IEEE 802.3 - 10G over FDDI Grade MMF
Study Group Minutes, Vancouver BC
Jan 13 - 14, 2004
John George

Day 1 – January 13

Bruce Tolley opened the meeting at 8:30 am. Introductions were made of all in the room. About 65 were in attendance.

Reference January 2004 SG Contributions at:

http://grouper.ieee.org/groups/802/3/10GMMFSG/public/jan04/index.html

Study Group Business

Agenda and Study Group Overview (tolley_1_04)

IEEE Process Overview

- Bruce noted that there were several new members of the group and provided an overview of the 802.3 ground rules
- Suggested possible interim meeting adjacent to OFC. (Later determined this was not required)
- Bruce moved to approve the agenda. Approved by acclamation.

802.3 Chair comments – Bob Grow

- Purpose of SG is to create PAR and 5 criteria.
- Charter for SG must be renewed in March.
- IEEE policy is 6 month maximum for SG, PAR and 5 criteria. Proposal to 802.3 and SEC must be submitted by July.
- Decision at the November closing plenary to acknowledge a call to the question while a queue formed to debate the motion to form this SG was not in the spirit of IEEE operating procedures, and stated (paraphrased) that he intended to operate future 802.3 meetings in the spirit of the operating procedures.
- The par must specifically justify that the distinct identity requirement is satisfied relative to the existing 10GBASE-LX4 PMD.

Call for Patents

- David Law reviewed the IEEE patent policy shown on 2 slides titled “IEEE-SA Standards Board Bylaws on Patents in Standards” and ‘Inappropriate Topics for IEEE WG Meetings” at www.ieee802.org/3/patent.html
- Bruce Tolley made the call for patents and there were no declarations.

Study Group Contributions

10GB/s on FDDI-grade MMF cable Straw Man Objectives – John Ewen (ewen_2_0104)

Ewen listed for discussion straw man objectives shown in his contribution.

Comments/Q&A

- Why not support EFM OAM unidirectional operation or EFM extended temperature range options? Presenter clarified that this is only a straw man and may be modified.
- Presenter acknowledged that 95% support for 300 meters is a radical departure from the 99% or better for existing 802.3 PMDs.
- Bob Grow comment - 95% will say to many members of 802.3 that “this is not plug and play”.
- Steve Swanson – FDDI grade MMF should be defined as OM-1.
- Bruce Tolley– must define media in more detail.

Par Discussion Slides (jaeger_1_0104)

Jaeger proposed listed for discussion PAR title, scope, and purpose shown in his contribution.

Floor Comments/Q&A

- Bob Grow - PAR should state that this project will be written for the current revision of 802.3.
- Floor comment: In purpose, may need to state lower cost is relative to LX4.
- Floor question: Should SM be supported to 10KM as with LX4? Response: Group might revisit.

5 Criteria Discussion Slides (jaeger_1_0104)

Jaeger proposed for discussion 5 criteria shown in his contribution.

Floor Comments/Q&A

- This PMD could be distinct in that it could be written to not require a mode conditioning patch cord.
- Mode conditioning native launch will eliminate singlemode support.
    - Bob Grow - Will carry little weight with 802.3 since LX4 objective was to operate over MMF.
- Compatible with XFP MSA.

Building the Business Case (babla_1_0104)

Babla emphasized that success of 10G over FDDI MMF PHY is highly dependent on achieving Economic Feasibility (EF) and Broad Market Potential (BMP). The SG should validate BMP by understanding customer link yield vs. distance using an agreed upon channel model. EF should be analyzed by understanding PHY cost

elements relative to LR and LX4, new fiber vs. new PHY cost, and effect of volumes on cost for each option.

Users Perspective – Mike Bennett (Bennett_1_0104)

There is a void in 10 GbE solution set. Even though a PMD was specified we don't have a MMF choice that works on the installed base. IT budgets are no longer blank checks. We need low cost choices for optical 10 GbE. Specifying a MMF solution that will operate on 300m of FDDI grade fiber will enable end users to save money on infrastructure. LBLs network consists of 3048 MMFs, most of which are >12 years old and were measured to be DMD challenged.

Floor Comments/Q&A

- Length distribution? – 50% >300m since much of fiber is building to building up to 2 KM
- 1300 nm bandwidth is 400 or 500 MHz-km
- Majority of fibers installed prior to 1992.
- What if reach was 250m? (Dave Cunningham). Response: Would still be happy.
- Should new standard be written to support cable that is "so old"? Willing to buy new fiber if cost of PMD over installed fiber is excessive.
- When is this needed? ~ 2 year timeframe
- Is a 220m solution viable? Would be OK.
- Do cable runs have mixture of SM and MM? Yes, but use SX on MM when possible.
- Lobbies to install hybrid cables.
- Comment: LX4 modules are shipping. Response: Have not been looking for LX4 recently.
- Budget for cable upgrades available in large chunks every 8 – 10 years. Latest "chunk" being used for copper upgrade.
- How does LBL installed base compare to others in the world? LBL is worst of the three national labs (Sandia and LLM other two labs).
- Are all 3048 being used? No, and the ones MBI measured are inactive fibers.
- Fraction of installed base using 10G Ethernet? None on MMF.

Lessons from Gigabit Ethernet – David Cunningham (Cunningham_1_0104)

One Gigabit Ethernet lessons

In Gigabit Modal bandwidth investigation up to 30 percent of multimode fibers were observed to have bandwidth less than 500 MHz.km for operation at long wavelength with near core center restricted-mode launches. Offset Single mode Launch (OSL) is required to satisfy the IEEE 802.3 WG requirement that 99% of 62 MMF support an operating range of 550 m (for GbE). If OSL is not used it was recognized that many links will still operate to ranges of 550 m but the failure rate will be much greater than 1%. With OSL D5 of the GbE standard was produced, accepted by IEEE 802.3 and it became the GbE standard.

10 GbE FDDI Recommendations

OSL is recommended, or an equivalent TIA encircled flux specification (the TIA has done great work in this area). This committee will need to study and define launch conditions. Both static and dynamic tests (shakers with defined points of mode selective loss are absolutely required for BER, IPR, FRS and modal noise specification. So far very few dynamic measurements or simulations have been reported. Static results are necessary but are insufficient! We need a common terminology for simulations and measurements of the power penalty or allocation for equalized links (and other proposed techniques too). We need a clear technical definition for the installed cables we are to operate over and a statistical definition of cable parameters. DMD seems to be the most succinct and relevant parameter. We should define test cables for lab testing and decide if we should perform field-testing.

A requirement for 99% coverage at 300 m will force the wrong tradeoff and increase complexity, increase cost, severely limit implementation scope and push the standard out of Ethernet's economic sweet spot. Recommend 220m @ 99% probability. Power budget should be 10 dB, with 7.5 for equalizer, 1.8 CH IL, 0.7 MN and RIN same as LR, not low cost.

Floor Comments/Q&A

- Level of effort to get initial definition of installed cable plant? Take data from MBI, which has >8 year old cables. Go to sites to measure and verify modeling.
- 850 nm distance? 100m on 62.5, 220m on 50, 600m on new 50 micron.
- Compliance test for MSL of receiver? No, but should be taken into consideration if MSL> ~2dB. May need max MSL specification.
- Difference of 220m vs. 300m costs? 300m power penalty very large, optics precision increased, equalizer complexity increased. 220m should be absolute lower bound due to existence proof of 1000BASE-SX.
- Launch condition of 50 vs. 62.5? May be able to have one "compromise" launch condition since 50 and 62.5 OSL are different, but would introduce additional penalty and reduce distance.

Multimode fiber link model for 1300 nm equalized links (John Ewen for Petar Pepeljugowski (Pepeljugowski_1_0104)

John reviewed the IBM (TIA FO) link model and simulation results for equalized links. His prediction for EDC is an improvement factor of 2 – 2.5 for practical equalizer designs. This due in part to the following: Wide variation in impulse response possible from a single fiber as a function of launch condition. Wide variation within tolerance specification of mode conditioning patch cord causes significant variation in launch conditions. Mode mixing such as at connectors can have significant effect on bandwidth (and possible impulse response), even in cases without mode selective loss that result in modal noise. There is significant precursor or postcursor ISI depending on launch condition. Typical fiber performance metrics offer little insight, with questionable correlation between OFL bandwidth & DMD to impulse response.

Floor Comments/Q&A

- Slide 30 – what type of fiber and WL to reach > 1KM? OM-3 and 850 nm.
- Ask Petar if he will make simulation tool available for group. Will possibly make Excel model available with shared libraries.

- Could one get to 4X distance? David Cunningham says virtually impossible, 2 – 2.5X realistic. What is in this presentation does not include dynamic effects, and is optimistic.

Multimode Fiber Channel Modeling – Ingham, Penty and White (penty_1_0104)

Richard Penty presented for Cambridge University. He recapped the MBI work that led to the offset launch spec and showed how it could be extended to predict the supportable length yield for the installed base. A Statistical "81 fiber" model compared with IEEE 802.3z MBI field trial fibers with good agreement in terms of DMD/bandwidth distributions between the two fiber populations. The 81 fibers are representative of "worst case" field fibers. The model was extended to 10 Gb/s system modeling, including noise effects and predict 99% yield length of ~85m for SR and ~100m for LR on the installed base. The model is easily extendable for incorporation of new PHYs. (see Cambridge's PHY talk)

Floor Comments/Q&A

- Is the assumption that the "other 95% of fibers" (the non-worst case) too optimistic? Won't some of the 95% will also fail? Yes, and actual failure rate (slide 33) may be ~98% for 110m.
- How was it determined that 2 ns/km of DMD represents worst 5%? Fiber manufacturers statements that this was 2sigma point in the distribution. Not cast in stone, may have to re-visit. This was why work was done on Peak-to-Peak ROFL measurements.
- Is time variation included? No, this is a static model.
- Will 81 fiber impulse responses be made available? Willing to put propagation delays and field distributions for the 81 fibers on the web. Can construct impulse responses from that information.
- Why is the assumption on alpha shift always in the same place, at 15 microns? Were shifts at other offsets examined? Yes, with minimal effect on the results.

Parametric Characterization and Channel Models for Worst-case MMF Channels & Applications - Venu Balasubramonian (Balasubramonian_1_0104)

Venu presented on a technique for generating stressed receive signals for qualifying EDC receivers. Observations were that a tap spacing of 1/3 symbol period provides sufficient time resolution of worst-case MMF channels. There is no need to use smaller tap spacing. An 8-tap FIR provides adequate realization of worst-case MMF channels. Further improved performance is possible with cascading a LPF with appropriate bandwidth and rolloff order or increasing the number of taps to 12-16. From complexity/MMF coverage standpoint it is recommended to use a LPF with 3 dB bandwidth ~1.5 to 2 GHz with a small number of taps (~8 taps).

He concluded that further evaluations of worst-case MMF channel models should be constrained within a simple framework of simple signal processing blocks. An FIR filter with ~8 taps with ½ symbol spacing cascaded with a LPF should be sufficient. Varying FIR tap coefficients from 1 configuration to another configuration over a certain time period can easily capture time-varying channel effects due to modal noise.

Floor Comments/Q&A

- If you build certain response for one type equalizer to work with, how can the response be assured to work with other types of equalizers? This is just an example. Other types of equalizers can be modeled with this approach.

MMF Modeling for Designing 10 GbE MMF Link - Katsumi Uesaka (Uesaka_1_0104)

MMF impulse response has been modeled by taking into account the variation of refractive index profile of actual MMF. Simulation results of eye-diagram after MMF transmission using calculated MMF impulse response show good agreement with experimental results. Calculated MMF impulse response can be used for the validation of EDC performance. Can model "worst case"MMF impulse response for designing 10G, MMF link. Impulse response modeled on actual 62.5 micron fiber with small center dip in refractive index profile showed large variation in response as function of launch offset.

Floor Comments/Q&A

- Fiber had 1 GHz-km of bandwidth? Yes.

The Ethernet Link Model – Piers Dawe (dawe_1_0104)

Piers reviewed the spreadsheet link model used by 802.3 for standards including Gigabit and Ten Gigabit Ethernet and EFM.

The advantages of Ethernet link model of Ethernet link model are that is mostly trusted and familiar, and seen mostly as official. The source code can be inspected and it is clean, not over complicated, but growing. It is fit for it's purpose, (1/10 Ethernets), and each physical effect can be turned on or off independently. Disadvantages of Ethernet link model of Ethernet link model for this project are the following: All bandwidth, rise time, DMD effects are modeled as Gaussian rise times. It is too simple for the variety of impulse responses we see with MMF and does not consider the variety of equalized response shapes. It assumes fixed input-referred receiver noise set by basic receiver sensitivity and BER limits, while equalizing receiver noise can vary. The bandwidth penalty (Pisi) goes to infinity in area of interest. Accuracy of the model may be spurious and some areas need experimental verification.

The Ethernet link model might be extended to this project with the following evolution. It would have to address variety of pulse shapes, though variety is not good for a quick, portable model. If we knew what the few "worst" case(s) were, we could revisit the Gaussian pulse-shape assumption. It would need to address variable input-referred receiver noise, which seems feasible when we know how it varies! Can work on an alternative Pisi definition if necessary. May also wish to the Modal Noise calculation if it becomes significant.

The model is related to other items that must be considered for it's use for this project: The measured vs. modeled results for the channel (fiber) and any associated specification limit. The signal at input to receiver created by the stressed eye

generator, test procedures, New information or theories regarding noises or equalization, etc. Terminology and definitions must also be considered, for example that for ISI penalty with an equalizing receiver, or a good metric of channel response?

Floor Comments/Q&A

- What should be the approach with this model? Should evolve this model over the course of the project to be set the demarcation for specifications.
- What is the starting point to get to a model? Need point models that may each address different scenarios. Once results in point models get to boundary conditions, include in model as a power penalty.

Link Considerations for MMF Links at 10Gb/s – Stefano Bottacchi (bottachi_1_0104)

Bottacchi presented on Link Considerations of MMF Links at 10Gb/s. Suggested that one needs to improve the transmitter launch power to –5 dBm (from-8.5) and the min Ext Ratio from –3.5 to 6 dB. Also increase Rx BW to 15 GHz min. Rise time to < 30 ps. ROSA needs a linearity requirement added. ROSA should have flat noise density so as minimize EDC noise enhancement effects.

Floor Comments/Q&A

- How can we balance your stated need to improve laser and receiver specifications with lower cost? These tighter specifications may be required to support 300 meters, need balance between cost and reach.
- Comment: We do not need to increase power budget for EDC vs. 10GBASE-LR since it must account for 5.5 dB of Ch IL, vs only about 2 dB for 300 m MMF plus connectors. Presenter said power budget relative to SR budget of ~7.3 dB needs to be increased. Commenter stated power budget needs to account for large amounts of jitter and must increased. Specific numbers will be discussed tomorrow.
- Test point interface/specifications between ROSA and EDC may need to be specified.
- Equalizer with FFE in front of DFE will not enhance/increase noise.
- Are these specifications accounting for use on SMF? Has only focused on 300m MMF to date, maybe SMF operation could be supported.

Optically Mode Filtered PHY Testing for 10GE 300m FDDI Fiber Transmission - Peter Hallemeier (hallemeier_2_0104)

Peter presented optically mode-filtered PMD testing. Modal noise can be reduced by Tx design, launch profile, and output mode filter. Used fundamental mode launch and filter. Experimentally determined a 6 dB MN penalty using fiber shaker and thermal cycling. Proposed using this technique in combination with EDC to achieve 300m target. Transmitter similar to DFB to reduce spectral generation of MN.

Floor Comments/Q&A

- 300m with mode filter on transmitter or receiver? Both

- Does this work only with a single transverse mode laser? Not necessarily.
- Receive filtering appears to require singlemode tolerance? Not clear until channel model is completed, looking at +/-4 um tolerances.
- Experiments here did require singlemode tolerance launch +/-1 or 2 microns. May need singlemode tolerance connectors on launch end to keep mode power in center of fiber.
- What about cladding modes in ROSA fiber stub filter? Did not know answer, has to check.
- At each connector junction, power lost, plus loss at ROSA.
- Can this be made adaptive? Cost prohibitive, would need active imaging system.
- GbE model did not study MSL for a receiver fundamental mode filter, needs to be studied for this approach.
- Transmitter sweet spot that works with all fibers? Worst case is with center dip profile. Work to date is with SM launch, which may end up being most economical, but other launches may also work.

Modal noise considerations for 10GE FDDI Fiber Transmission - Peter Hallemeier, Optium (hallemeier_1_0104)

The following must be considered to bound the modal noise in the channel: Temporal mode propagation variations caused by channel environmental effects. Mode Selective Loss (MSL) accumulation in the channel resulting from any MSL contributing effect. (The Effective MSL will depend on the mode field at the MSL point so the MSL can be reduced with restricted launch). MSL points include connector junction offsets, or fiber defects. The SG needs to work on bounding the modal noise generation in the channel model.

Effect of Launch Conditions on Bandwidth of TIA 12/96 Round Robin Fibers – Jonathan King, Big Bear Networks. (king_1_0104)

King presented on the effects of launch conditions on the TIA 12/96 fiber set. Shows that offset launch is better than center launch from a stability perspective, with offset launch resulting in negligible temporal wander, vs. 200 ps for center launch resulting from slight mechanical perturbation of input connector or fiber.

- No questions or comments

MMF Channel Characteristics – John Ewen (ewen_1_0104)

John showed variation with different offset launch patch cords, which was due to small shifts in the offset picking up different mode groups in the fiber. Favors using a restricted radial range for DMD that corresponds to the launch we may use.

A wide variation in impulse response is possible from a single fiber. There is a wide variation of impulse response within tolerance specification of MCP. Mode mixing at connections can have significant effect on BW. Bandwidth is not a useful performance metric since details of the impulse response determine actual performance. DMD is not a useful performance metric because scanning across the entire core of the fiber not representative of expected launch conditions. “Controlling” the channel response seems impractical since almost any mode power distribution (MPD) seems possible with reasonable tolerances on launch conditions. Channel model requirements should assume “worst case” MPD and will depend on proposed

solutions. Proposed identifying simple channel metrics, e.g. “restricted” DMD, i.e. time extent of impulse response for defined launch (with tolerance)

Floor Comments/Q&A

- Were the modes excited by the OSL patch cord those that the DMD plot showed to be split pulse? Yes.
- OSL does reduce the interval between split pulses by avoiding high center DMD.
- Seems to be contradiction as to if DMD is useful performance metric wrt EDC. John clarified that restricted radial range DMD measurements that do not extend to the core/cladding boundary are useful.

10GBit/s Pulse Response of Multimode Fiber Simulation and Measurements - S. Bottacchi (Bottacchi_2_0104)

Mr. Bottacchi showed 10G pulse response of MMF, both simulation and experimental. Showed that pulse response could change remarkably with small changes in offset launch position and by mechanical disturbances of the fibers. The basic pulse shapes pre-pulse, after-pulse and double pulse are demonstrated by using simple two-exponent refractive index profiles. Offset launch condition defined in GbE should exceed the specified fiber bandwidth in most cases but it cannot be guaranteed. Small variations of 2-3µm of the offset can cause significant change in pulse response. Pulse shape can vary if the power distribution in the fiber is changing (e.g. by change of fiber bending) Experiments confirm the pulse shape simulations.

Floor Comments/Q&A

- At what point in the simulated fiber was the alpha shift inserted? Between 25 and 40 microns (he probably meant 12.5 to 20 microns).
- No big differences in results between externally and directly modulated DFBs.
- No mode mixer was used.

FO-4.2.1 Support for Dispersion Compensation – Jim Tatum for Petar Plenius (plenuis_1_0104)

Jim presented for the TIA FO4.2.1 on the ability of TIA to contribute to MMF solutions. F04.2.1 has track record of contributions and standards related to characterization of

- Is F0-4.2.1 volunteering? Will accept the help, thank you for volunteering.

Day 2 – January 14, 2004

Meeting Resumed at 8:30. About 65 were in attendance.

An Overview of Techniques for EDC for 10 Gb/s over FDDI Grade MMF – Paul Voois, Sudeep Bhoja (bhoja_2_0104)

Showed the performance trade-offs in terms of power penalty for several different types of EDCs for three cases of MMF channel response.
Conclusions:

EDC significantly reduces the ISI penalty caused by fiber dispersion. EDC reduces the slope of the power penalty vs. fiber length curve, allowing more flexibility in formulating the link budget (i.e. ISI power penalty is "well-behaved"). Blind adaptation eliminates need for training sequence. No protocol change/bit-rate change required. Low power solutions compatible with XFP are feasible with today's state-of-the-art technology. EDC relies on proven Signal Processing technology, already in wide commercial use in wireless, 1000Base-T, disk drive read channel, and many other applications.

Floor Comments/Q&A

- Speed of adaptation for EDC is 1 KHz rate.
- ADC can be absorbed into feed forward function.
- Well-designed EDC must detect energy of largest amplitude pulse.
- With NRZ transmission some relaxation of optical specifications is possible.
- Do not want to train equalizer with echo present.
- Impulse responses were measured without OSL using ROFL for two of the fibers and OFL for the third fiber.
- Relative power consumption in descending order: MLSD, DFE, FFE, can work with XFP.
- Impulse response scaled linearly to 300 meters, an approximation.
- Fibers with OFL <500 MHz-km excluded. Are not suggesting that the group should use these three fibers as representing worst case.
- Regardless of channel configuration expect power penalty performance to be MLSD, DFE, FFE is ascending order of increasing penalty

MMF Pulse Response and Impact on EDC – Peter Popescu, Quake (popescu_1_0104)

Mr. Popescu showed the relative cost and power dissipation for properly equalizing different types of MMF channel response. A variation of a factor of 3 in power and factor of 2 in cost spanned the various cases.

Floor Comments/Q&A

- 300 meter MMF length assumed
- Steep ramp in group 2 vs. group 3 power dissipation results from additional stages in a linear plus DFE architecture.
- Green impulse response waveform in fiber group 3, assuming LMS algorithm, can cause EDC to jump from pulse to pulse.
- The test methodology accounts for fiber response change with environmental effects up to 10 KHz.

Equalizer Simulation Results for 10 Gb/s MMF Channels - Sudeep Bhoja, Big Bear Networks, (bhoja_1_0104)

Mr. Bhoja showed that 300 m coverage of 99% of all national labs fiber that met 500 MHz-km OFL would be possible with about 7 dB of implementation penalty using a FFE plus DFE equalizer (20 tap FFE T/2 and 4 DFE taps).

Floor Comments/Q&A

- 100 Hz – 1 KHz dynamic tracking performance at 1 KHz may need to be revised to include higher frequencies.
- Did not want to make projection of power dissipation at this time.
- <500 MHz-km fibers might be accommodated with more taps, increasing complexity.
- With 7 dB power penalty can approach 100% coverage of measured fibers.
- 7 dB EDC penalty is just for eye closure. No analysis of jitter in this presentation.

EDC Performance Bounding Limits – Roland Penty, Cambridge University (penty_2_0104)

Penty showed the limits of EDC and compared results to the Pepeljugoski publication. GbE statistical "worst-case" model was reviewed and extended to 10 G EDC, including noise effects. The DMD scaling technique appears reasonable. Showed general agreement with published experiments. The extended model allows different EDC approaches to be easily investigated. FFE and DFE implementations appear valid. Preliminary indication of benefit of EDC for 10.51875 Gb/s over 62.5-µm MMF at 1300 nm is achievable link length increase by a factor ~ 2 for 99% link yield. Precise EDC yield curves will be implementation specific.

Penty proposed working with the Ethernet standards body to develop a statistical fiber model for EDC-enabled 10GbE links. Once the model is agreed, the standards group would need to provide a set of corner-case impulse responses for input into simulations to enable estimation of theoretical performance of different classes of EDC. Also proposed to investigate the development of a "worst-case" spreadsheet based on 10GbE spreadsheet and power-budget model for EDC-enabled links

Floor Comments/Q&A

- Slide 17 shows 95% of conventional fiber will support 300 meter, and Roland said model inaccurate at 5% failure rate, that 5% should be viewed as unacceptable, while model is accurate at 1 – 2% failure rates
- Factor of 2 to 2.5 increase at 99% failure rate translates to about 200m at 4 dB allowed penalty.
- This analysis assumes 1 tap per bit period.
- Can provide offset launch impulse responses for the 81 fibers with 3 launch conditions (17, 20, and 23 microns)

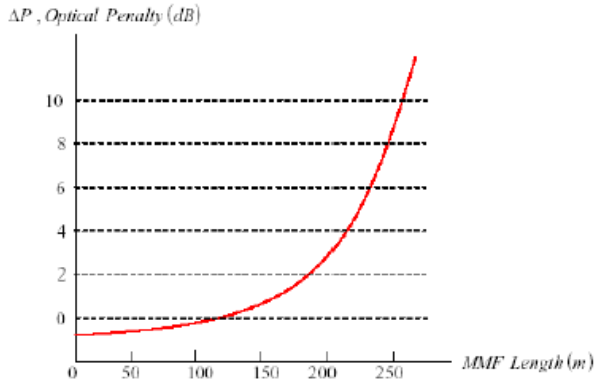
Mixed Signal EDC – Andrew Baek, Independent (baek_1_0104)

Mixed signal architecture provides practical solution for 10G optical link, and consists of analog feed forward transversal filter with digital look up table feedback. Digital control compensates for non-ideal analog circuits. Clock is recovered after the forward transversal filter for robust convergence. System simulations demonstrate excellent performance. Implementation architectures realizable in 0.18 um CMOS technology with power estimate below 1 Watt.

- No questions or comments

EDC Performance Evaluation Proposal – Steffano Bottachi (bottachi_3_0104)

The final plot gives a quantitative criterion for evaluating the performances of EDC based optical receiver over MMF link.



The proposed evaluation procedure for EDC based optical receiver serves as a common reference test in order to align compensation performances through different EDC architectures and technologies. The optical transmission system is not a digital system and it cannot be evaluated assuming only digital interfaces and tool characteristics of conventional DSP.

In order to have quantitative link length extension or improved link margin, it is not sufficient to evaluate EDC performance just in terms of eye closure reduction. Since EDC works between optical front-end and clock recovery, its frequency response during adaptive equalization changes the noise bandwidth of the whole optical receiver and this affects signal to noise ratio and related BER performances.

Floor Comments/Q&A

- Need to transmission performance with and without EDC to determine figure of merit for EDC component qualification.
- Physical effects that will cause BER floor in tested system may be jitter, modal noise, or RIN.

Using EDC to Relax Component Specifications – Paul Voois ClariPhy, Ed Cornejo, OpNext, (voois_1_0104)

Paul and Ed presented on the trade off of adding EDC to relax component specifications. Ed raised options on driving to lower cost. His means were: MM launch conditions, coding scheme, Tx rise and fall times. Paul focused on PAM-4 modulation (4 levels, 2 symbols per bit, half the baud rate). He projected that this modulation would improve power penalty by about 5 dB at 300 m on a minimally compliant (by 500 MHz-km OFL BW metric) MMF.

Floor Comments/Q&A

- Cost of LR + EDC could be reduced by leveraging LR volumes, but would not achieve step function reduction.
- Correction: Optimal offsets are 13 +/-3 for 50 micron and 20 +/- 3 micron for 62.5
- With common offset for 50 and 62.5, supportable link length would be reduced by
- 20% or more.
- Transmitter must be more linear than for NRZ to support multilevel modulation.
- This work needs to explore channel responses other than Gaussian.
- Cunningham: Analysis is very optimistic since ideal assumptions made are very favorable relative to practical implementations. For example low rise time transmitters will cause eye compression, requiring a very good EDC.
- RIN not included in model. (Reference presentation by Cunningham in 802.3ae archives).
- A fast laser is more linear than a slow laser.
- Voois responded that even if all the penalty improvement is wiped out, EDC might still offer a way to cost reduced TOSA and ROSA.

Differential Modal Dispersion Emulator for 10 Gb/s MMF Links - Peter Kirkpatrick, Intel (Kirkpatrick_1_0104)

Kirkpatrick presented on a DMD emulator for MMF links built from a parallel arrangement of SMF with variable attenuations (weights) and delays (lengths). Could be used as a means to stress the EDC receiver.

Floor Comments/Q&A

- Does not capture modal noise effects
- Benefit of this test methodology in optical domain is can test receiver front end along with EDC.
- Testing in optical domain does not include electrical transmit noise.

Design Considerations of Compliance Testing of EDC Receivers – Tom Lindsay, ClariPhy, and Viphul Bhatt, Independent (bhatt_1_0104)

Reiewed the presentation from 10GbE prior study group. EDC implementations need to be tested with jittered signal because they show widely varying response to it. It is critical to include jitter in the compliance test because EDC implementations can show wide-ranging sensitivity to it. Link jitter terms should consider dispersion and noise sources. Depending on implementation of the filter and noise source, their effects may already be included. Clock jitter tends to be band-limited. Should we include some DCD? It may even be necessary to test an EDC's ability to track wander (low frequency jitter). Fortunately, group can piggyback on much of the work done for stressed eye sensitivity test.

- No questions or comments

Evaluating EDC Compliance in MMF Channels – Abhijit Phanse, Scintera Networks (phanse_2_0104)

Abhijit believes we'll need a small suite of worst-case channel characteristics. Need to test Rx linearity. The test input that matters is the impulse response of the channel, not BW or DMD. Proposed normative and informative compliance tests. Normative for the Rx and Tx, but informative for the ROSA, EDC/Phy. The informative parts were intended not to be requirements at the module of system vendor level, but rather tests for the components that go into the transceiver.

Objective Review and Voting/Straw Polls – Bruce Tolley, SG Chair, Cisco (tolley_2_0104)

- If PAR, objectives and 5 criteria agreed upon today, the SG can request PAR approval in March. If such are agreed upon in at an interim meeting prior to July, the SG can request PAR approval in March.

Draft PAR, Objectives, and 5 Criteria resulting from the motions passed below are documented in the following:

http://grouper.ieee.org/groups/802/3/10GMMFSG/draft_par_0104.pdf
http://grouper.ieee.org/groups/802/3/10GMMFSG/objectives_0104.pdf
http://grouper.ieee.org/groups/802/3/10GMMFSG/5_criteria_1_0104.pdf

The motions and associated discussions follow.

Straw man Proposals for Objective- John Ewen, IBM (ewen_3_0104)

Considerations for using existing 10GBASE-R PCS

- If there is need for training sequences and existing 10GBASE-R PCS is adopted, objective may have to be changed.

Objective Motions

Motion #	**1**		75% technical	
Move that the 10Gbs on FDDI Grade MMF Study Group accept the following objective: Use the existing 10GBASE-R PCS.				
Moved	**J. Ewen**			
Seconded	**A Ghiasi**			
	Yes	**No**	**Abstain**	**Result**
SG	**47**	**1**	**7**	**Pass**
802.3	**6**	**1**	**4**	**Pass**

After motion 1 was passed, the question was asked which class of voters counted. The Chair stated that SG vote of the entire room would determine the outcome of all motions during this SG meeting. The Chair clarified that the IEEE 802.3 voters were being polled to gauge whether there might be a problem with the motion from an IEEE 802.3 point of view that the study group might need to address.

Motion 1 Discussion:

- Paul Kolesar, Avaya: Is 64/66B Encoding required with this PMD?
  Richard Dugan, Agilent: No, but leverages existing PMDs.
- Norm Swenson, ClariPhy: Do not want to rule out other PCS possibilities this early in process.
- Lew Aronsen, Finisar: Should stick with this objective. If not, this process over since must work with existing slots.
- Ali Ghiasi: Agrees with Lew
- John Jaeger, Big Bear: Can change objectives if needed, so supports the motion.
- David Cunningham, Agilent: Will not need to change 10GBASE-R PCS for XFP.
- Petre Popescu, Quake Technologies: Supports the motion

Motion #	**2**		75% technical	
Move that the 10Gbs on FDDI Grade MMF Study Group accept the following objective: Support a BER of Better than 10 –12.				
Moved	**J. Ewen**			
Seconded	**T. Lindsay**			
	Yes	**No**	**Abstain**	**Result**
SG	**62**	**0**	**0**	**Pass**
802.3	**12**	**0**	**0**	

Friendly amendment	**Paul Kolesar**	
Add "and media" after "all supported distances"		
Moved	**J. Ewen - Friendly**	
Seconded	**T. Lindsay - Friendly**	

Friendly amendment	**Daving Cunningham**	
Remove: "at all supported distances and media"		
Moved	**J. Ewen - Friendly**	
Seconded	**T. Lindsay - Friendly**	

Motion 2 Discussion:

- David Cunningham: Wording of "at all supported distances and media" is extraneous, and distances and media are defined by other objectives.

- Norm. ClariPhy: For 1000BASE-T for example, objective stated was BER or 10 – 10 with no mention of distance or media

Question Called by Richard Dugan

Media types supported – John Jaeger, Big Bear Networks

- No ISO Specification for 160/500 MHz-km 62.5 micron MMF.
- IEC 60793-2 is reference for several 802.3 PMDs including 10GBASE-LR and LX4.
- IEC 60793-2 specifies ranges of minimum bandwidth specifications for 62.5 and 50 micron fibers, including 160/500 MHz-km 62.5 micron fiber
- 1G Ethernet specifies 160/500 and 200/500 62.5 micron, and 400/400 and 500/500 MHz-km 50 micron

Proposed supported media for discussion

62.5 Micron
- 160/500 MHz-km (A1b, 6079302: 2003)
- 200/500 MHz-km (A1b, 6079302: 2003)

50 Micron
- 500/500 MHz-km (A1b, 6079302: 2003)
- 400/400 MHz-km (A1b, 6079302: 2003)
- 1500/500 MHz-km (A1b, 6079302: 2003)

Motion #	**3**	75% technical		
Move that the 10Gbs on FDDI Grade MMF Study Group accept the following objective: Support fiber media selected from IEC 60793-2-10:2003 **62.5 Micron** • 160/500 MHz-km (A1b, 6079302: 2003) • 200/500 MHz-km (A1b, 6079302: 2003) **50 Micron** • 500/500 MHz-km (A1b, 6079302: 2003) • 400/400 MHz-km (A1b, 6079302: 2003) • 1500/500 MHz-km (A1b, 6079302: 2003)				
Moved	J. Jaeger			
Seconded	E. Cornejo			
	Yes	**No**	**Abstain**	**Result**
SG	**60**	**0**	**1**	**Pass**
802.3	**14**	**0**	**0**	

Motion 3 Discussion:
- What about reach? Will be specified in another objective
- Piers Dawe: 400/400 MHz-km MMF should not be included since it is extremely small part of installed base.
- Paul Kolesar: National labs data set contains significant number of 400/400 fibers.

- Steve Swanson: In 1996 Corning provided data to IEEE that 20% of Corning distribution at that time was 400/400.
- LX4 did specify a shorter distance (240 meters) with 400/400 fibers.
- Lew Aronsen: Standard must be written to support a specification, not fibers non-compliant to the specification
- David Cunningham and others: Fiber that is out of spec for supported media is outside of scope of the standard

Reach Objective Discussion – David Cunningham

- 300m and low cost are recognized goals
- Emulate success of 1000BASE-SX 220 meter economical support on existing media with 10Gb/s 220 meter installed base solution.

Economic Feasibility Discussion

- Steve Swanson: SR should be used as cost benchmark.
- Ed Cornejo, OpNext: LX4 and LR are very close in cost, with more innovative packages leveraging existing technology
- Bob Zona, Intel: Using LX4 as a peg to stand on in not a very sturdy peg. LX4 to anything ratio will change over time.
- John Dallassassee, Emcore: As other manufacturer of LX4 modules, stating cost ration statements difficult to support.

IEEE 802.3 WG Chair Bob Grow confirmed that SG vote of the entire room would determine the outcome of all motions during this SG meeting.

Motion #	**4 as amended**		75% technical	
Move that the 10Gbs on FDDI Grade MMF Study Group accept the following objective: Provide a single Physical Layer specification which supports a link distance of • **At least 220m over installed 500 MHz-km MMF** • **At least 300m over MMF**				
Moved	D. Cunningham			
Seconded	J. Ewen			
	Yes	**No**	**Abstain**	**Result**
SG	**41**	**5**	**3**	**Pass**
802.3	**9**	**1**	**2**	

Discussion/Changes on Motion 4

- Ali Ghiasi, Broadcom: “to 300m” should be removed
- **Friendly amendment:**
  - Piers Dawe: Friendly: Remove the word “single.
    - Accepted by both mover and seconder.
- Steve Swanson: Precedent is to specify one minimum distances.
- **Friendly amendment:** Steve Swanson change motion to:
  - At least 220 meters over installed multimode fiber

        - Accepted by both mover and seconder.
- Jim Tatum: If there are media/PMD combinations that do not meet 220 meters, do we fail to meet the objective. Group: No.
- **Friendly amendment:** Paul Kolesar- add a "single PMD fiber combination" withdrawn
- **Friendly amendment:** Ed Cornejo
    - Add bullet: At least 300m on MMF.
        - Accepted by both mover and seconder
- **Friendly amendment:** Swanson
    - Change length to "220m < :L <=300m"
        - Rejected and withdrawn

- **Friendly amendment:** Jim Tatum, Honeywell
    - Add bullet stating at least 2X reach or existing 10G serial PMDS
- Tom Lindsey: Against motion, likes original wording
- **Friendly amendment:** Bob Grow: Add "500 MHz-km" before installed, accepted.

Motion #	**5**		75% technical	
Move that the 10Gbs on FDDI Grade MMF Study Group accept the following objective: **Support singlemode fiber specified in IEC 60793-2** • **Type B1.1 (dispersion unshifted)** • **Type B1.3 (low water peak dispersion unshifted)**				
Moved	Paul Kolesar			
Seconded	Steve Swanson			
	Yes	**No**	**Abstain**	**Result**
SG	**8**	**32**	**15**	**Fail**
802.3	**3**	**5**	**2**	

Motion 5 Discussion:

- Bob Zona, opposes motion since forcing this decision now may reduce cost effectiveness of solution.
- John Ewen: Interoperable with LR? Either way
- John Jaeger: Same or different PMD? Same
- Richard Brand: Against motion

5 Criteria Motions

Broad Market Potential

Motion #	**6**	75% technical
Move that the 10Gbs on FDDI Grade MMF Study Group accept the **Broad Market Potential Criteria as stated in 5_criteria_1_0104.pdf** • **Passed by acclamation without opposition**		

Motion #	**7**	75% technical
Move that the 10Gbs on FDDI Grade MMF Study Group accept the **Compatibility with IEEE standard 802 as stated in 5_criteria_1_0104.pdf** • **Passed by acclamation without opposition**		

Motion #	**8**		75% technical	
Move that the 10Gbs on FDDI Grade MMF Study Group accept the Distinct Identity as stated in jaeger_2_0104				
Moved	Paul Kolesar			
Seconded	Steve Swanson			
	Yes	**No**	**Abstain**	**Result**
SG	**35**	**9**	**2**	**Pass**
802.3	**6**	**3**	**1**	

Motion	**to reconsider motion 8**		50% procedural	
Moved	Steve Joiner			
Seconded	Jim Tatum			
	Yes	**No**	**Abstain**	**Result**
SG	**28**	**9**	**8**	**Pass**

Motion	**9** (reconsidered and amended motion 8)		75% technical	
Move that the 10Gbs on FDDI Grade MMF Study Group accept the Distinct Identity as stated in 5_criteria_1_0104.pdf				
Moved	John Yaeger			
Seconded	Ali Ghiasi			
	Yes	**No**	**Abstain**	**Result**
SG	**39**	**5**	**2**	**Pass**
802.3	**6**	**3**	**1**	

Discussion/Changes on motions 8 and 9

- Steve Swanson: Not true that LX4 not available. More LX4 available than supply. If both LX4 and EDC support 300m on installed MMF. Therefore we fail this criteria.
- John Jaeger addition based on discussion.
  - "It will be the only PHY that supports a serial interface at the PMA, which is required for some module form factors. Accepted
- Bruce Tolley suggested removing paragraph referring to LX4
- Paul Kolesar: How can we follow IEEE rules and insert and additional solution the solves the same problem as LX4? Is against the distinct identity of this SGs objectives.
- Clay Hutchinson, Emcore: LX4 will reach 1KM on 50 micron, 500m on 62.5 micron. How can we compare cost of LX4 vs something that does not exist.
- Ed Cornejo: Work that needs to be done to provide a lower cost solution.
- David Cunningham: Add
  - "Currently the industry is moving toward smaller form factor serial solutions and it is expected that with time these will become dominant." Accepted

- Bob Grow: Add
    - Supports multimode fiber over installed MMF and pluggability at the 10GBASE-R PMA interface. Accepted
- Jim Tatum
    - Add “links of 220m distance” before “over FDDI-grade multimode fiber”. Accepted
- Steve Swanson: As speeds move to 40 Gb/s, industry likely to move back to CWDM. Does not support this wording.
- Insert “at least” in front of “220m” – accepted.
- Paul Kolesar: Injection of form factor in our documents is orthogonal to scope of IEEE standard. Trying to justify distinct identity on basis of something the reader will never see is not relevant.
- Dave Cunningham: Distinct Identity is not part of the standard. If someone can show him how to support LX4 in a small form factor interface, he will stop supporting this SG.
- Ali Ghiasi: Enabling small form factors increases port density and lowers cost.
- Bob Grow: One unique per problem is a very subjective criteria. 100BASE-T2, and T4 are examples. But concerned that 802.3 needs to be convinced that the objectives of this SG meet the distinct identity criteria.
- Paul Kolesar: Technology such as VCSELs will solve power dissipation issues for LX4 in XFP. Other heat contributor is XAUI interface, and thermal output will be reduced by smaller line width silicon.
- Dave Cunningham: There was a previous lab demo of LX4 in XFP, but it is patently nonsensical to
- Tom Lindsey: 220m is a concern and wording may need to be modified prior to submittal to 802.3. Rejected.

Motion to call question, vote by acclamation unclear.

Procedural vote: Y: 31 N: 10. Motion to call question passed

Motion #	**10**	75% technical
Move that the 10Gbs on FDDI Grade MMF Study Group accept the **Economic Feasibility as stated in 5_criteria_1_0104.pdf.**		
Moved	J. Yaeger	
Seconded	A. Ghiasi	
Passed by Acclamation		

Motion 10 Discussion:

- Steve Swanson: The implication that SX and LX costs are the same is incorrect as SX is much lower cost than LX today. Accepted, changed SX/LX to LX. Also concern that the

Motion #	**11**		75% technical	
Move that the 10Gbs on FDDI Grade MMF Study Group accept the **Technical Feasibility as stated in 5_criteria_1_0104.pdf.**				
Moved	J. Yaeger			
Seconded	A. Phanse			
	Yes	**No**	**Abstain**	**Result**
SG	**42**	**3**	**2**	**Pass**
802.3	**6**	**2**	**2**	

Motion 11 Discussion/Changes

- Steve Joiner: Change LR to R. Accepted
- Paul Kolesar
  - Remove phrase referring to 3 – 4 x complexity. Accepted.
  - Add "With production volume" in front of "the 10 Gb/s on FDDI grade MMF PHY" – accepted
- Steve Joiner: Change last sentence from "..installed cost.." to "cost of upgrades.
- Abjihit Phanse. General comment that LR is expensive due to optical complexity and EDC can reduce that complexity.
- Paul Voois:
  - Delete "implementation" in front of "economics" of first sentence. Accepted.
- Abjihit Phanse. Change complexity comparison from 10GBASE-LR and 1000BASE-SX. Rejected.
- Steve Swanson. History suggests that PHYs on existing media have not been economically feasible. Examples include many flavors of 100BASE-X on existing media that failed while 100BASE-T over new cabling (CAT5) succeeded, 1000BASE-T that required new CAT-5E, and 1000BASE-SX that required higher grade media to support structured cabling distances.
- Unknown; LX4 was not a failure, and any PMD that requires new cabling violates economic feasibility.
- John Dallassee: LX4 has not failed. Emcore, Acuta, and OpNext currently support and ship LX4. There is room for both LX4 and objectives of this SG.
- Paul Kolesar: In favor of removing LX4 to resolve distinct identity issue.
- Steve Swanson: Not in favor or removing LX4 except to resolve distinct identity issue. Maintains that in stallion new cabling lower the installed cost of the total system.
- Tom Lindsey: Make cost/complexity comparison relative to 1000BASE-SX. Rejected
- David Cunningham: At end of first paragraph, add, "Additionally, it is expected that serial solutions will have the highest volumes and this standard will therefore have economies of scale. Accepted.
- Nick ???, change "complexity" to "cost" and "similar to" to "lower than" in first line. Accepted

John Ewen called the question, no opposition.

PAR - Title, Scope, Purpose Motion

Amended as shown in **draft_par_0104.pdf**. No opposition

Motion #	**12**		75% technical	
Move that the 10Gbs on FDDI Grade MMF Study Group request the Chair of 802.3 circulate the SG approved PAR (completing the basic fields), SG approved Five Criteria, and SG approved Objectives to 802.3 and the SEC for consideration at the March 2004 plenary.				
Moved	S. Joiner			
Seconded	N. Weiner			
	Yes	**No**	**Abstain**	**Result**
SG	**37**	**4**	**0**	**Pass**
802.3	**6**	**3**	**0**	

Bob Grow: Highest priority item for SG at March plenary is to defend PAR and 5 criteria. The SG may be asked to present to other WGs in their meetings and should be prepared to address the question of distinct identity relative to LX4, for example.

Poll –Have interim SG meeting on Sunday night before March plenary. Moved Approved by acclamation.

Motion to adjourn.
Moved and Seconded. Approved by acclamation.

Meeting adjourned at 7:20 pm PST.