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Understanding 40G and 100G Ethernet Distances and Trade-offs on OM3 and OM4 Fibers

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The IEEE 802.3ba amendment that will add 40 Gb/s and 100 Gb/s rates to the Ethernet standard is nearing completion, scheduled for publication in mid 2010. The draft currently specifies supportable distances of 100 meters on OM3 fiber and 150 meters on OM4 fiber for both rates. The common distances for both rates are the result of using inverse multiplexing over parallel fibers, wherein the signals are transmitted over multiple lanes, each operating at 10 Gb/s. The 40 Gb/s interface employs four of these lanes in each direction, while the 100 Gb/s interface employs ten.

Given that the rate per lane is the same as that defined for 10 Gb/s Ethernet, one may wonder why the distance has been reduced from 300 meters to 100 meters on OM3 fiber. Simply put, the distance reduction is a conscious decision made by the IEEE 802.3ba Task Force in order to provide the lowest cost optical channel, albeit with shorter distance capability in trade.

Technology Trade-off Results in Shorter Distances

The technical cause of the reduction in distance is a matter of relaxed transceiver specifications, resulting in smaller and lower cost transceivers. The main relaxation is an increased allocation for jitter (i.e. the timing variation between bits caused by electrical cross-talk and noise) due to elimination of clock recovery and attendant retiming functions in the optical transmitter and optical receiver. These functions are present for 10G transceivers (e.g. X2 and XFP forms) but absent for 40G and 100G transceivers (e.g. QSFP and CXP forms). Elimination of retiming permits jitter originating at each stage in the transmission path to accumulate and propagate with the signal through the entire transmission chain to the receiving device as depicted in Figure 1. For 40GBASE-SR4 and 100GBASE-SR10 the jitter begins at the Transmitting Chip electrical output signal (j1), and accumulates as the signal propagates:

a. across the Electrical Conductors to the Optical Transmitter input (j2),
b. through optical conversion without retiming in the Optical Transmitter (j3),
c. across the Optical Fibers (j4),
d. through electrical conversion without retiming in the Optical Receiver (j5),
e. across the Electrical Conductors to the Receiving Chip (j6).

At the Receiving Chip the jitter = j1 + j2 + j3 + j4 + j5 + j6. The Receiving Chip retimes the signal and thereby removes most of the accumulated jitter permitting error-free reception.

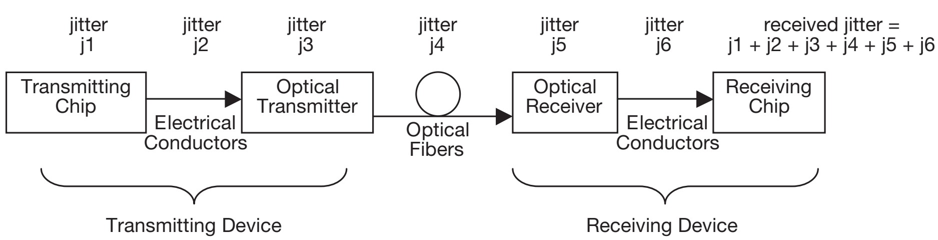

Figure 1 – Transmission path accumulating jitter

Because the vast majority of the jitter budget is consumed by the electrical portions of the transmission channel, the total jitter accumulation can be tolerated only if the fiber optic channel is essentially perfect. Therefore the distance is reduced from 300 meters to 100 meters on OM3 fiber. It is interesting to note that at this reduced distance, the optical fiber behaves almost the same as a short patch cord, adding only 1 dB of impairment.

A second reason why the distances are shorter for 40G and 100G is due to relaxation of the spectral width requirement of the optical transmitter. Wider spectral width lasers (VCSELs) are easier to manufacture, but increase the amount of chromatic dispersion (pulse spreading) in the fiber. The total dispersion of the fiber is the quadratic sum of the modal component and the chromatic component. This, in combination with the extra jitter, causes the distance increase of OM4 relative to OM3 to be smaller than what is suggested by the increase in modal bandwidth that OM4 provides.

For additional perspective on optical channel perfection, consider that the 2000 MHz•km bandwidth-distance product of OM3 provides a modal bandwidth of 20,000 MHz at 100 meters. That is three times more than the modal bandwidth used for 10GBASE-S. Even more striking, the 4,700 MHz•km bandwidth-distance product of OM4 fiber provides 31,333 MHz of modal bandwidth at 150 meters. With retiming in the optical transmitter and receiver, that amount of bandwidth could support 47 Gb/s per lane! So the OM3 channel provides three times the modal bandwidth previously required, while the OM4 channel provides almost five.

CommScope Pushes for Longer Distances

As a remedy, CommScope has proposed a screening test that can select transmitters that are better than minimally compliant from among the variation in standard production runs. Defining such a test provides a specification that customers can cite to request transmitters that support transmission over at least 200 meters of OM4. At the time of this writing, it appears more likely that such a test will be produced by TIA as a Telecommunications Systems Bulletin (TSB) rather than by IEEE as an informative annex to 802.3. A diagram of the proposed test fixture is shown in Figure 2. This is exactly the same test fixture defined in draft IEEE 802.3ba except for a change to the “Test fiber” as indicated.

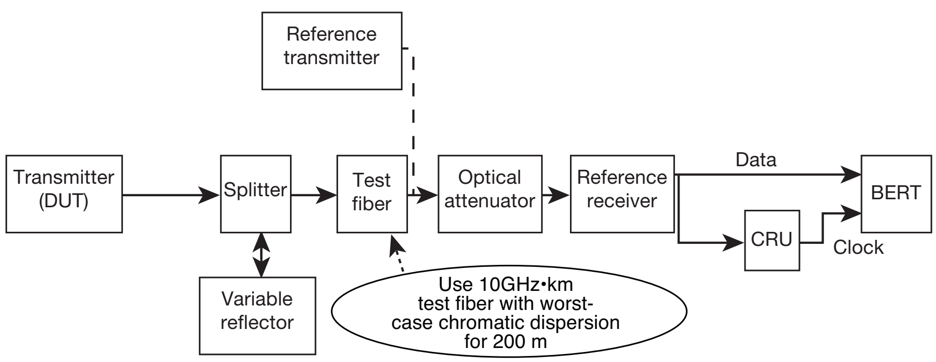

Figure 2 – Proposed test setup for measurement of transmitter and dispersion penalty

Extended channel length is also achievable by employing higher performance connecting hardware that provides lower loss connections. For many years CommScope has detailed this trade-off between connection loss and distance for every supported fiber optic application, as documented in the SYSTIMAX Performance Specifications. Figure 3 illustrates this trade-off using a graph extracted from an IEEE 802.3 link model for OM4 fiber supporting 100GBASE-SR10. It shows increasing total power budget consumption, represented as the sum of several impairments, as a function of increasing channel length. Note that the P_DJ (green squares) impairment is the largest, consuming at least 3 dB of the 8.3 dB available budget. This is the impairment related directly to jitter. While the largest, the nearly flat slope of this impairment indicates that the contribution to jitter from the fiber is minimal, as previously mentioned. Note also that at 125 meters 1.5 dB of budget remains for connection insertion loss. This is the amount allocated within the draft IEEE standard for two worst-case connections within the optical fiber cabling channel, and corresponds to a 125 meter channel length for OM4 fiber. In January 2010, driven by comments submitted by CommScope representatives, the IEEE 802.3ba Task Force agreed to increase the stated reach in the draft from 125 meters to 150 meters for OM4. In order to achieve this increase, the connection loss allocation was reduced from 1.5 dB to 1 dB in recognition of the value that low-loss connection technology offers to customers. This illustrates that the unused portion of the nominal 1.5 dB connection loss allocation can be employed to overcome an increase in other impairments, confirming the link model of Figure 3.

Since the aggregate impairment level increases with distance, the freed-up power from lower loss connections translates into extra distance capability. Taking this one step further, note that at 170 meters the budget remaining for connection loss is 0.6 dB, sufficient for two low-loss MPO connections of the SYSTIMAX InstaPATCH® 360 offer.

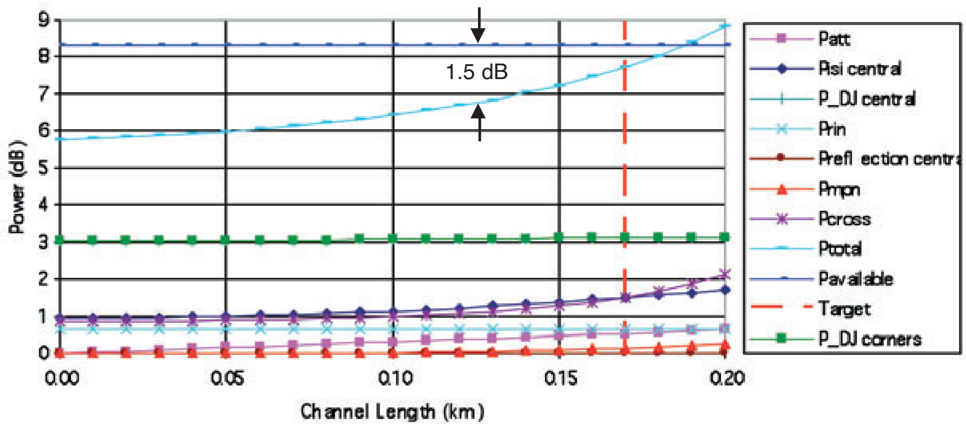

Figure 3 – IEEE 802.3 link model analysis for OM4 fiber supporting 100GBASE-SR10

Continued CommScope Innovation

When lower loss connections are combined with transmitters that are screened for 200 meter capability, the InstaPATCH® 360 channel can support up to six MPO connections over 200 meters of LazrSPEED 550 fiber. Thus the capability of existing multimode technology found in CommScope's LazrSPEED 550 and InstaPATCH® 360 fiber solutions is considerably greater than the values found in the draft standard. This extended distance capability will prove very useful in addressing real world topologies in many data centers at far lower cost than singlemode alternatives.

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