**Synopsis**

The distance capability of existing 10 Gigabit Ethernet products is severely limited by modal bandwidth. 10GBASE-SR supports only 33m with OM1 and 82m with OM2. A 4-channel CWDM version, 10GBASE-LX4, increases the operating range to 300m using existing multimode fibre types however this solution is complex and products are not widely available. 10GBASE-SR operating distance may be increased to 300m by using OM3 multimode fibre, but OM3 is more expensive than OM1/OM2 and its installed base is no yet significant. This white paper describes a more advanced version of 10 Gigabit Ethernet that operates over increased lengths of legacy multimode fibre.

## 1. The Market for 10 Gigabit over Legacy Multimode fibre

In November 2003, a Study Group was established within IEEE 802.3 to investigate the feasibility of running 10 Gigabit Ethernet over 300m of legacy multimode fibre. The proposal is known as 10GBASE-LRM (10GBE over *Long Reach Multimode*). This initiative was led by Cisco Systems and supported by a wide range of optoelectronics, transceiver and network system suppliers.

The market need for 10GBASE-LRM is being driven by the fact that a high percentage of enterprise customers are reluctant to pull new fibre to support 10GBE. This is not helped by the fact that post-2002 IT budgets are either static or declining. A total addressable market revenue opportunity of $ 400-600 million was estimated to be at stake.

Surveys indicate that building backbone links up to 300m represent 88% of the installed base (see figure 1). 10GBASE-LX4 has been dogged by complexity and cost, and technology advances such as 1310nm VCSELs and electronic equalisation now support a lower cost alternative to fill this market space. This leaves a huge gap between supported lengths of legacy multimode fibre and its installed base; 10GBASE-SR supports only 26m of 160/500 MHz.km “FDDI-grade” multimode fibre, 33m of 200/500 MHz.km multimode fibre (OM1) and 82m of 500/500 MHz.km multimode fibre (OM2). On top of this, all 10GBE products remain expensive (10GBASE-fibre products were 10-times the cost of 1GBASE-fibre products in 2003). Specifying a multimode fibre solution that will operate up to 300m of legacy multimode fibre will therefore enable end users to save money on infrastructure.

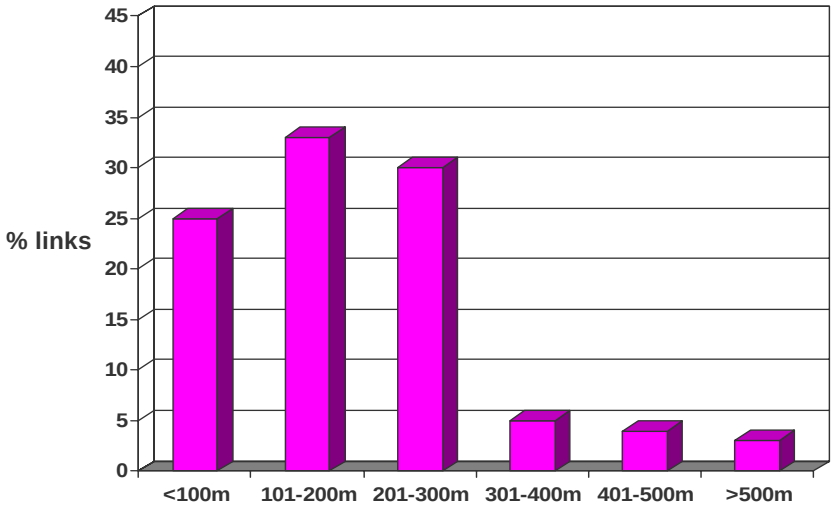


**Figure 1: Distribution of Building Backbone Link Lengths (Source: Flatman 1999)**

The 10GBASE-LRM Study Group completed its analysis in March 2004 and a new Task Force was formed, IEEE 802.3aq.

## 2. 10GBASE-LRM Technical Approach

Conventional 10 Gbit/s serial transmission over legacy multimode fibre will be severely limited by Differential Mode Delay (DMD), which is a complex, multi-path impulse response. It is worth noting that DMD can vary with time due to cable movement, temperature variation or other effects that change the optical power distribution across mode groups.

White Paper

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Measurements made in 1997 found that 30% of installed multimode fibres had less than 500 MHz.km modal bandwidth @ 1300nm with near-core Restricted-Mode Launch (RML). The majority of legacy multimode fibre had a modal bandwidth of at least 400 MHz.km.

Technical solutions investigated for 10GBASE-LRM were:

- Constrained launch conditions/optical mode filtering
- Receiver equalisation (Electronic Dispersion Compensation, EDC)

Initial investigations with FDDI-grade multimode fibre indicated that 10GBASE-SR with receiver equalisation was capable of supporting up to 100m, and 10GBASE-LR with receiver equalisation was capable of supporting at least 220m. There was concern that pushing for 300m operation with FDDI-grade multimode fibre would increase complexity and cost, severely limit implementation scope and push the project out of Ethernet's economic sweet spot.

Each of the target fibre types was characterised for modal behaviour by extensive testing. This led to a recommendation to use Mode Conditioning Patch (MCP) Cords to provide Off-Set Launch (OSL) for non-OM3 MMFs, and Direct (i.e. Centre) Launch for OM3 fibre. Alternative launches are listed in Table 1. MCP cords have the same offset value as existing cords specified for 1GBE but have an additional cord return loss requirement of $\geq$ 20dB

It was eventually agreed reduce the target link length from 300m to 220m for OM1, OM2 and FDDI-grade 62MMF. As 220m is the maximum link length supported by 1000BASE-SX over FDDI-grade multimode fibre, it would provide a convenient upgrade path for 10GBASE-LRM. Operating range for 400/400 MHz.km 50MMF was also reduced to 100m. An analysis on the effect of connectors in OM3 channels concluded that the maximum supported distance was 220m, not 300m; this was due to the mode power redistribution of connections. There is a minimum range of 0.5m in all cases.

A summary of the reach and launch conditions for each supported fibre types is shown in Table 1.

| MMF Type (core + MHz.km) | ISO 11801 Fibre Type | Preferred Launch | Alternative Launch | Operating Range (m) | Max Channel IL (dB) |
|---|---|---|---|---|---|
| 62 + 160/500 | | 62MMF MCP cord | Direct Launch | 0.5 to 220 | 2 |
| 62 + 200/500 | OM1 | 62MMF MCP cord | Direct Launch | 0.5 to 220 | 2 |
| 50 + 500/500 | OM2 | 50MMF MCP cord | Direct Launch | 0.5 to 220 | 2 |
| 50 + 400/400 | | 50MMF MCP cord | Direct Launch | 0.5 to 100 | 2 |
| 50 + 1500/500 | OM3 | Direct Launch | - | 0.5 to 220 | 2 |

**Table 1: 10GBASE-LRM Optical Launch Recommendations & Supported Link Distances**

Attempts were made to introduce additional guidance on the use of MCP cords however this was not possible due to the variability of modal behaviour in non-OM3 fibre types. This will remain a designer/installer issue.

**3. Multimode Fibre Installed Base**

The worldwide installed base of building backbone fibre to 2007 is shown in figure 2. This is based on BSRIA shipment data and assumes 10% wastage during installation. No replacement has been assumed. OM1 fibre is clearly dominant up to 2007. There is also a high presence of OM2 and FDDI-grade multimode fibre. While OM3 is beginning to experience aggressive deployment in some regions (notably US and Europe), its impact on installed base will not be significant up to 2007, or probably even 2010.

Of particular interest to 10GBASE-LRM is the high level of low modal bandwidth fibre in the worldwide installed base. Much of this fibre will be DMD-challenged, as there was no awareness of this issue until 1997-98. DMD became less of an issue with multimode fibres manufactured after 1999, and the contribution of post-1999 fibre to the installed base has been calculated to be 39% by end-2003 and 53% by end–2007.

Figure 3 shows the composition of building backbone optical links up to 200m by fibre type up to end-2007. This calculation is derived from figures 1 and 2 above and assumes that each fibre type is deployed evenly in campus and building backbones. 58% of building backbone links are installed in the 0-200m length band, while only 20% of campus backbone links fall into this band. The high presence of low modal bandwidth multimode fibre is clear to see, as is the market opportunity for 10GBASE-LRM. The addressable market for a 220m 10GBASE-LRM product would be slightly higher than this and should include campus backbone links that fall within this range (estimated to be an additional 10%).



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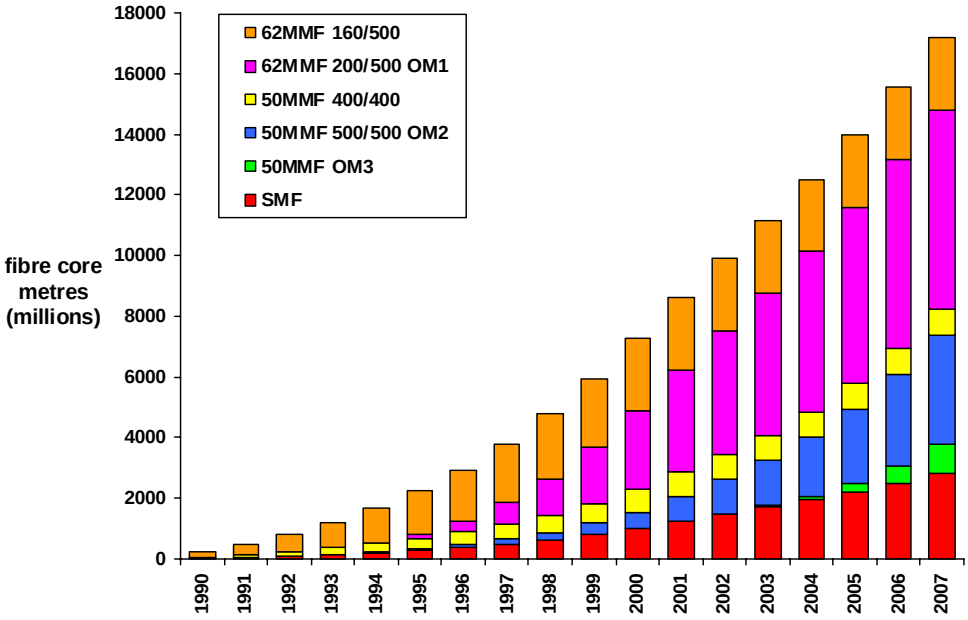


**Figure 2: Worldwide Installed Base of Building Backbone Fibre (Source: Flatman 2004)**

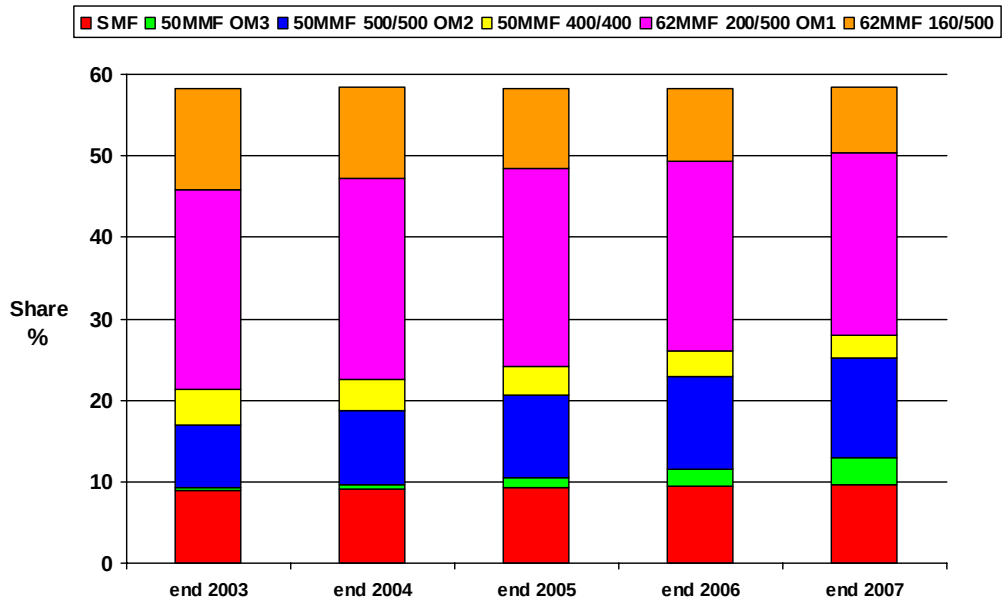


**Figure 3: Worldwide Installed Base of Building Backbone Links up to 200m (Source: Flatman 2004)**

### 4. 10GBASE-LRM Availability

IEEE 802.3aq was approved as a standard in September 2006.

### About Brand-Rex

Brand-Rex is a designer and manufacturer of copper and fibre based cabling systems, headquartered in Glenrothes, Scotland with facilities across Europe. Brand-Rex has two primary businesses: Connectivity and Speciality. Its Connectivity division designs and manufactures cabling systems (both copper and fibre) for data communications and is the No.2 player in Europe. The Speciality division exclusively produces cables that are used for control, communications, power and instrumentation within hostile environments.



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