking about why we want to do different PHYs leads one to the realization that there are a lot of existing WAN infrastructures, so this means we'll have unique requirements to adapt to these WAN infrastructures. Howard apologized for using the same naming convention, i.e. EOS, as the previous presentation. Howard points out an issue with EOS is that 10GE Phys need to understand frame lengths and MACs must pass the frame length to 10GE Phys, this is an operational

requirement that is not specified in 802.3 MACs today. Another proposal that has surfaced includes the 64b/66b line code. This resulted in a 10.3125 Gbaud rate as opposed to 12.5 Gbaud for the LAN PHY. An alternative WAN PHY proposal that includes the nice attributes of 64b/66b encoding was proposed. Here the PCS and PMA layers would include 8B/10B, 64b/66b, Framer + FIFO, scrambler, SERDES, which are connected to the optics. This is a 2 polynomial scrambler system that does not require frame lengths passed from the MAC to the PHY and does not overwrite preamble. Howard's data and signal rate comparison table shows the LAN PHY based on 8B/10B dropping from 12.5 to 10.312 Gbaud if the LAN PHY uses the newly proposed 64b/66b line code. It also shows the WAN PHY EOS rate of 9.95328 Gbaud staying at 9.95328 Gbaud when we use the 64b/66b code. Howard outlined his issues with the word-by-word rate control process; for example it interrupts flow of data through pipeline stages and doesn't work with Hari since there is no provisioning in Hari for this rate control mechanism. A new rate control process called "Busy Idle Rate Control" was proposed that does work with Hari. A new FIFO of approximately 256 bytes is needed in the WAN PHY transmit path. Busy Idles encoded as K28.1/K23.7 are only sent between frames. The benefits of Howard's proposal include a common interface (i.e. Hari), common functions, and common optics between the LAN & WAN Phys.

- Data and Signal Rate Comparison Table (pg. 16 of Howard's presentation)

	LAN PHY (8b10b)	WAN PHY (EOS)	LAN PHY (64b/66b)	WAN PHY (64b/66b)
MAC Data Rate	10.0000 Gb/s	9.58464 Gb/s	10.0000 Gb/s	9.29419 Gb/s
XMII signal rate	156.25 MHz x 32 DDR	156.25 MHz x 32 DDR	156.25 MHz x 32 DDR	156.25 MHz x 32 DDR
XMII Data Rate	10.0000 Gb/s	9.58464 Gb/s	10.0000 Gb/s	9.29419 Gb/s
Encoded Data Rate	12.5 Gbaud	9.95328 Gbaud	10.3125 Gbaud	9.58464 Gb/s
Serial Signal Rate	12.5 Gbaud	9.95328 Gbaud	10.3125 Gbaud	9.95328 Gbaud

- Discussion (Q&A):
  - In SONET there is 640 bytes of time which would require us to increase the size of the WAN PHY transmit path FIFO from 256 bytes to approximately 1000 bytes. Howard is not aware of any 64/66 patents. There was an assertion that if we go with this unified proposal that the LAN solution would be higher in cost than what could be achieved via other methods. LAN Phy's no not need to use the busy idle rate control.

9. Architecture and Objectives for a HARI PHY

- Presenter: Paul Bottorff (Nortel Networks)
- Time Allocated: 20 minutes
- Start Time: 2:09PM
- Presentation Highlights:
  - Mr. Bottorff converted the Hari model into architectural level diagram. An interesting element of this is the Jitter Buffer (Relay) used to go from the Hari encode to a fiber transceiver encoding. One way to think about this Jitter Buffer is as a translational relay. The relay can be a LAN-to-LAN, WAN-to-WAN, or LAN-to-WAN repeater. Hari has all the design elements of a short distance copper PHY with some compelling positive attributes such as low pin count and long PCB trace lengths. On board chip-to-chip, back-plane, and intra-box connections are the three main applications for a Hari data link. Paul feels a single (1) meter of PCB trace is required for chip-to-chip and back-plane applications.
- Discussion (Q&A):
  - When we say repeater, this is more with regards to FDDI sense as opposed to 802.3 sense. This is a level 1 repeater, not a level 2 repeater.

10. MB810 Applications for HARI Interface

- Presenter: Dae Young Kim (Chungnam National University)
- Time Allocated: 20 minutes
- Start Time: 2:25PM
- Presentation Highlights:
  - Mr. Dae Young Kim's presentation attempts to apply MB810 to Hari. An assertion made was that the Hari interface code virtually dictates the medium line code. There was a suggestion that Hari implementation details are out of scope from the 10 GE standards effort. Dae Young views Hari as a serial version of the XGMII. If Hari is used, Dae Young stated that a PMD, which implements anything other than an 8B/10B line code, as unnecessarily complex. The fact that Hari is getting all the attention over the medium line code is baffling to Dae Young Kim. The MB810 code can be modified to include the same special code words as 8B/10B (K, S, E, and R) and two EOP delimiters (T1 and T2). Summarized by saying Hari is not needed and complicates everything, but if the standards body insist on Hari then the MB810 can also be applied to Hari since it has better sensitivity, less jitter, and requires less bandwidth. Lastly as a compromise the transceiver can be designed to be a dual mode device.
- Discussion (Q&A):
  - No discussion.

11. New Sources of Lane to Lane Skew, and a Proposal for Alignment

- Presenter: Joel Dedrick (AANetcom)
- Time Allocated: 20 minutes
- Start Time: 2:58PM
- Presentation Highlights:
  - Mr. Dedrick started with the previously defined Hari skew budget presented to the HSSG in November 1999 by Rich Taborek. Two sources of skew were not identified in Taborek's budget. First, byte alignment which can introduce 0-9 UI of skew and secondly the clock domain crossing which can add up to 10 UI of additional skew. A revised Hari skew budget shows that the overall skew budget is nearly 2x larger than originally thought, i.e. 37 U.I. 'vs' 20 U.I. This will require an 80-but deskew pattern. Joel suggested a single distinguishable symbol, e.g. /A/ should be used for alignment. The /A/ character could be transmitted once per IPG.
- Discussion (Q&A):
  - Can we look for transitions (e.g. idles to beginning of packet) instead of character to do alignment. Problem is you want to get the channel working before data is sent.

12. Hari Coding Issues & Proposal

- Presenter: Rich Taborek (N Serial Corp.)
- Time Allocated: 40 minutes
- Start Time: 3:06PM
- Presentation Highlights:
  - Mr. Taborek started with yet another view of the scope of Hari. An important point to be made is that the Hari is just a chip-to-chip interface. The benefits are independent jitter budget, low pin count, low power SERDES, 0.25 micron CMOS, etc…..Hari creates three jitter budget domains, i.e. local PCS/PMA to PMD, link medium PMD to PMD, remote PMD to PCS/PMA. Hari enables the PMD to have an optional medium encoding for the various optical link objectives. A mapping of Hari to PAM5x4, 64/66 was shown. Some Hari Idle encoding rules were presented. Rich pointed out a number of Hari issues to be resolved, they are: 1. Usage of 8B/10B, 2. Column 'vs' word stripping, 3. EMI concerns with BW constrained codes, 4. multi-protocol support (e.g. IEEE, InfiniBand, SONET OC-192c), 5. Multi-PMD support, and initialization pattern for deskew/link sync. One of the strongest points suggested for Hari using 8B/10B is simplicity and robustness. Striping came up again, Rich feels that low power can not be achieved with word stripping. A new problem that has surfaced is EMI, however Rich feels that it is solvable by leveraging technology, such as 1394. These Hari, 8B/10B, and column striping decisions need to be made soon so the silicon guys can go off and build solutions. Rich picked a code, i.e. /A/ = /K28.3/ for the alignment code-group.
- Discussion (Q&A):

- Define low power design. It depends on the process used. If you're going to reduce power, attack the device that consumes the maximum amount of power, i.e. the SERDES. The EoS standards effort covers l0 GE plus the lower speed Ethernet. Since there was so much confusion the chair cut this discussion off and kicked off an ad-hoc group to continue with this subject.

13. Break 3:37PM

14. 10GE WAN PHY & EoS

- Presenter: David Martin (Nortel Networks)
- Time Allocated: 45 minutes
- Start Time: 4:14PM
- Presentation Highlights:
  - Mr. Martin's presentation clarifies the differences between the IEEE 10 GE WAN efforts with the standardization efforts underway within the ANSI T1X1.5 EoS committee. If an IEEE WAN PHY were subjected to BellCore compliance testing it would fail. However the IEEE 802.3ae standard will develop a WAN PHY that is compatible with a traditional SONET PHY. The IEEE WAN PHY will be a stripped down version of a SONET PHY, for example it will have only 4 bytes of overhead as opposed to two dozen bytes used in a SONET PHY. The IEEE 10 GE WAN PHY will have a less stringent clock tolerance (+/- 20ppm 'vs' 4ppm), higher jitter tolerance (this allows a higher level of integration, less engineering headaches) and must include lower cost optics. The scope of T1X1.5 EoS applies across all SONET applications. David's reference model shows a WAN-C PHY in a data switch within the enterprise connecting to another WAN-C PHY interface in a carrier class SONET device, in IEEE terms this device is called a repeater. This WAN-C PHY recovers clock/data and does a line decoding to the SONET frame only and adds the additional overhead needed for the wide area. David pointed out some STS-192c Payload header differences between EoS and WAN PHY, for instance the EoS ring application uses the 5 unused byes of preamble and requires an additional 14 bytes currently not used or provisioned for in the WAN PHY application. These additional 14 bytes imply the total overhead per Ethernet frame is 36 percent higher in the EoS case as compared to the IEEE WAN PHY, i.e. 39 bytes 'vs' 53 bytes. The differences between these WAN PHY types became much more apparent when David listed the ingress and egress processing that takes place in a WAN edge device where both PHY types are expected to exist.
- Discussion (Q&A):
  - An observation was made that goes like this, since T1X1.5 is specifying a "pure" 10GE WAN PHY (i.e. EoS) why bother designing a sub-optimal 10 GE WAN PHY in the IEEE committee that would fail the BellCore compliance testing. The ANSI committee is *ONLY* working on SONET, not DWDM optical networks. The 10 GE WAN PHY can be used to tie into DWDM equipment.

15. Considerations on MB810 decoder for 10 GbE

- Presenter: ChanGoo Lee (ETRI)
- Time Allocated: 15 minutes
- Start Time: 8:39am
- Presentation Highlights:
  - Mr. Lee's presentation began with a report of ETRI's FPGA implementation of their MB810 decoder logic; this included bit-by-bit decoder rules. A decoder block diagram was shown, the elements of this decoder block diagram include a XOR logic, combinational logic, control code & RAS,RDS calculation plus control logic that ties these three blocks together. The PCS architecture shown included both MB810 and 8B/10B decode coexistence. MD810 uses the same comma codes as 8B/10B. Mr. Lee concluded by stating the MB810 Decoder can be implemented in simple combinational logic and that the comma words should be the same ones used by 8B/10B.
- Discussion (Q&A):
  - No discussion.

16. MB810 Encoding Method with Control Codes

- Presenter: Heyung Sub Lee (ETRI)
- Time Allocated: 20 minutes
- Start Time: 8:53AM
- Presentation Highlights:
  -
- Discussion (Q&A):
  - No discussion.

17. Error Detectability of MB810

- Presenter: Han Chul Do (ETRI)
- Time Allocated: 15 minutes
- Start Time: 9:09AM
- Presentation Highlights:
  - Mr. Han Chul Do showed how MB810 even and odd states are classified into the BUDA cell stack plane using the RAS (or vertical axis) and RDS (or horizontal axis) coordinates. The analysis presented shows a 2 percent probability of undetected word errors and a rich estimation of error detection capability was highlighted. Point your web browsers to http://ccl.cnu.ac.kr/LineCoding for more information.
- Discussion (Q&A):
  - No discussion.

18. 64b/66b low-overhead coding proposal for serial links

- Presenter: Rick Walter (Agilent Technologies)
- Time Allocated: 30 minutes
- Start Time: 9:20AM
- Presentation Highlights:
  - Mr. Walker did some hamming distance, baseline wander, and scrambler analysis since the last meeting in Hawaii and reported on his latest work on the 64/66 line code at this meeting along with a general overview of the 64/66 code. There are two types of 64/66 frames, each is distinguishable by the first two bits transmitted. The first bits transmitted are '01' for a frame what contains only data codewords, otherwise '10' are the first two bits transmitted for 64/66 frames that contain a mixture of control and data or just control codewords. An 8-bit TYPE field is used to indicate which of the possible eleven (11) different ways a Hari transfer could be done. Recall that there are eight possible packet endings, one pure control, and two possible packet starts. Those Hari transfer types use the TYPE filed. All eleven TYPE bytes have a mutual 4 bit hamming distance. These 8-bit TYPE values have some interesting characteristics, for example the 0xA5 code definition means there are 2 data bytes followed by a trailer (EOP) and then one control character in the first Hari transfer. The second Hari transfer has four control characters. Looking at the high order nibble, 0xA (1010) we see this has even parity so the 2nd nibble will be inverted, or 0x5 (0101). The three least significant bits of the high order nibble tells us there are two data bytes because only the second bit is a '1'. If the most significant bit of the high order nibble is a '1' we know that this 64/66 frame contains a trailer character. The term Z is used for control characters, examples include K, R, and A…. All the possible Hari columns were shown, for example the four EOP combinations. Some modifications to the code were made to account for hamming distance, most importantly the change for a 4 bit hamming protection for packet data. The analysis uncovered that a two bit error in the sync preamble could convert the packet boundary into a data frame. The table that shows the control code mappings was cleaned up to make it simpler. Three different criteria were applied to the code to verify the scrambler selection. Each of these criteria was discussed in detail. The analysis of jamming shows that malicious jamming is not possible, i.e. MTTF(jamming) of 29 years. Two different scrambler polynomials have been identified and one has been chosen, Rick asked for some people in the audience to review this selection. Simulation of a terabit of data shows that a system designed to a tolerance of 2.5% baseline wander will have an error rate of less than 10EE-22 due to wander effects.
- Discussion (Q&A):
  - Rick has not discussed with his legal staff where they are in the patent process, however he feels Agilent If Hari is not used, a similar structure code will give similar low overhead. Rick feels the complexity of the implementation is simple. This code could be used without Hari at the 10 GE GMII interface. Shimon asked the question; what's the probability that at a certain error rate you'd have multiple errors go undetected by the Ethernet

CRC32? Rick had not performed this analysis yet, however he has done the analysis since the January meeting and plans to report on this in March. Shimon stated that in the past for 10M & 100M Ethernet where the 8B/10B code was used, that analysis was extremely difficult. In fact, several mathematicians were hired to do the analysis. Rick's 64/66 code is easier to analyze. This code could be applied to other systems such as Infiband. If we have an error that makes a false termination in the packet, the state machine doesn't know we have an error until the next packet, in this case an implementation would have to have a pipeline process where it could invalidate the packet in the next stage.

19. The Impact of PWB Construction on High-Speed Signals
    - Presenter: Chad Morgan (AMP Circuits & Design)
    - Presenter Contact Info: Chad.morgan@tycoelectronics.com (717) 986-3342
    - Time Allocated: 1 hour
    - Start Time: 10:28AM
    - Presentation Highlights:
        - Mr. Morgan began approximately one year ago looking into dielectric materials, trace geometries, and interconnect structures to see how far FR4 can go for 1-10 gigabit data rates. Trace widths, lengths, impedances were studied. In addition to FR4 they also looked at GETEK, ROGERS 4350, and ARLON CLTE materials. Chad's materials review chart shows relative costs for using the materials; there is a 6.8X delta between the most and least expensive materials. A test board for each material was built and then extensive frequency domain measurements were made, for example dielectric constant and loss tangent. Trace measurements with and without connectors were made, the eye diagrams were shown for these trace measurements for all four materials. The measured eyes correlate well with the simulated eyes. If we stay with the four Hari 3Gb/s lines then we should be OK using any of these materials. The vias and footprints cause problems with traces running at 10 Gb/s, AMP says keep your eyes open for more work they are doing at these speeds.
    - Discussion (Q&A):
        - The rise time for the eye diagrams show was 60ps. When you specify an FR4 material make sure you are specific on the electrical characteristics. The simulation assumptions are indicated in the lower left hand corner of the trace eye patterns, example see page 22 of the pitch. We are now at the point where we need line models when making presentations like this. Chad agreed to help develop these line models, he referred to this exercise as "writing the spec". As we try to push 10 GE do we use FR4 or take a safer path with a more expensive technology with better characteristics? This is a matter of economics.

20. Limits of FR-4 in High-Speed Designs

- Presenter: Ed Sayer (Northeast Systems & Assoc.)
- Time Allocated: 30 minutes
- Start Time: 11:05AM
- Presentation Highlights
  - Mr. Sayer's pitch also focused on the limitations of FR-4 material. FR-4 enjoys 98% market share in PCB fabrication. Ed showed us the total RF transmission line loss equation. Dielectric losses will dominate the total loss. An 8 mil 100 ohm differential PCB line ranging from 10 to 50 inches was used to show peak to peak loss as a function of data rates from 0.5 to 5.0 Gb/s. Then a series of charts to show the same data were presented, for example Loss 'vs' PCB Length that shows a jump in loss after 2 Gb/s. The chart on page 13 shows line sizes of 4, 6, and 8 mils. Each line exhibits losses that are within 10 percent of each other. NGIO has a standard that requires at least 2.5Gbps which requires 8 pairs, we could us this information. Construction and fabrication are the most important things to think about. Properly etched differential pair and over-etched differential pair eye diagrams were shown to emphasize the effects of poor fabrication. The jitter is deterministic and can be compensated for by equalization. The maximum length depends on a number of factors, like devices used (e.g. CMOS), bit rates, reflections, etc.
- Discussion (Q&A):
  - Equalization can be used to open eye diagrams. Ed will include some of the NGIO information that is important to us. Ed will be able to rerun some of the simulations at 3.125 Gb/s for us by this committee and will run this through some connectors to see what the impacts are.

21. 10GbE Feasibility over Twisted Pair Copper

- Presenter: Vivek Telang (Cicada Semiconductor)
- Time Allocated: 30 minutes
- Start Time: 1:10PM
- Presentation Highlights:
  - Mr. Telang discussed the feasibility of transmitting 10 GE over 25 meters of CAT-6 cabling and proposed a line code. This would be viewed as a wiring closet technology for switch to switch interconnections. A strawman line code for 10GE 25 meter UTP PHY was presented, it includes a 17-PAM/4D line code, 625 Mbaud symbol rate, 18-PAM/8D trellis coding and 8 dB of signal to noise margin. This strawman obviously comes with some design challenges, however Vivek feels they can be overcome.
- Discussion (Q&A):
  - The signal thread speed for looking at these line pairs is 625MHz. Another challenge is power consumption. Cat 6 connector losses were included in this analysis. The asynchronous aspects of this have not been considered. Cable dispersive effects are included in the analysis. The impedance of the active sources is important, they transform the level of the pulses transmitted, and these non-linearities are extremely difficult to deal with.

22. Update on Serial PMD Activities

- Presenter: Vipul Bhatt (Finisar)
- Time Allocated: 30 minutes
- Start Time: 1:51PM
- Presentation Highlights:
  - Mr. Vipul's goals for this presentation included a snapshot of where the Serial PMD designers are. Sixteen individuals and companies collaborated on this presentation. The companies include Finisar, Lucent, Agilent, Gore, Intel, New Focus, Tyco, Ortel, Picolight, IBM, Mitsubishi, Infineon, Micrel, Sumitomo, Cielo and Corning. The group is not aware of any shop stopper issues with a Serial PMD implementation. However four (4) design issues were highlighted, they are; link modeling, SerDes data path width, coding for transmission, and Hari interface stripping. The link modeling dove-tails off of the previous 1 GE (802.3z) link model with refinements to laser RIN (relative intensity noise), for example –130dB/Hz for a DFB laser. A lower RIN may require improved laser isolation or increased receiver return loss. The old ISI methods used in 1 GE link modeling will change; now ISI link modeling will also be a function of signal waveform, laser and receiver non-linearities. The serial PMD group does not have an accurate 'k' factor value to accurately predict the mode partition noise (MPN) for 850 nm lasers. Vipul referenced a paper that helps the Serial group deal with the issue of SerDes widths that effect power. The group is keeping the options open on the coding selection, but this appears to be leaning towards 64/66. The group will be verifying models in lab experiments, dealing with RIN adjustments, quantifying jitter and trying to gain some sort of consensus on the striping issues with Hari. Until the 10 GE group achieves consensus on striping, this serial PMD group will be unable to develop Hari prototypes, so lets get on with it!
- Discussion (Q&A):
  - Some items missing from the further work category are DFB lasers. The skew out of the CMOS Hari chips will be a key parameter to study, the Serial group will factor this into their further work items.

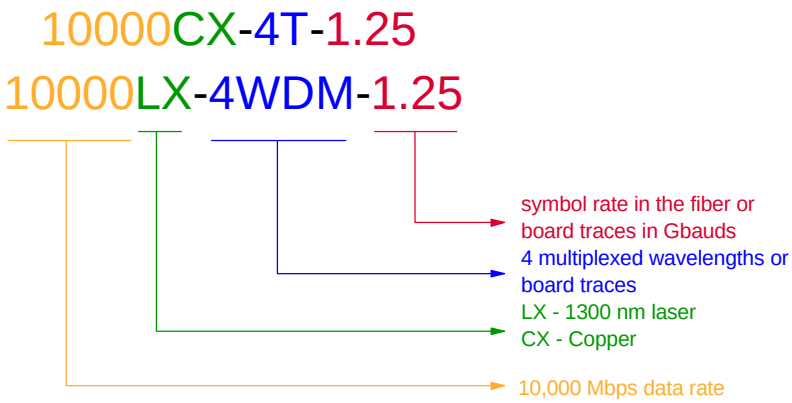
23. MultiLevel MultiChannel PMD Proposal

- Presenter: Rich Taborek (nSerial)
- Time Allocated: 20 minutes
- Start Time: 2:15PM
- Presentation Highlights:
  - Mr. Taborek's claims this new PMD proposal meets or exceeds all HSSG distance objectives. Rich stated this new technology is scalable to 40 Gbps. It uses two WDM channels running at 2.5 Gbaud for a line rate of 10 Gbps. These low channel rates contribute significantly to his assertion of a very low cost solution. This does however come with some risks, for example it's a new technology for optics, will now need a linear TIA. NSerial will be building these types of devices; this is new technology and will take longer to develop than other serial PMD technology.

- Discussion (Q&A):
  - There was some discussion; I was not present in the room when it happened.

24. 10000LX-4WDM-1.25 and 10000CX-4T-1.25 Transceivers

- Presenter: Stefan Wurster (Micro Linear)
- Time Allocated: 15 minutes
- Start Time: 2:27PM
- Presentation Highlights:
  - Mr. Wurster discussed the 10000LX-4WDM-1.25 and 10000CX-4T-1.25 transceiver solutions. Stefan proposed a common nomenclature, see below. Stefan claimed that the lower baud rates of these proposals (i.e. 1.25 Gbaud) would enable the transceivers to transmit over longer distances than the other proposals on the table. Lengths of 300 –500 meters can be achieved from and SNR point of view. The presentation material claims approximately 90 percent of the installed MMF can run at 10GE with link lengths of up to 300



    meters. The solution includes some reuse of prior 1 GE PCS technology. The CX solution is great for backplane runs at a meter or less with current standard layout techniques and PCB materials. By mixing the two technologies one can develop media converters. This technology is already running in simulation and first prototypes are expected by 1Q01.
- Discussion (Q&A):
  - No discussion.

25. 8 Channel VCSEL

- Presenter: Eric Grann (Blaze Net)
- Time Allocated: 30 minutes
- Start Time: 3:48PM
- Presentation Highlights:
  - Mr. Grann's proposal is a CWDM VCSEL based proposal, called 10GBASE-SX8. This is targeted at both the installed base and new MMF, uses 8 FDX channels running at 1.5625 Gb/s. The solution reaches lengths of 200 meters on installed MMF. This is an extremely low cost option. Eric feels this can be accomplish with today's technology. System (MUX / DeMUX) performance results were reported. Wavelength spacing is temperature dependent (i.e.

0.06nm/C), the range is 775 – 865 nm. Extremely low cost (yield 1000s/wafer for pennies) detectors are utilized. These transceivers come in MTRJ, GBIC, and 1x9 styles. One very compelling chart shown was the one with the relative optoelectronics costs.

- Discussion (Q&A):
  - No discussion.

26. 10Gb/s PMD Using PAM-5 Modulation
    - Presenter: Oscar Agazzi (Broadcom)
    - Time Allocated: 30 minutes
    - Start Time: 4:01PM
    - Presentation Highlights:
      - Mr. Agazzi focused on preliminary simulation and modeling results for a 300 meter solution over existing MMF. This PMD uses a 5 Gbaud line rate. A nonlinear equalizer can compensate for laser nonlinearity. The channel model uses a pseudo random model of a PAM-5 symbol generator as opposed to a PCS and a laser model based on the rate equations that are well known, e.g. Marcuse & Lee. This rate equation model was used because it is well known. Exact equations as opposed to approximations were used. The fiber model came from Kaspers. Decision feedback equalization is used to control intersymbol interference . A conceptual receiver model was discussed and Oscar's says that more details on implementation will follow later. The equalizer training process using two level symbols. The next step is to improve the accuracy of the models. During the March plenary Broadcom will also go into details of incorporating the trellis code, plus some measurements and experimental data.
    - Discussion (Q&A):
      - The precision of ADC used in the simulation is 6 bits. The complexity of a 6 bit ADC will be discussed in March. The rise and fall times observed in the laser can be found in the view graph labeled "zoom of modulated laser output". The fiber response may not be gaussian. There is a low pass fiber in the receiver in particular to cover low length fibers.

27. Emerging 10GbE Applications
    - Presenter: George Claseman (Kendin Communications)
    - Time Allocated: 30 minutes
    - Start Time: 4:35PM
    - Presentation Highlights:
      - Mr. Claseman discussed an emerging Ethernet metropolitan area networks application that might use 10 GE as a backbone with inter-connections to residential SOHO for telecommuting, corporate networks, local merchants, video servers for video on demand, local merchants for e-commerce, etc…This network would have FE connections to users. the
    - Discussion (Q&A):
      - No Discussion.

Action Items :

1. Response to ITU Letters
   - The committee was not able to act on this item because no tutorial explaining the implications of the ITU position was presented at this meeting. This will be taken up at the March meeting as an Action Item.

New Business:

1. Procedure for Presentations:
   - Presenter shall request time by Wednesday of the week preceding the presentation from the appropriate chair or sub-chair via direct email or using the reflector. Provide the following information:
     - Name of presenter
     - Title of presentation
     - Length of time requested
     - Brief description of topic.
   - If the schedule is missed, time will be provided on a best-can-do effort following the completion of the regular agenda (or as deemed appropriate by the chair or sub-chair).
2. Procedure for Uploading Presentations to the Web:
   - Presenter shall send a PDF, softcopy version of the presentation to the "Web Master" by Wednesday of the week preceding the presentation for publication to the 802.3 web page.
   - If the schedule is missed, the presenter will be allowed to present only if hard copies of the presentation are made available to the committee members at the beginning of the meeting during "document distribution" and a PDF, softcopy version of the presentation is made available to the "Web Master" prior to the beginning of the talk.
3. Membership on the 802.3ae & HSSG Reflector
   - The 802.3 HSSG Reflector is provided to the members of 802.3ae for the benefit of moving the work of the Task Force (TF) forward. Communications are expected to be respectful, dignified, and germane to the work of the TF. The HSSG reflector is not a "free speech" forum. Subscriptions are granted by the TF to further its purposes and may be revoked for inappropriate communications. These include, but are not limited to: recruiting, advertising, soliciting, spamming, flaming, whining, and disparaging individuals or companies. The chair shall enforce this policy.
4. Reduce the Number of PMD Options
   - The HSSG (802.3ae) shall reduce the number of distinct PMD's being worked on to 7(?) by July 2000 (?) and 3 (?) prior to Working Group Ballot. If possible, fewer are preferred. Criteria 1, 4, and 5 should be applied in the process.
   - PMD (transceiver companies) were asked to come back with a plan for culling the number in March.

Motions:

- **Motion # 1**
  - Description:
    - Adopt long term schedule goals (particularly cut-off dates).
  - Motion Type: Technical > 75% required
  - Time: 8:49 AM
  - Moved By: Bill Quackenbush
  - Seconded By: Tom Dineen
  - Results: Withdrawn
    - There were objections to this motion being technical. There were objections to this motion because this group is just a study group. Per recommendation to not vote on this until the HSSG became the 802.3ae task force, this motion was withdrawn. Both mover and seconder withdrew the motion.

- **Motion # 2**
  - Description:
    - Add to the HSSG (802.3ae) Objectives: "Specify an optional PMD Interface (PMDI)."
  - Motion Type: Technical 75% required
  - Time: 9:01AM
  - Moved By: Jonathan Thatcher
  - Seconded By: Not Seconded
  - Results: There was an objection to this optional interface because we have enough of a challenge with the work in front of us already. With outside consultation, the chair decided that this work was within the scope of the objectives and no motion was needed. The chair requested any motion that might overturn this decision. None was offered.

- **Motion # 3**
  - Description:
    - The IEEE 802.3 HSSG communicates to ISO/IEC SC 25/WG 3 that the passive connection's back reflection values of –20 and –26 dB for the MM and SM optical fiber as specified in the ISO/IEC – 11801: 1995 Standard will meet the requirement of current work for 10 GE.
  - Motion Type: Procedural
  - Time: 9:10 AM
  - Moved By: Tad Szostak
  - Seconded By: Paul Kolesar
  - Results: **Pass** Yes = 44, No = 1, Abstains = 66

This should be an 802 exec action, however Mr. Thompson felt it was appropriate at this time because the SC 25 meeting is in two weeks and the next IEEE Plenary meeting is in March 2000. The intent here is to get a sense within the group if they want the SM back reflection value of –26 dB to change to – 35 dB.

- **Motion # 4**

- Description:
  - Approval of minutes.
- Motion Type: Procedural
- Time: 9:51AM
- Moved By: Tom Dineen
- Seconded By: Bob Grow
- Results: Pass by acclimation

HSSG PHY Spreadsheet:

A total of 62 individuals ranked seventeen (17) 10GE PHY proposals. The top seven PHY proposals are highlighted in green. The spreadsheet below was developed at the Dallas interim meeting and posted to the HSSG reflector by Stefan Wurster from Micro Linear Corp., a few corrections we made. There are several columns that have been omitted, they will be filled in at a later date, they deal with schedule risk, cost, coding assumptions, volume production date, and how the PHY compares to the 5 criteria.

Name	***SMF***	***MMF 62.5um 160MHzkm@850nm 500MHzkm@1300nm***	***New MMF 50um 2200MHzkm@850nm 500MHzkm@1300nm***	***Wave Length***	***Baud Rate***
8λ-WWDM SW		200m		850nm	1.5G
4λ-WWDM-LW	40km	300m		1300nm	3.125G
4λ-WWDM-SW				850nm	3.125G
4λ-WDM PAM5 LW		500m	500m	1300nm	1.25G
4λ-WDM PAM5 SW				850nm	1.25G
PAM5 Serial LW	40km	500m	2km	1300nm	5G
PAM5 Serial SW		160m		850nm	5G
5λ-WDM LW	60km	300m		1300nm	
12-Ch VCSEL SW			225m Ribbon	850nm	
4-Ch VCSEL SW			300m Ribbon	850nm	
2λ-WDM PAM5 LW	40km	1km	1km	1300nm	2.5G
2λ-WDM PAM5 SW		320m	2km	850nm	2.5G
Serial FP LW	2km	85m	85m	1300nm	
Serial DFB LW or VCSEL	10km	85m	85m	1300nm	
Serial Cooled DFB LW	40km	85m	85m	1300nm	
Serial SW		25m	300m	850nm	
Serial LW	40-80km			1550nm	

Name	*Votes of 62 Voters*	*Order of Rating*	*Contact People*	*Company*
8λ-WWDM SW	3	14	Ken Herrity	Blaze
4λ-WWDM-LW	35	4	Del Hanson	HP
4λ-WWDM-SW	6	12		
4λ-WDM PAM5 LW	5	13	Stefan Wurster Jaime Kardontchik	Micro Linear
4λ-WDM PAM5 SW	3	14	Stefan Wurster Jaime Kardontchik	Micro Linear
PAM5 Serial LW	13	8	Oscar Agazzi	Broadcom
PAM5 Serial SW	10	9	Rich Taborek	nSerial
5λ-WDM LW	7	11		
12-Ch VCSEL SW	3	14	Mark Donhowe	Gore
4-Ch VCSEL SW	14	7	Mark Donhowe	
2λ-WDM PAM5 LW	9	10	Rich Taborek	nSerial
2λ-WDM PAM5 SW	3	14	Rich Taborek	NSerial
Serial FP LW	41	2	Vipul Bhatt	Finisar
Serial DFB LW or VCSEL	52	1	Vipul Bhatt	Finisar
Serial Cooled DFB LW	25	5	Vipul Bhatt	Finisar
Serial SW	38	3	Vipul Bhatt	Finisar
Serial LW	22	6	Vipul Bhatt	Finisar

York, UK (9/99) 10 GE PHY Evaluation Criteria:

- Rate ability to meet the broadest set of applications & distance/fiber type objectives
- A working prototype of a PHY is available by completion of Sponsor Ballot (meets MDI specs)
- Relative cost comparison - short/long term
- Qualitative Reliability (e.g. MTBF, etc.)
- Time to standardization, Time to market
- Multiple vendor supply available by completion of Sponsor Ballot