The Fundamentals of Long Range Fast Ethernet (LRFE)

With more than 500 million ports installed worldwide, Ethernet is the dominant networking technology. It is inexpensive, ubiquitous, and extremely familiar to users. Many “first-mile” equipment providers are therefore considering Ethernet technology for first-mile broadband access. To date, Ethernet adoption in the first mile has primarily been in “closed” environments, i.e., Multi-Tenant, Multi-Dwelling, and Multi-Hospitality (collectively termed MxU) buildings. However, many independent first-mile service providers are implementing Ethernet connections over fiber and copper in the first mile.

Table of Contents

First Mile Requirements

For deployment in the first mile, a technology must have the following characteristics:

- It must run over existing infrastructure. In today's cash-constrained environment, service providers want to conserve cash. Since there is a glut of fiber capacity, they do not want to make huge investments in new fiber installation. They can increase revenues and cash flow from services quickly and with significantly lower investment, by deploying new technology over existing copper assets, instead of installing new fiber.
- It must be capable of end-to-end high-speed transmission over the distances between the customer and the concentrator without a repeater, hub, or similar equipment. Customers that seek high-speed symmetric services are usually located within 5,000 feet of the concentrator. This is corroborated by Vertical Systems, Inc., who states that 76% of business customers are within 1 mile of a fiber network. Additionally, typical distances in MxU environments rarely exceed 2,000 feet.
- In outside plant scenarios, the technology must coexist with existing services such as Plain Old Telephone Service (POTS), Integrated Service Digital Network (ISDN), Digital Subscriber Line (xDSL), etc.
- It must have scalable performance to ensure that service providers can offer different Service Level Agreements (SLAs).

For all its popularity, traditional Ethernet (10/100 Mbps) does have two major stumbling blocks:

- The technology can only be deployed for up to 300 feet over copper. Beyond that, repeaters, hubs, or switches are required to regenerate and transmit the signal. This limitation translates into higher expenses in the form of additional equipment, and major provisioning difficulties.
- The technology can only be deployed over Category 3 (CAT3) or Category 5 (CAT5) wiring and cannot operate over existing telephone wires. Since a vast majority of businesses, especially those in international markets, do not have CAT3 or CAT5 wiring, traditional Ethernet cannot be used there. Installing CAT3 or CAT5 wiring translates into higher investment costs. If new wiring has to be installed, service providers may very well choose to install fiber.

Introducing Long Range Fast Ethernet

Ikanos' Long Range Fast Ethernet (LRFE) technology is designed to meet the requirements for a first-mile technology, and solve precisely the problems enumerated above. Its key features are:

- LRFE works over existing copper wire. The media can be ordinary telephone wires or enhanced cabling such as CAT3 or CAT5.
- The technology can transmit symmetric data rates up to 25 Mbps on a single pair and 100 Mbps over four pairs up to distances of 1,600 feet. With additional pairs, LRFE can transmit up to 100 Mbps up to distances of 5,000 feet.
- LRFE can coexist with POTS, ISDN, and various xDSL services, as defined by the T1.417 Spectral Compatibility document.
- LRFE throughput can be configured in 64 Kbps increments. This enables service providers to offer different SLAs and tiered services.

Table 1 Feature Comparison Between Traditional Fast Ethernet and LRFE

Traditional Fast Ethernet (100BASE-T)	Long Range Fast Ethernet (LRFE)
100 Mbps throughput	100 Mbps throughput
CAT5 wiring	Any type of wiring (CAT3/5, telco)
Reach of 300 feet	Reach of 1,600 feet (5,000 with more pairs)

Table 1 shows a comparison between Ikanos LRFE and Fast Ethernet. These characteristics make LRFE the technology of choice for deployment in first-mile applications that need very-high-speed symmetric bandwidth. Immediate applications include the MxU market for in-building distribution as well as the Metro Fiber Extension (MFE) market for aggregating fiber-like bandwidth to buildings that are not located on fiber. Since both these markets are expected to grow rapidly in the next 3 to 5 years, LRFE technology offers equipment manufacturers the opportunity to grow revenues and profits rapidly.

Figure 1 LRFE in MFE Applications

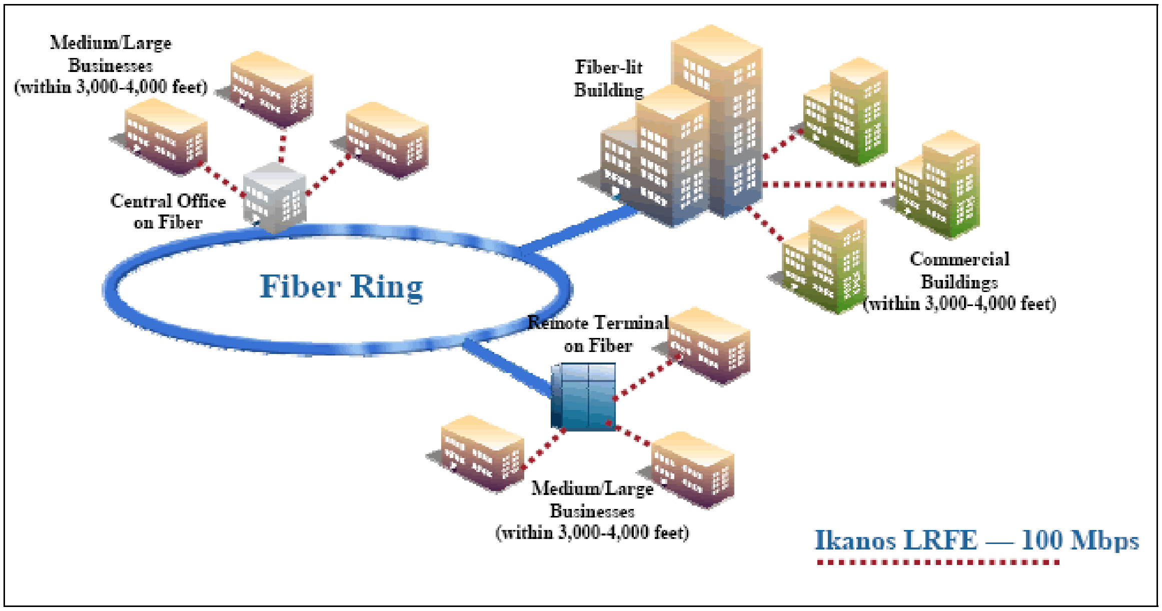


Figure 1 shows how LRFE technology can be used in MFE applications. The dotted lines indicate LRFE running on telephone wires. These wires are part of existing infrastructure and are used to provide fiber-grade bandwidth to buildings that are not on a fiber ring.

Figure 2 LRFE System Implementation

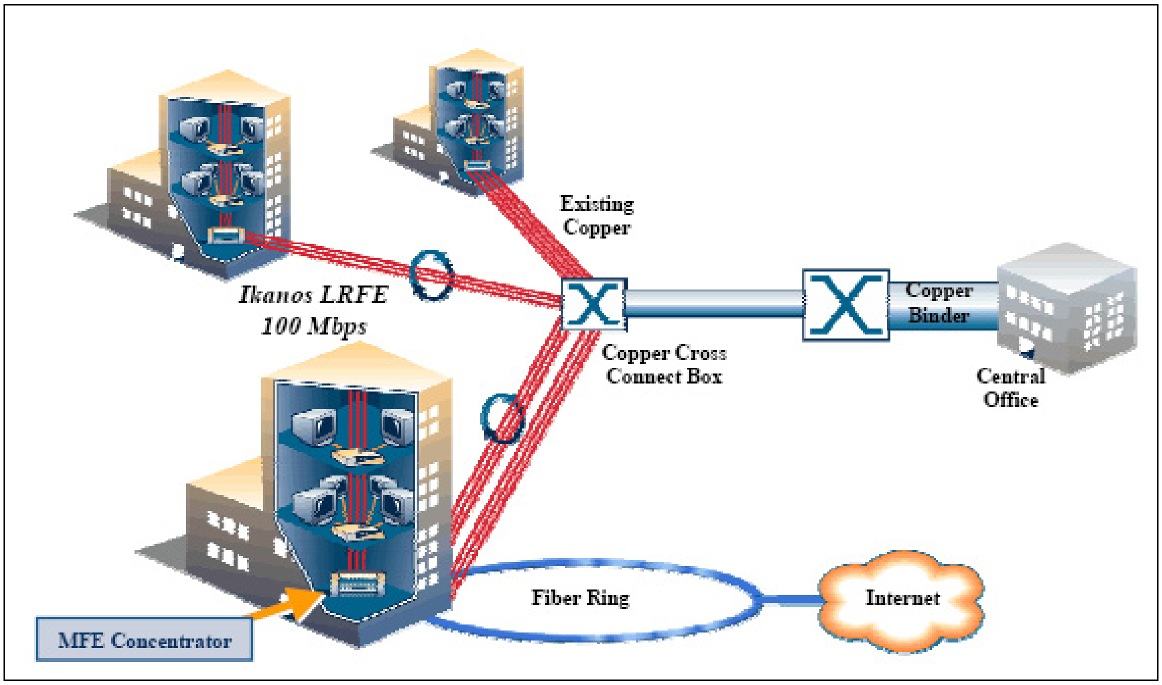


Figure 2 shows the implementation details of an LRFE system. A building, which is on a fiber ring, is connected to a building that is not on a fiber ring by using Ikanos' LRFE technology. LRFE can transmit up to 25 Mbps on one pair and up to 100 Mbps on four pairs of telephone wire. Therefore, an appropriate number of copper wires can be bonded together with on-chip Inverse Multiplexing (IMUX) to distribute high-speed data. The appropriate connections of the copper wires are made at the Copper Cross Connect box, which might be a pedestal, which is commonly located in most neighborhoods. Thus, there is no need for the data to go through a Central Office.

In MxU applications, LRFE can be used for distributing Ethernet frames within the building. In these applications, LRFE provides a better performance than traditional Ethernet with a minimum of additional investment. The typical setup is to install an MxU/MFE concentrator in the basement and then use the building's existing telco wiring to distribute LRFE. The net result is that LRFE helps eliminate LAN-WAN bottlenecks. **Figure 3** shows such an application.

Long Range Fast Ethernet Technology Overview

LRFE uses Ethernet over High Level Data Link Control (HDLC) over Very High Bit-Rate DSL (VDSL) technology. In addition, Ikanos' SmartLeap™ 8100 chipset incorporates on-chip inverse multiplexing (IMUX). This enables the chipset to bond up to eight physical ports (depending on the band plan used) into one logical port without the need for any additional external components.

LRFE uses the Flex Band Plan or Plan 998 or Plan 997, which allows the SmartLeap 8100 chipset to IMUX up to eight physical ports into one logical port. Also, as is indicated in **Figure 4**, the Flex Band Plan allows for transmission of up to 100 Mbps on four pairs at a distance of 1,600 feet, which is the "sweet spot" of installations in MxU environments. In addition, more than four pairs of telco wire can be bonded to transmit 100 Mbps up to 5,000 feet. The Power Spectral Density (PSDs) for Plan 998 and Plan 997 are shown in **Figure 5** and **Figure 6**, respectively.

Figure 3 LRFE in an MxU Building

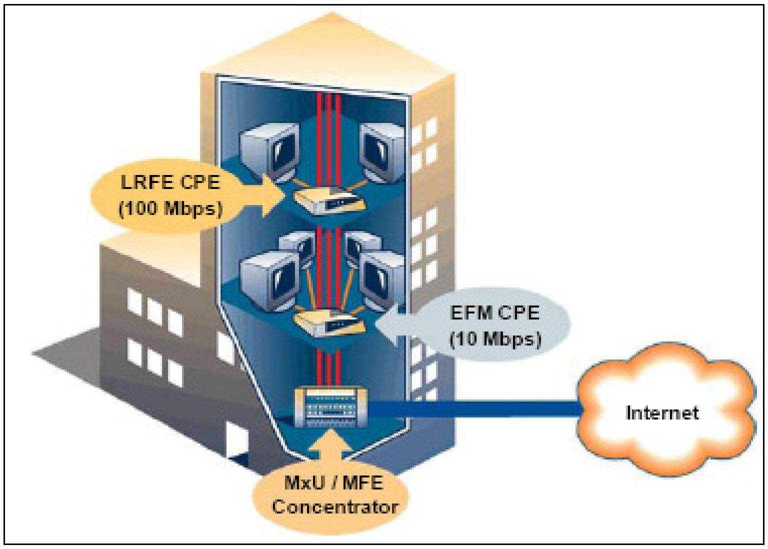


Figure 4 LRFE Performance

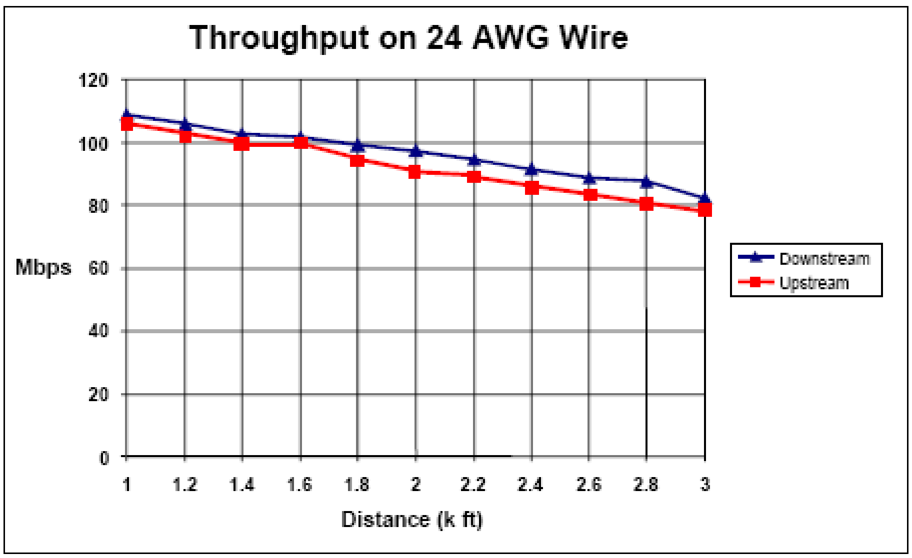


Figure 5 Power Spectral Density for Three-Band Plan 998

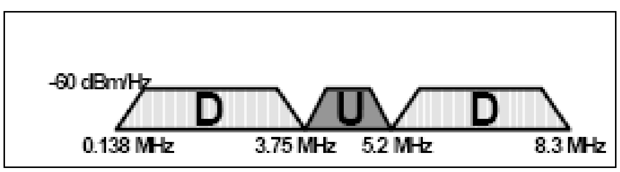
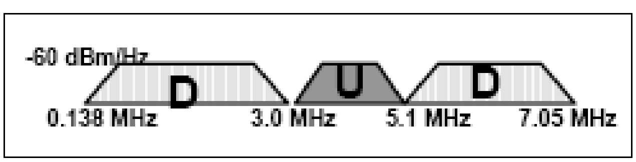


Figure 6 Power Spectral Density for Three-Band Plan 997



Details of Inverse Multiplexing

The VDSL modem sublayers include the:

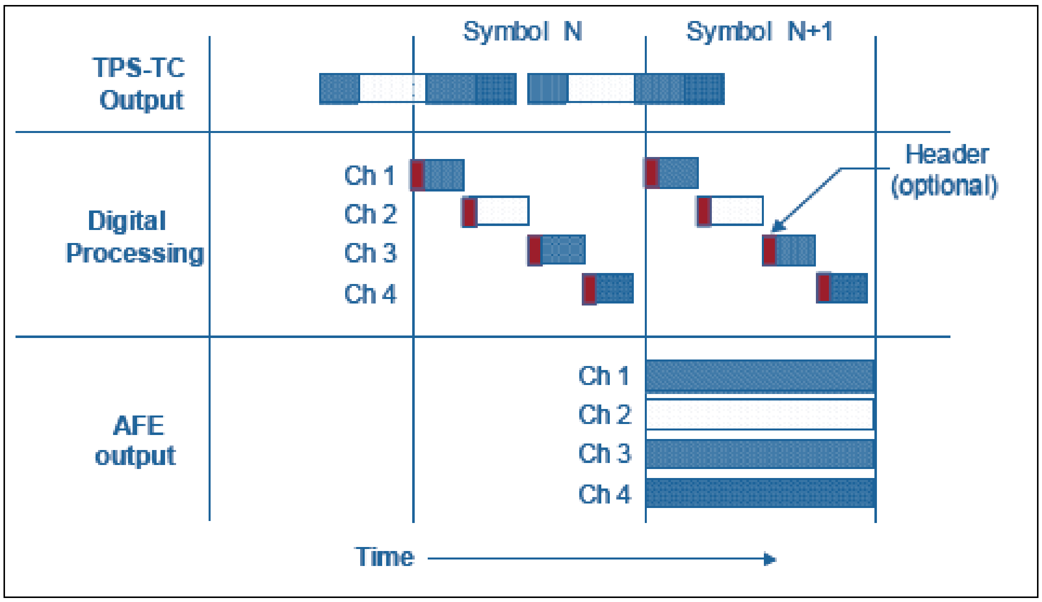
- Transport Protocol Specific Transmission Convergence (TPS-TC) sublayer
- Physical Media Specific Transmission Convergence (PMS-TC) sublayer
- Physical Media Dependent (PMD) sublayer

The TPS-TC layer that is defined for Ethernet transport over VDSL uses HDLC framing with byte-stuffing for rate matching. To bond the output of the TPS-TC layer over multiple lines, the following will happen:

1. The TPS-TC output is rate matched to stream of bytes.
2. The TPS-TC output is sent on each line, once every symbol, in sequence.
3. Each line takes only the number of bytes that can be sent per symbol on that line.
4. The receive side puts them back together in same sequence.

A graphical representation of Ethernet data flow over four bonded VDSL lines is shown in Figure 7.

Figure 7 Ethernet Data over VDSL



Control of the Bonded System

The bonded system can be controlled in the following ways:

- An optional header has the sequence number, which is used for segmenting and reassembly.
- It can work without a header:
  - When a line comes up, it is assigned an ID by the concentrator side and a position in the line sequence used for segmenting and reassembly.
  - When a line goes down, Embedded Operations Channel (EOC) messages can be sent on other lines to drop the line from the line sequence.
- Cyclic Redundancy Check (CRC) of segments is not needed:
  - Segments sent on each line already have CRC and Reed Solomon (RS) encoder (DSL framing).
  - HDLC encapsulation adds its own CRC.
  - Ethernet frames have their own 32-bit CRC.

Benefits of Inverse Multiplexing

There are many benefits to the IMUX scheme that is described previously.

- It increases reach to deliver high-speed services.
- It offers low complexity; it can be implemented in multi-line DSL transceivers without extra ICs.
- There is no extra overhead since it reuses existing DSL messaging methods—no extra header bytes are wasted for bonding.
- It rapidly adapts to line errors and failures since it can drop (or add) lines quickly when lines fail (or come up).
- It is transparent to upper layers since it acts like a single line and maintains byte (and packet) order.
- Cross-talk cancellation can be coordinated between the Central Office and the Customer Premise Equipment.

Conclusion

Long Range Fast Ethernet (LRFE) is an ideal technology for adoption in first-mile environments that need high-speed symmetric bandwidth. It provides symmetric bandwidth of up to 100 Mbps on four pairs of telco wire at a distance of up to 1,600 feet (5,000 feet with more pairs), offers scalable throughput in 64 Kbps increments, is spectrally compatible with POTS, ISDN, and other xDSL services, and runs over existing infrastructure. These reasons make it the technology of choice for use in MxU and MFE applications.

For more information, contact Ikanos.

Ikanos Communications, Inc.
47669 Fremont Boulevard
Fremont, California 94538

www.ikanos.com

P +1 510.979.0400

F +1 510.979.0500

E **sales@ikanos.com**

ikanos™