Loop Management System Standards: An Automated Approach

July 16, 2001

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LMS Focus Group
July 11, 2001

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Introduction

The market for digital subscriber line (DSL) loops to provide broadband services is currently experiencing explosive growth. Some industry forecasts predict that up to 50 million customers may be connected to the Internet via DSL services within four years. The DSL Forum reported at the end of 2000 that there are more than 2.5 million DSL customers in North America. The line count is expected to double approximately every 12 to 18 months.

With this explosive demand, service providers face a significant challenge in fulfilling the customer demand. Using traditional methods, it may require three site visits to unmanned CO, a remote terminal and/or customer premise to install DSL service. Personnel must be dispatched to the customer's location and also to various points along the outside plant infrastructure, in order to configure, provision, and test the loop.

Burgeoning demand, combined with a shortage of qualified personnel, has resulted in long delays for the customer and competitive pressures for the provider. This is a serious problem that is limiting the growth of the DSL market as potential customers become frustrated with these long delays. To be competitive and address the issues it is necessary to automate as many of these functions as possible, reducing or eliminating the need for site visits.

<u>The DSL Forum has an on-going commitment to remove obstacles to a DSL mass market. Current efforts underway include flow-through provisioning, interoperability, CPE auto-configuration and DSL anywhere initiatives. An additional key to achieving the goal of reduced provisioning cycles and overall improved quality is to automate various aspects of loop management.</u>

A Loop Management System (LMS) is an integrated solution addressing many of these aspects. The purpose of an LMS is to simplify testing, provisioning, and maintenance functions, enabling service providers to install, troubleshoot and maintain their local loop more efficiently.

Purpose

The purpose of this document is to provide a basic overview of an LMS with an emphasis toward automation of the metallic access matrix (MAM). The term "automation," as used in this paper, is limited to the remote management of the LMS elements.

Scope

This document is a starting point to introduce the problems faced by service providers with respect to loop management and discuss possible solutions, functions, definitions, technical attributes, and various applications for an LMS. A detailed discussion on loop management is beyond the scope of this document. The DSL Forum LMS focus group is considering the development of a more comprehensive working text that will have a broader approach to LMS.

Approaches to Loop Management

Currently, the loop management connections are typically performed manually by running jumpers on a CO MDF or outside plant cross-connect. The task of loop management may include service activation, service reconfiguration, maintenance, and testing. This often involves connections between the MDF, the IDF, and the DSLAM.

The connections can be managed either manually or automatically. In the manual method, the need for a technician to be physically present at the specific location where the loop management connections are required has following pros:

- By having the connections made on demand, it is possible to grow the required hardware based on service requests only, thus reducing the initial investments.
- An employee who is physically present at the MDF can perform other functions such as maintenance activities.
- With the manual process, it is possible to correct errors associated with poor loop records.

However, this method also has numerous drawbacks, such as:

- This physical presence incurs manpower costs and possibly truck roll costs if the loop management location is unmanned.
- If connections are required at a CLEC co-location, then getting a technician physically on-site involves additional coordination, costs and delays.
- A CLEC/ILEC line-sharing environment creates additional concerns regarding security and permissions to perform specific loop management connections, resulting in additional costs and delays.
- Human interventions can be a source of errors.

Software-controlled loop management equipment solves these problems in the following ways:

- It permits remote control, which eliminates need for on-site personnel.
- It means that entities can be selectively provided with access to specific loops and/or loop management connection types.
- It allows automated flow-through provisioning.

In the manual process, when a loop requires a new service activation or a service change, the craft has to connect the equipment port with the loop using a jumper on the frame. One possible way to automate this is to place a cross-connect matrix between the active equipment ports and customer loops.

In order to test and isolate fault on a customer loop manually, the craft often has to open (split) the loop and connect a test device to that loop to measure the attributes of the loop. One of the possible ways to automate this would be to have a Test Access Matrix that can open up a loop remotely and put a Test Device on that loop.

Additionally, to make a loop available for line sharing requires use of a splitter to combine the voice frequency and the data frequency. A craft has to manually connect the high- and the low-frequency ports to the input of splitter and jumper the output to the frame. This can be automated by having a splitter where the high- and the low-frequency inputs are connected to corresponding equipment ports and the output is connected to the customer loop automatically.

Based on the above functional requirements, there are four primary hardware components that are involved in loop management:

Metallic Access Matrix (MAM) - The MAM is comprised of the metallic fabric that is used to perform the metallic switching of the input and output ports.

Test Access Matrix (TAM) - The TAM is used to provide a Test Device (TD) with metallic access (via the MAM) to the customer loop.

Test Device (TD) - The TD performs the service testing.

Splitter - A Splitter is comprised of an electrical circuit that contains a low-pass and high-pass filter. The function of the Splitter is two-fold:

1. Prevent the xDSL service from interfering with the POTS service (and visa-versa) on a xDSL/POTS shared loop

2. To combine the POTS and xDSL frequencies that will be served by a xDSL/POTS shared loop.

The level of automation of various components defines three types of loop management systems, namely manual, semi-automated, or automated as described in the table below.

Classification/Components	**MAM**	**TAM**	**TD**	**Splitter**
Manual	Manual	Manual	Manual	Manual
Semi-automated*	Manual/Auto.	Manual/Auto.	Manual/Auto.	Manual/Auto.
Automated	Auto.	Auto.	Auto.	Auto.

*Need at least one manual and one automated component

All of the above are valid approaches to help solve some of the issues mentioned previously. The remainder of this paper will concentrate on the automated and remotely managed approach to loop management systems.

The following section defines the automated loop management system followed by how it relates to issues faced by the DSL community.

What is an LMS?

An LMS is a system that may contain multiple elements to automate testing, provisioning and maintenance functions, enabling service providers to install, trouble-shoot, and maintain existing and emerging services on their local loop more efficiently.

An LMS may provide the following functionalities:

- Testing/Qualification of loops
- Test access functionality
- Service migration/provisioning
- Line sharing
- Automated loop unbundling
- Maintenance

The LMS can verify whether the connecting copper loop will support the service access technology, rapidly connect a given loop from the customer to the DSLAM, restore service quickly during outages and provide for service access upgrades. It can perform all of these functions remotely, eliminating the need for the on-site manual intervention that is now required. Service providers may use LMS in one or more of the following locations (See Figure B-1 in Appendix B):

- Central Office
- Co-Location Space
- Remote Terminal/Vaults
- MTU/MDU
- Wireline SACs

A large COs may require multiple access matrixes to create the LMS systems. The use of the LMS in a RT and smaller unmanned COs may provide a more compelling justification.

The elements that make up an LMS may include:

- Metallic Access Matrix
- Test Access Matrix
- Test Device
- Splitters
- Remote Management Interface

An LMS is made up of a physical matrix that couples inputs-to-outputs and provides access to any loop for testing purposes (See Figure 1). Once installed, a properly implemented system can greatly reduce and even eliminate visits to central offices, co-location sites, remote sites and multiple dwelling units.

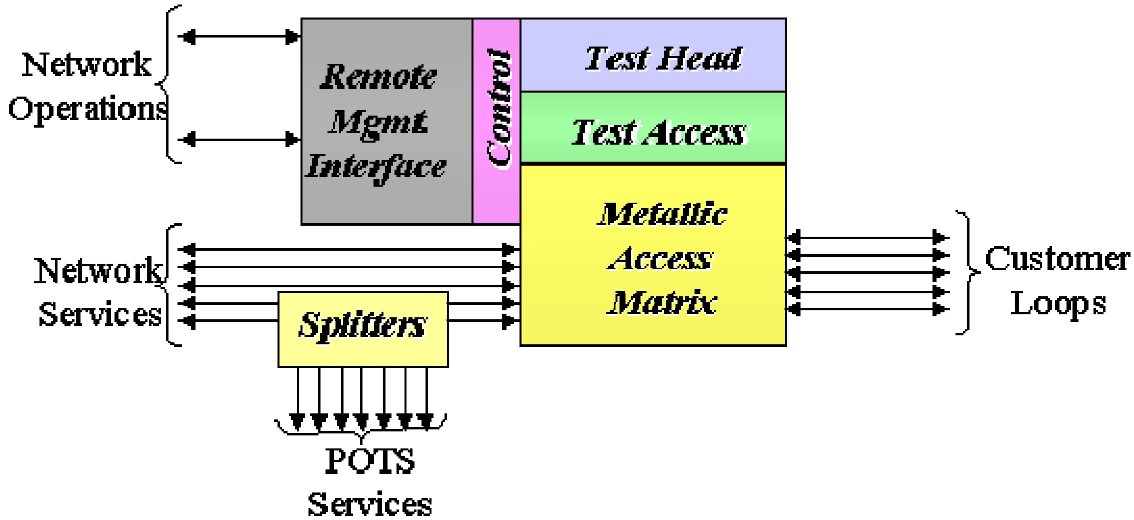

Figure 1

Based on the level of automations, an LMS can be classified under one of three categories:

1. **MLMS – Manual Loop Management System**. This system supports manual operation utilizing jumper wire and/or jumper cables to connect the access equipment terminating cable port(s) to the target local loop pair(s). The interface to the network Operating Support System is generally through a Work Force Management OSS that issues work orders for field technicians to perform the work and confirm completion back to the OSS.

2. **ALMS – Automated Loop Management System**. This is a fully automated loop management system that provides all the required functionality of the LMS through a remote management interface that is directly connected to one or more of the service providers Operating Support System (OSS). These are the Loop Test System OSS, Service Activation System OSS, and Loop Management System OSS.

3. **SALMS – Semi-Automated Loop Management System**. This is a semi-automated loop management system that fully automates a portion of the LMS functionality and leaves the remainder of the LMS functionality to be performed in a manual means via a Manual LMS. In this mode of implementation a portion of the LMS will operate seamlessly with the service company's OSS via the remote management interface, and the Manual LMS portion will operate with the OSS via a human operator input.

LMS Elements

The following section outlines key functionalities of various LMS elements.

The first two sub-sections contain drawings that show different ways an LMS could be used to provide connectivity between the equipment, the subscriber's loop and/or the Test Device.

The MAM and TAM are the LMS elements that enable the automation of the physical layer provisioning, test access, and maintenance. The Test Device performs the service testing. The Splitter is used for line-sharing applications on the loop. The Remote Management Interface provides the means to remotely control and manage the hardware elements.

Metallic Access Matrix

Input-to-Output (Provisioning)

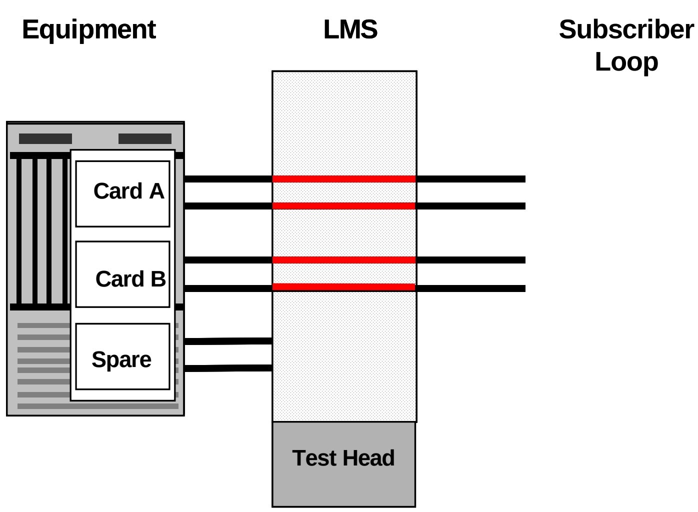

Figure 2

Multipoint (Provisioning)

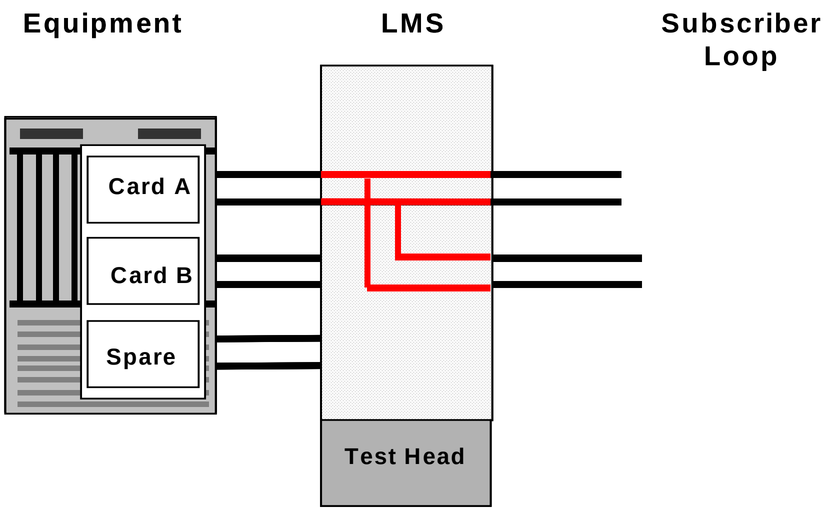

Figure 3

Test Access Matrix

Look-in

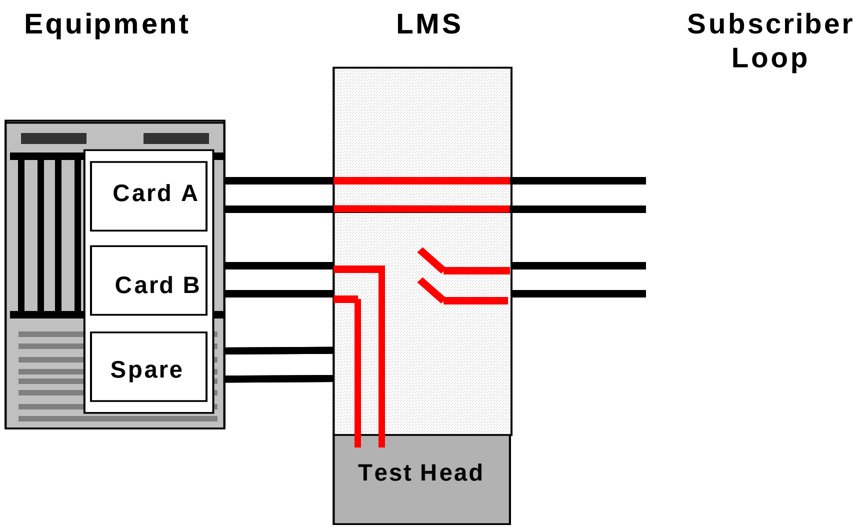

Figure 4

Look-out

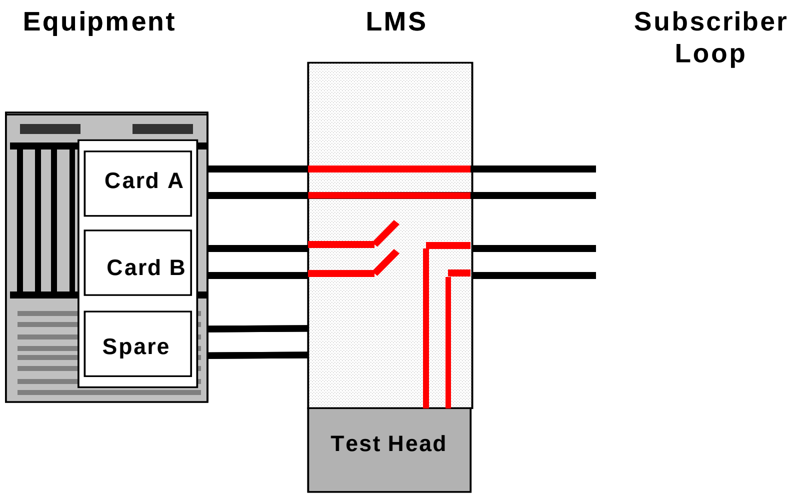

Figure 5

Monitor

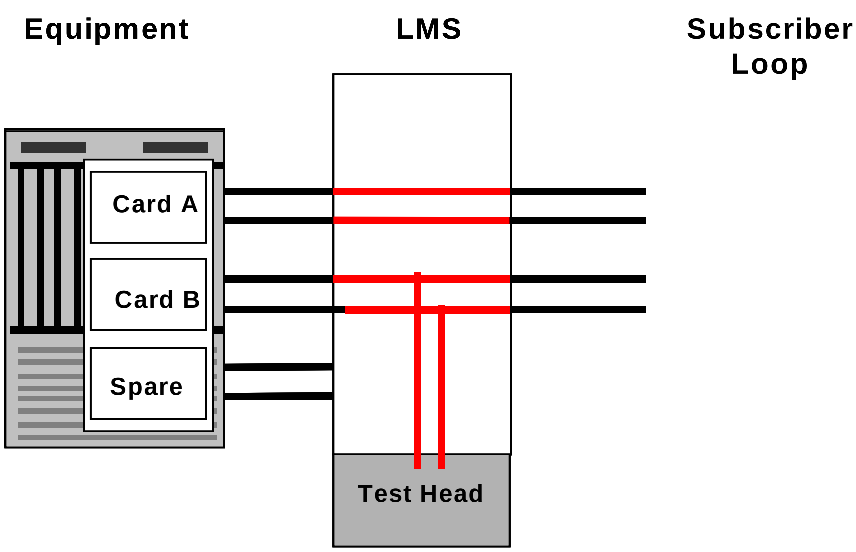

Figure 6

Multiple-pair LoopBack:

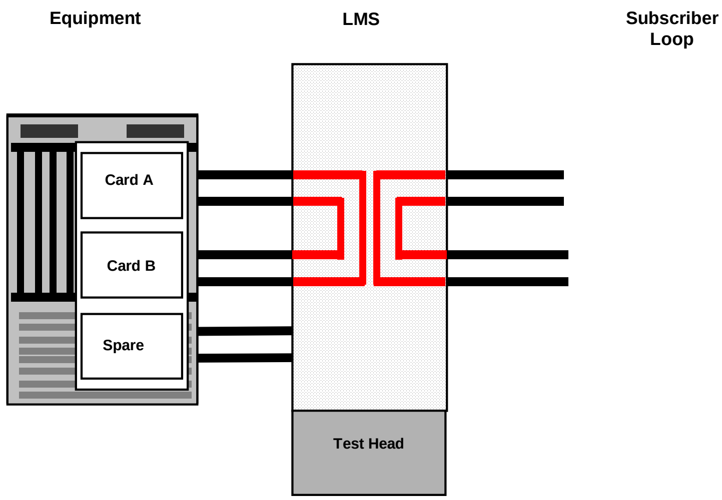

Figure 7

Single-pair Loopback:

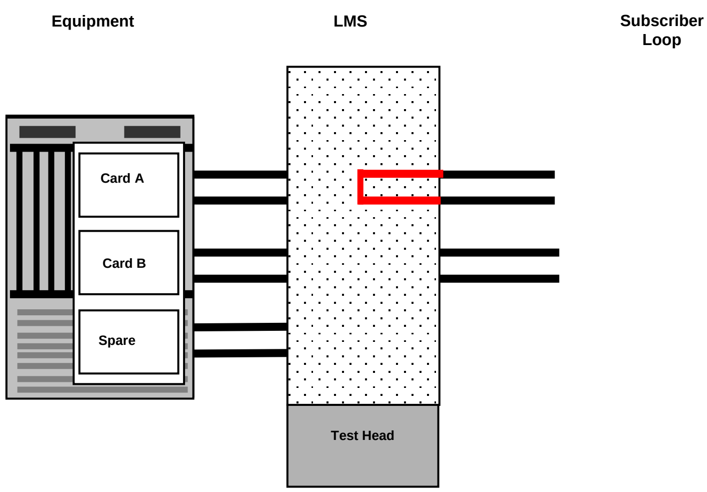

Figure 8

Test Device

LMS systems either have an integrated test device or the ability to connect to an external test head via a test bus and communication interface. Testing is a critical step towards the successful turn-up of a DSL loop. A test device can assist the service provider in all steps of DSL deployment – *before, during,* and *after* installation and turn-up:

- ***Before Service Turn-up*** – A test device allows the service provider to perform a pre-qualification of the loop to determine the quality of the loop and maximum transmission speeds.

- ***During Installation*** – Most test devices provide a locater tone to assist technicians wiring equipment to the Main Distribution Frame (MDF). This is a common feature found in most voice switches, but not in DSLAM equipment.

- ***After Installation*** – Many new troubles can occur after a DSL line has been in service, such as interferers introduced into the cable bundle (such as a T1 or E1 signal), wideband noise, technician wiring problems, and weather (wet lines, etc). Addressing troubles after turn-up with handheld DSL testers is very costly and time consuming. A test head, either internal or external to the LMS, allows the service provider to quickly and efficiently locate and solve problems. The baseline data saved during pre-qualification may be compared to subsequent test data to quickly isolate troubles. Some LMS test devices provide the ability to proactively test the circuit to ensure Quality of Service (QOS) and Service Level Agreements (SLA) are maintained.

This document does not attempt to describe the test functions that may be addressed in a future document.

Splitter

The splitter consists of a high-pass and a low-pass filter. It is used in line-sharing application where it separates and/or combines the voice and data signals. In some cases, the high pass filter is part of the DSLAM and is therefore not required in the splitter.

The splitter could either be an integrated part of the LMS or external to it.

The advantage of housing the splitter device inside the LMS is to provide greater flexibility in test access functions. This implementation also reduces the number of network elements.

When the splitter is external to the LMS, the service providers can field configure their LMS using components from their supplier of choice. Another advantage to this approach is that by isolating the functional circuits of the LMS only this portion of the LMS functionality needs to be disabled for repair or servicing.

By allowing the LMS to support both implementation approaches the service provider can select the optimal solution for their network operations.

Remote Management Interface

An essential component of an automated LMS is a remote management interface, which provides the ability to remotely control and manage the LMS. This management interface may be as small in scope as a simple craft port or as extensive as an interface into a carrier's OSS for automated provisioning and trouble ticketing. The subcomponents that define such an interface include the physical connection type (RS232, Ethernet, etc), the network protocol suite (X.25, TCP/IP, etc), and the application protocol (SNMP, TL1, proprietary API, etc).

As already stated, rapid service turn-up is one of the primary goals to facilitate widespread acceptance and deployment of DSL. Toward this end, carriers are deploying OSS software that better integrates the tasks of order entry, service turn-up, billing, etc. These connected systems are crucial to the "flow-through provisioning" whereby a simple order entry automatically triggers a cascade of events that result in service turn-up with little human involvement and delay. An automated LMS can be a vital part of such a solution if it supports the management interfaces needed to interface with the OSS.

Security

LMS access should be controlled since it can be shared among different functional groups in an organization or among different organizations if used in a line-sharing or wholesaling environments. For those reasons, it is paramount to provide a good level of security.

Maintenance and Service Issues

Since LMS is the transmission path of the access network, it should be reliable and serviceable. The reliability is achieved by designing the system with high Mean Time between Failures (MTBF) as well as redundant components. In the event of a power loss to the LMS or control link failure, customer service should not be compromised.

Glossary of Terms

Any-to-any matrix: A matrix where any primary access port can be connected to any of the tertiary access ports.

Blocking connection: A type of connection where all primary access ports can not be connected to all of the tertiary access ports. As the number of connections increases, it eventually reaches a point where some of the primary or tertiary ports can no longer be interconnected.

DSLAM: Digital Subscriber Loop Access Multiplexer.

Exception Matrix: A type of matrix that is used to temporarily route resources to a back-up switch, transmission port or card, or to a redundant DSLAM.

Intrusive connection/switching: A connection/switching that results in the interruption of service.

Line sharing: An application where the same loop is used for both voice (with low frequency) and data (with high frequency), usually achieved by using splitters.

Loop Management System (LMS): A system that may contain multiple elements to automate testing, provisioning, and maintenance functions, enabling service providers to install, troubleshoot, and maintain their local loops more efficiently.

Primary Access Port: The access port of LMS that terminated to the service company's provider line or subscriber lines. The final functional component is the secondary interconnection.

MDU/MTU: Multiple Dwelling Units/Multiple Tenant Unit.

Metallic Access Matrix (MAM): The heart of a LMS system that consists of access ports and secondary interconnect. It is one of the following- Test Access Matrix, Exception Matrix, Some-to-Some Matrix, or Any-to-Any Matrix.

Network Element: Equipment used in a circuit to provide service.

Non-blocking connection: A type of connection where any primary access port can be connected to any of the tertiary access ports.

Non-intrusive connection/switching: A connection/switching that results in no interruption in service.

Remote Management: Ability to manage the LMS from a remote location using a remote access device such as modem, Ethernet connection, wireless technology, etc.

Secondary Interconnect: The component that establishes the connection between the primary access ports and the secondary access ports in accordance with the general matrix type under which the MAM is classified.

Some-to-some Matrix: A matrix where a subset of the primary access port can be connected to a subset of the tertiary access ports.

Splitters A card that combines the high frequency and low frequency inputs so they can be combined and carried on to a single loop.

Tertiary Access Port: The access port of LMS that is terminated to the other side of primary access (i.e., subscriber lines and provider lines respectively based on the usage of the primary access connection).

Test Access Matrix: A matrix type that provides look-in, look-out, monitor or loop-back connection functionality for a connection of subscriber lines and/or provider lines to a test head/device port.

Test Device: An external or internal device that is used to measure the loop attributes (such as voltage, signatures, bridge taps, etc.) that determine the suitability of the loop for DSL services.

Appendices

Appendix A: Metallic Access Matrix Specification Consideration

General

In selecting an LMS it is important to take into account the type of Metallic Access Matrix (MAM) required to optimize the network operations. In general there are four basic types of MAMs, which are:

1. Test Access Matrix
2. Exception Matrix
3. Some-to-Some Matrix
4. Any-to-Any Matrix

Under each of these general types there are various functionalities that should be taken into consideration to determine the matrix type best suited for the specific operation. Before proceeding with a description of the general types of MAMs available and the functional consideration a brief description of a matrix has been provided below.

MAM Description

A MAM is designed to support the connection of subscriber lines to equipment ports or to a test device. The interconnection functionality in terms of how subscriber lines and equipment ports can be interconnected is what distinguishes between the different general matrix types.

In order to achieve this functionality a MAM is composed of the following functional components: (a) A primary access connection, which can be terminated to the service company's equipment ports or subscriber lines, or (b) A tertiary access connection, which can be used to terminate to the other side of the service companies network (i.e. subscriber lines and equipment ports respectively based on the usage of the primary access connection). The final functional component is the secondary interconnection. This component is used to establish the connection between the primary access ports and the tertiary access ports in accordance with the general matrix type for which the MAM is classified under. Regardless of the MAM type, the minimal interconnection capabilities must allow for a primary port to be connected to at least one tertiary port for all access ports supported by the MAM.

General Types of MAMs and Functionality Description

Test Access Matrix

The test access matrix type provides the following functionality for the connection of subscriber lines and/or provider lines to a test head port: look-in, look-out, monitor, or loop-back connection. The test access matrix should also provide the functionality for selection and connection of the test head port(s) to the selected line(s) for test. A test access matrix may also provide for the following optional functionality: the connection of subscriber, provider or test head ports to open, short or loads for reference/calibration measurements, as well as, single (i.e. 2-Wire Test Head for POTS, ADSL, SDSL, VDSL, etc.) or multi-pair (i.e. 4-Wire Test Head for T1, E1, HDSL, etc.) connections to a test device.

An important consideration for the monitor connection is the mode in which the connection is made. This connection can be made either intrusively (a connection that results in the interruption of service) or non-intrusively (a connection that results in no interruption in service. A non-intrusive connection can be achieved functionally (hardware operation of the monitor connection) or operationally (software-managed connection during a period of inactivity on the line). The exact connection mode supported by the Test Access Matrix should be evaluated on a service-by-service type basis since the parameters for defining intrusive or non-intrusive vary by the type of service.

Exception Matrix

An exception matrix is one that is intended to temporarily route resources to a back-up switch, transmission port or card, or to a redundant DSLAM. In addition, an exception matrix may also provide test access matrix functionality. An exception matrix is typically used to maintain service to the customer temporarily while the primary equipment can be services or reconfigured. Once the work on the primary equipment has been completed the resources are restored to their original assignments so that the exception ports are available as a back-up to other primary resources.

Since a switched connection by definition is intrusive (interruption in service) the mode of operation for restoring the connection to its original assignment can only be achieved non-intrusively through an operationally non-intrusive switch (software-managed switch during a period of inactivity on the line)

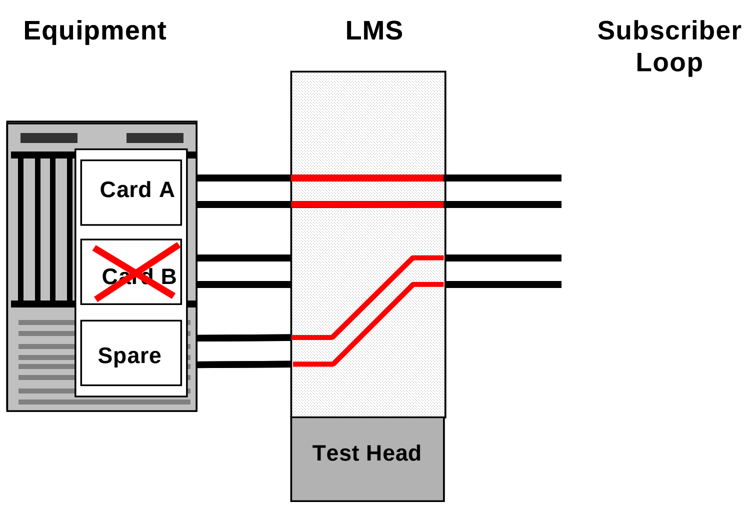

Figure A-1

Some-to-Some Matrix

An LMS with a some-to-some matrix is one where one of the following occurs:

a) A subset of primary access port can be connected to any of the tertiary access port through the secondary interconnect.
b) Any of the primary access port can be connected to a subset of the tertiary access port through the secondary interconnect.
c) A subset of the primary access port can be connected to a subset of the tertiary access port through the secondary interconnect.

The some-to-some connectivity supported by secondary interconnect is generally one of the two forms: (1) non-blocking within a subset (all connections within a subset are always supported), or (2) blocking (as the number of connections increase the matrix eventually reaches a point where some of the primary or tertiary ports can no longer be interconnected).

The non-blocking within a subset of a some-to-some matrix can be further classified either as intrusive or non-intrusive. In a non-intrusive non-blocking matrix, the interconnection between the access port takes place in such a way that there is no service interruption (as the hardware supports a parallel connection routing and/or software-managed connection between the primary and tertiary access ports.) In an intrusive non-blocking matrix, the interconnection between the access port takes place in such a way that results in a service interruption on an established connection (as the connection is rerouted to free-up resources for the new connection.)

Any-to-Any Matrix

An any-to-any matrix is one that supports the connection of all primary access ports to all tertiary access ports. In addition, an any-to-any matrix will support some-to-some matrix functionality, and it may also support exception and test access matrix capabilities. The interconnectivity between the primary access ports and tertiary access ports that can be supported by the any-to-any matrix is defined by the design of the primary access, tertiary access, and most importantly the secondary interconnection components. The secondary interconnection component will also structure the blocking ratio of the matrix system.

An any-to-any matrix design can be non-blocking without rerouting if the hardware is designed to support all connections. This applies regardless of the usage level and without interruptions to pre-established connections. The any-to-any matrix may also have a low probability of blocking. This possibility will occur as the number of connections increases, the matrix reaches a point where some of the primary ports can no longer be connected to some of the tertiary ports. The possibility that such a situation happens is called the blocking probability expressed based on the utilization percentage of the matrix connections. The potential for blocking in the service provider’s operation can be eliminated by designing the system to be operationally non-blocking.

There are two common approaches being used today to provide a physically and economically justifiable operationally non-blocking matrix. First, the any-to-any matrix can be operationally non-blocking with intrusive rerouting (hardware and software-managed design that supports all any-to-any connections such that service on an established connection(s) will be interrupted as it is rerouted to free-up resources for the new connection(s)). Alternatively, the any-to-any matrix can be designed to be operationally non-blocking with non-intrusive rerouting (hardware and software-managed design that supports all any-to-any connections such that service on an established connection(s) will not be interrupted as it is rerouted to free-up resources for the new connection(s)).

Appendix B: LMS Applications

There are two general applications for the use of an LMS inside of the local loop. These two general applications are (1) loop unbundling and (2) sub-loop unbundling. These two general applications can co-exist within the same local serving area. Within this section we have provided an overall diagram of where an LMS can be deployed in a local loop. We then go on to describe the typical LMS configuration and function at each area based on its applicability to the general application.

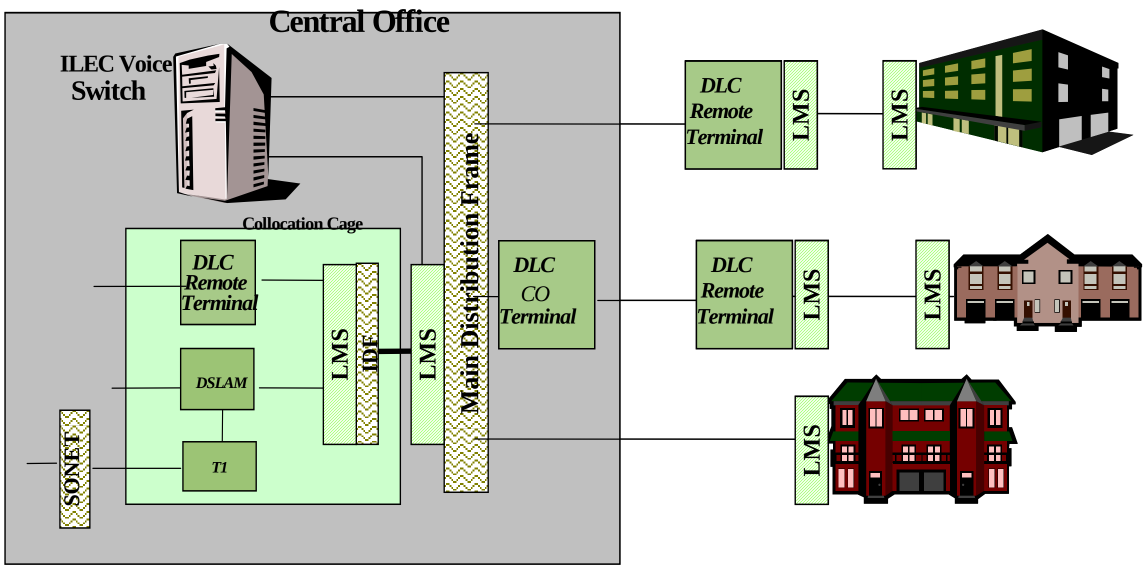

Figure B-1

Loop Unbundling Application

In a loop unbundling application POTS and/or DSL service is delivered directly to the customer over copper twisted pair from the local central office or exchange office. In this event the incumbent local exchange carrier has the opportunity to deploy an LMS of their own if they are providing both POTS and DSL service to their customer base. When a CLEC is implementing loop unbundling they will deploy their active transmission equipment (POTS DLCE and/or DSLAM) in the co-location space provided by the ILEC. In the case where one or more competitive local exchange carriers are delivering either POTS or DSL service to the customer base their exists the opportunity for them to deploy their own or a shared LMS.

Central Office: An LMS installed at this point of the network is the ownership of the ILEC. An LMS deployed at this point in the network can serve the following functions: DSL Test Access, DSL Line Qualification, DSL Performance Monitoring, Line Sharing (if the ILEC is offering both Voice and DSL service), POTS signal conditioning, DSL signal conditioning, coordinated cut-over (if a CLEC is present) and main frame distribution automation all through a remote management interface that can be controlled by the ILEC's Network Operating Center (NOC) or the CLEC's NOC. The exact components included with the LMS will be based on the ILEC's operation and service offering.

Co-Location: An LMS installed inside the co-location cage by a CLEC is typically deployed to provide the following functionality: DSL Test Access, DSL Line Qualification, DSL Performance Monitoring, Line Sharing (if the CLEC is offering both Voice and DSL service), POTS signal conditioning, service type provisioning, intermediate main distribution frame automation and/or co-ordinated cut-over between CLECs. All of this functionality can be accessed via a remote management interface controlled by the ILEC's Network Operating Center (NOC) or the CLEC's NOC.

Sub-Loop Unbundling Application

In a sub-loop unbundling application POTS and/or DSL service is delivered to the customer over copper from a remote terminal or from a co-location space inside of a multi-tenant/multi-dwelling building. The reason for taking such an approach is two-fold. First, the ILEC may have run out of cable pairs in the outside plant and is therefore using wiring fiber, T3, T1/E1 or some other multi-channel technology to deliver mass services out to a remote DLC. When this is done the access point to a single subscriber pair is moved out of the central office to a cabinet commonly referred to as a Serving Area Interface Cross-Connect (SAIC) cabinet. Secondly, due to the volume of telephone circuits and/or data circuits required to satisfy the needs of a multi-tenant/multi-dwelling building, these locations will typically be serviced by a multiplexed technology such as wireless, fiber, T3 or T1/E1. Again, when this is done the access point to a single subscriber pair is moved outside of the central office to the individual building.

When this approach is taken it becomes necessary for the ILEC and the CLEC to deploy signal channel transmission equipment at points in the network other than at the central office. This is necessary in order for the ILEC to offer DSL service to their customer base, and for a CLEC to gain access to the subscriber pair for competitive POTS and/or DSL service. This application poses several challenges for a CLEC to deploy competitive service since they now must gain access rights or negotiate with the ILEC for feeder access to the remote terminal or MDU/MTU. To overcome these issues many CLECs have taken the approach of feeding these remote locations via wireless or line-of-sight laser technologies. This application also introduces several challenges that both the ILEC and CLEC must contend with. These challenges include remote powering, remote power management, remote management communications, installing a controlled environmental vault for remote terminals or source hardened active equipment for use in traditional wire-line serving area cross-connect (SAC) cabinets.

Remote Terminal: In this application the remote terminal provides the same functionality as the central office for the ILEC and as the co-location space for the CLEC. Therefore, the same functionality for an LMS applies here as described for these related areas. The only additional consideration the service provider must take into account is the type of housing they will be placing their equipment in (i.e., environmentally controlled or traditional SAC box). Based on this consideration the service provider must select an LMS capable of operating in the selected environment.

MTU/MDU Co-Location: In this application the remote terminal provides the same functionality as the central office for the ILEC and as the co-location space for the CLEC. Therefore, the same functionality for an LMS applies here as described for these related areas.

Appendix C: Deployment Considerations

In order to determine whether an LMS will properly function in a specific application, there are several parameters of the LMS that must be scrutinized. These parameters define characteristics of the system that determine its ability to work across various DSL technologies and the extent to which the LMS will affect the DSL signal.

Some of these parameters include:

Frequency Limits - Some systems, especially test heads, may work properly only within a specified frequency range. This range will determine with which DSL technologies the LMS is compatible.

Voltage Limits - A carrier's plant may expose an LMS to a variety of high voltage signals (ringing voltage, CO battery voltage, etc). An LMS must be capable of performing its functions in the presence of these signals.

Cross-talk - Cross-talk describes the extent to which a given signal is affected by physically adjacent signals. Because loops are likely to have close physical proximity within an LMS, an LMS will affect the cross-talk characteristics of a DSL service. A good LMS will minimize the amount of induced cross-talk.

Return Loss - Any network element, including an LMS, will have a characteristic impedance, which can vary with respect to the loop's impedance. Return loss measures the degree to which energy is reflected back toward an energy source as a result of this impedance mismatch.