Introduction to Repeaters, the RIC™ and LERIC™ and Their Applications

National Semiconductor
Application Note 843
Larry Wakeman
Bill Carlson
May 1993

INTRODUCTION

The completion of the IEEE 802.3 10BASE-T Ethernet standard has introduced the need for new products in the LAN marketplace, the twisted pair multi-port repeater. The repeater, functioning as a centralized wiring hub for the 10BASE-T star topology, is experiencing a wide variety of requirements as the number of 10BASE-T users increases. (Note: In this document the terms Hub, Concentrator, and Repeater are used interchangeably.) Some want a simple, low cost repeater that can be used in a small office environment. Other's, foreseeing a need for expansion, need a repeater that can grow with their requirements. Large companies with hundreds of nodes need a large, expandable repeater incorporating features MIS administrators can use to control a complex, enterprise wide network. With the growing need for controlling and maintaining large networks, end users are also wanting 10BASE-T repeaters that offer both basic and sophisticated management capabilities.

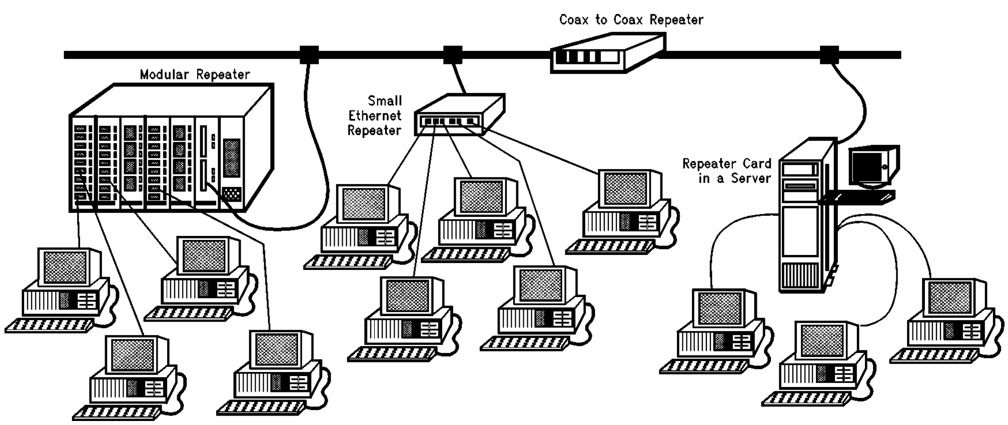
The LERIC and RIC repeater chips from National Semiconductor provide functions to meet a large variety of requirements for the repeater marketplace. Not only do these devices have the necessary features for implementing different management capabilities, but they also have many other important features that allow them to be effectively used in a wide variety of repeater architectures, from personal computer adapter cards to huge rack mounted systems containing hundreds of ports.

The LERIC, or LitE Repeater Interface Controller, is targeted at the smaller, cost sensitive applications, where basic management or no management at all is the only requirement. The LERIC can connect to 6 twisted pair segments and 1 thick or thin coax segment through its integrated 10BASE-T transceivers and AUI port. Statistics can be gathered from internal registers or from LEDs. It also has a simple bus for cascading many LERICs together.

The RIC on the other hand is for networks requiring full network management, from small or medium size networks expecting to expand and for the larger, corporate wide networks containing hundreds of ports. The RIC has twelve integrated twisted pair transceivers, an AUI port, and a cascading bus similar to the LERIC. It also has a management bus for easily obtaining the network statistics that are needed by high end network management software.

The purpose of this application note is to explain and define the use of 10BASE-T Ethernet repeaters incorporating the LERIC and RIC. The following subjects will be addressed in this application note:

- The role of the repeater
- Network management fundamentals
- Types of repeaters
- Basic repeater functions
- The LERIC and RIC architectures and their uses



TL/F/11493–1

FIGURE 1. Different Types of Repeaters and Hubs

Inter-LERIC™, Inter-RIC™, LERIC™, RIC™, and SONIC™ are trademarks of National Semiconductor Corporation.
Velcro® is a registered trademark of Velcro USA, Inc.

 RRD-B30M75/Printed in U. S. A.

THE ROLE OF THE REPEATER

The need for the multi-port repeater stems from the IEEE 802.3 architecture and standards. The 10BASE2 and 10BASE5 standards specify a coaxial cable media connected to a bus topology. 10BASE2 has a 185 meter cabling limit and 30 node limit per segment. 10BASE5 has a 500 meter length limit and 100 node maximum per segment. When the network requires longer distances or increased numbers of nodes, a repeater is necessary. While coax based Ethernet requires the repeater to be used to extend the maximum cable length, 10BASE-T twisted pair cabling requires the repeater to act as the central hub to implement its star, point-to-point topology. While it does serve to enlarge a network, its primary responsibility for 10BASE-T nodes is to allow them to access other nodes on the network. (Note: A single repeater connection is referred to as a port, i.e., a 12 port repeater can attach up to 12 cable segments.)

Figure 1 (on first page of this note) illustrates several repeaters used to expand and configure a network. There are four repeaters in this figure, each different, and each providing an example of types of repeaters most of which are described later in this paper. At the top there is a simple two port Coax Repeater; on the left is a modular (expandable) repeater for large networks; on the right is a server configured with a PC Hub Card converting a typical file server into a combined server-repeater (sometimes called a ''Serpeater''); and finally in the center is a simple small repeater for a small work group. Each of these example repeaters has a port to connect to the coax cable which is used in this example as a network backbone.

Since 10BASE-T is a star topology, the repeater becomes the network center, and each port of the repeater connects to a single individual node. While the 10BASE-T network requires the repeater function, increasing the materials cost over the standard coaxial cable implementation, the above features offer many advantages over 10BASE5 and 10BASE2 cabling. These reasons for the growing popularity of this form of Ethernet are:

- Utilizes existing data grade twisted pair cabling similar wiring scheme to phone wiring.
- Ethernet can be transmitted over low cost, standard telephone wire.
- Point-to-point wiring eases cable installation.
- Distributed star has a central hub for ease of network expansion.
- Topology and media type results in low installation costs.
- The hub enables centralized network management and centralized point for connection to other communications technologies.

While MIS is interested in the financial costs of owning the network, they also want more control over their networks to maximize up-time and minimize support costs. Network management provides this. Since network management is so important, what exactly is it?

NETWORK MANAGEMENT FUNDAMENTALS

Network Management is the process of monitoring and controlling various parameters to give administrators greater control over the networks they manage. There are 5 principle tasks and benefits of Network Management:

Types of Management		
Task		**Benefit**
Fault Management	→	Prevents network downtime
Configuration Management	→	Smoothes moves and changes
Performance Management	→	Makes effective use of network capacity
Accounting Management	→	Tracing network utilization
Security Management	→	Protects assets and resources

Management gives the network administrator a wide variety of significant, practical, and cost saving capabilities. For example, with fault management, a defective or non-compliant node can be partitioned off the network to prevent consuming up valuable bandwidth, without degrading the network. Performance management helps determine when, where, and what type bridge or router to install to optimize performance on a particular segment. Charging a department for excessive network utilization could be done with accounting management.

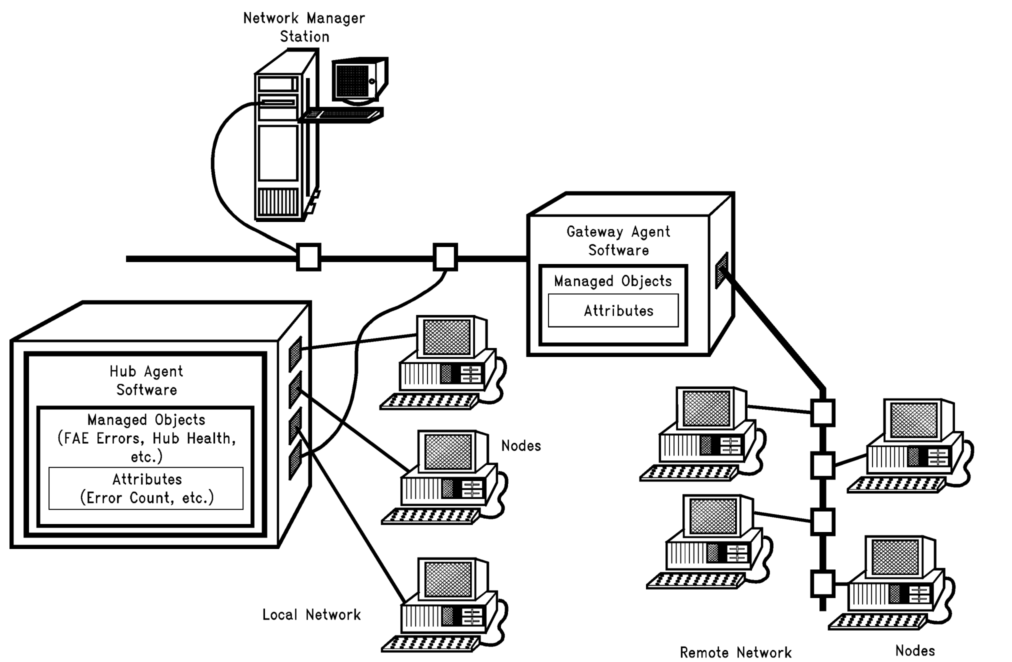
The 10BASE-T Ethernet topology is ideal for implementing network management. Because only one twisted node is attached to a port. In this point-to-point star topology, network statistics can now be collected in the repeater because each node is mapped to a particular port. The port can be individually isolated or partitioned from the rest of the network if it is defective.

It is this simple architectural feature that has compelled IEEE 802.3 Hub Management standards to solidify. These standards enable vendors to have a common reference point and give buyers the flexibility and assurances for hardware and software interoperability. These important benefits all rely on the hub as the central component of data transmission, expandability and manageability. It should be noted that ALL network components (Bridges, Routers, Servers, and Nodes) can contain some form of network management or some mechanism to make the control, maintenance and support of each device easier. It is also ideal if all network components could ''talk'' the same management language to simplify the monitoring of the entire network.

Before delving into the concepts of Network Management, managing a network involves a number of activites, and network hardware can be designed to provide several levels of management for repeaters. Generally the more powerful the management functions the more costly the product to purchase, but the more automated network support (and vendors would argue) the lower the support costs. These levels of management provided by repeaters can be broken up into three basic categories:

1. Minimal (or None): Typically no information is gathered by the repeater. There is no intelligence monitoring activities. However, generally some form of LED indicators are provided to enable visual inspection of the repeaters operation.
2. Out-Of-Band: Generally a lower cost method to gathering information than the In-Band. The Hub is intelligent and accumulates statistics. The user can only obtain these statistics through some visual alphanumeric display or more likely via a terminal attached to the hub. The major disadvantage of this technique is that it requires the network manager to either physically visit the Hub to determine its operational state, or to add a modem connection to access remotely. This has reduced the popularity for this solution.
3. In-Band: This method generally can obtain the same and in most cases more information about the network than the Out-Of-Band. The major difference is that this type of repeater has a node controller that can be addressed by a remote station over the network, and information can be transferred across the network. This allows the network manager to obtain the hubs information from any network location.

Within each of the last two categories there is further differentiation by how much data is gathered as will be explained later.



TL/F/11493–2

FIGURE 2. The Network Management Model

To further amplify the previous concepts, it is important to see how a repeater fits into standard network management mechanisms. *Figure 2* shows another typical network, this time illustrating the terms and concepts for network management. This concept applies only to a network fully capable of ''In-Band'' management. The terms are described below.

The *Network Management Station* is a node on the network running network management applications software. This station is where the administrator can access the managed objects. In an enterprise LAN, network management application software typically is able to control network segments other than the one it is on. For instance, in *Figure 2* the network manager software can be a node on one network segment while the managed entities are on another network segment (such as a PC on the right side of *Figure 2*).

The *Agent* is a network resource which receives commands from the manager to perform management operations and also reports status back to the manager. The agent is a separate piece of embedded software resident in the managed hub (or other device). This software communicates with the manager software via the network itself (in the case of In-Band management). Currently, standard protocols exist that enable Manager-Agent communication across multi-vendor environments. Ideally a standard protocol would allow a 10BASE-T hub agent from one manufacturer to communicate with the manager from another. SNMP (Simple Network Management Protocol) is one of these. Management application software from major manufactures use these protocols as the lower transport layer. For instance, Novell's Hub Management Interface (HMI) and Hewlett Packard's Openview use SNMP to communicate with their agents. In *Figure 2* the hub on the left and the Gateway on the right are shown to have agent software embedded in them. However, it is likely that the nodes would be running some agent software.

The entities being managed are called the *Objects*. Objects are various network statistics that are monitored and controlled by the network manager. Objects gathered by the agents depend on the type of network device (i.e., Node, Gateway, etc.). For Hubs and repeaters, objects include hub status, number of ports per hub, CRC Errors, FAE errors, number of good packets, etc. A defined set of objects are called a Management Information Base, or MIB. (Again, different pieces of network equipment can gather information for different objects, and hence support a different MIB.) For Ethernet repeaters objects are defined by the IEEE 802.3 Committee. The IEEE has standardized on the type of objects, their attributes and a database format in which an agent can present the information to a manager. As stated, this database is called a Management Information Base, or MIB. The IEEE 802.3 MIB consists of 34 attributes classified into 3 categories called capabilities. A table detailing the specific objects, and how they are supported by the RIC and LERIC is shown at the end of this note.

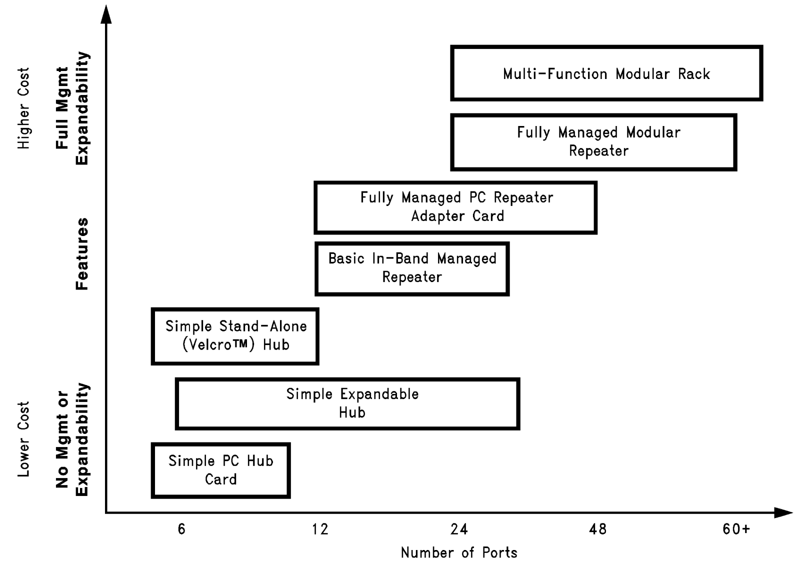
Attributes are parameters of an object that the agent collects on a per hub, group, or port basis. As described above for hubs, these objects include various physical layer parameters of an Ethernet node, such a CRC errors, collisions, packet length, as well as more general information such as the hub status. *Actions* are those that the agent performs on an object at the request of the manager. As an example, an action could be for the agent to partition a port from the network or to request the source address of the last packet received by the hub. *Notifications* are unsolicited reports of events that may be generated by an object. An example of a notification would be the hub agent communicating to the manager if a serious hardware error occurred.

The *Basic Control* objects consists of 19 objects which are mandatory, yet simple, for an agent to implement. Very little is required of the hardware as most of the objects are defined by the manufacturer in software. Certain key actions are partioning off a port and notifying the manager if a port is enabled or disabled or if it has been partitioned by the autopartition state machine.

There are 2 *Address Tracking* objects that are recommended. These objects provide the network administrator with information on the node addresses and changes that occur on a port. With the hub monitoring these, it is able to map each node's address to the port it's attached to and keep track of nodes that change port location. This could be from an administrator moving cables around or from a user moving Ethernet controller boards or swapping cables. Implementing the Address Tracking category is more complex for the hub as the source address of all the incoming packets must be detected and tabulated.

While the 13 *Performance Monitoring* objects are optional, they provide the most insight into the operation and characteristics of the network. Hubs that have this capability monitor CRC errors, collisions, PLL errors as well as many more. Doing this requires a lot of hardware sophistication.

These 3 categories were chosen by the IEEE Hub Management Task Force to give hub manufacturers the flexibility to design products with 3 different price and capability levels. This was done to prevent hub manufacturers from being forced to implement all 3 categories if only a low cost Basic Control hub is required. It should be noted that if a hub agent supports one managed object in a category, then it must support them all to claim IEEE conformance of that category. For instance, if a manufacturer's hub collects the number of transmit collisions a port experiences but is not able to count the number of frame alignment errors, then the vendor can't claim to support the IEEE Performance Monitoring category.



TL/F/11493–3

FIGURE 3. Examples of Different Types of Repeaters Plotted by Number of Ports versus Features

TYPES OF REPEATERS

Before discussing how the RIC or LERIC is used in various repeater applications, it is very useful to look at the kinds of repeaters typically available and what they are used for.

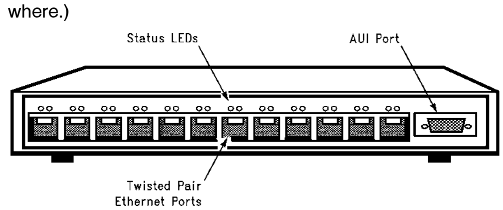
At its core a repeater function is a very simple concept (retransmit data coming in on one port out another port). Product differentiation comes from the features added to the basic repeater function. The key differentiators are number of ports, maintainability (really network management capabilities), expandability, and ease of integration into a network. The first two features are the most important and form the axis of *Figure 3*. This figure breaks down the repeater types into 7 basic categories. In any given feature category other port counts than those shown are likely, however, this figure attempts to categorize the most popular configuration sizes.

As networks grow larger they require the repeater to have more features, as this diagram shows. Larger installations require a repeater to be expandable. As the network grows the repeater must grow with it to minimize duplicating equipment purchases. Having proper expansion capabilities enables this. These larger installations also require standardized network management that communicates across vendor boundaries. On the other extreme are the smaller offices where low cost and ease of use are the primary issues. These environments experience limited growth (a small dentist's office for example) so expandability is not as important either.

In the following sections we will describe the basic functions and features of these 7 repeater types.

SIMPLE STAND-ALONE HUB

The simple stand-alone hub as shown in *Figure 4* has between 6–12 ports, doesn't have any management, and isn't easily expandable. This type of repeater is a fully self contained box, containing the repeater function, and power supply. (Note the term Velcro® hub is applied because the small size of these hubs let you stick them almost anywhere.)



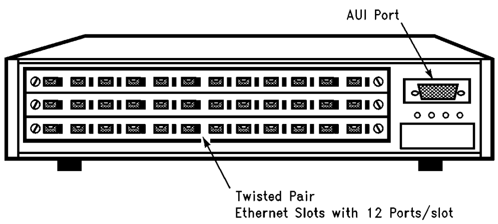
TL/F/11493–4

FIGURE 4. Simple Stand-Alone Repeater

The primary features of this product is its simplicity and low cost. This hub is simply intended for a small network where the users needs and understanding are simple. The user places a high value on a simple ''plug-n-play'' box. For maintenance and troubleshooting, this type of hub would have some status LED indicators, at least receive and collision activity LEDs for each port. This facilitates simple diagnostic on the network. These hubs typically provide an AUI (Attachment Unit Interface) port to connect to an existing 10BASE2 or 10BASE5 Ethernet LAN. The AUI can also be used to cascade other repeaters boxes if needed. However, this method of cascading is relatively more expensive than using an expandable repeater because expansion is probably through external MAUs (Media Access Units) and the proper cabling. Expansion can also be accomplished by cascading 10BASE-T Ports but this reduces the number of available ports by 2.

SIMPLE EXPANDABLE HUB

The simple expandable hub is essentially the Stand-Alone hub, but designed with card slots to facilitate the addition of more ports into the repeater chassis (as shown in *Figure 5*). This is used when a network is expected to grow but not too large. These hubs could support up to 24–36 nodes. The key feature of this type is its ability to expand very simply and inexpensively. These hubs typically use a proprietary bus to cascade 6 or 12 port repeaters together. This bus implementation is less costly than using coax to cascade repeaters.



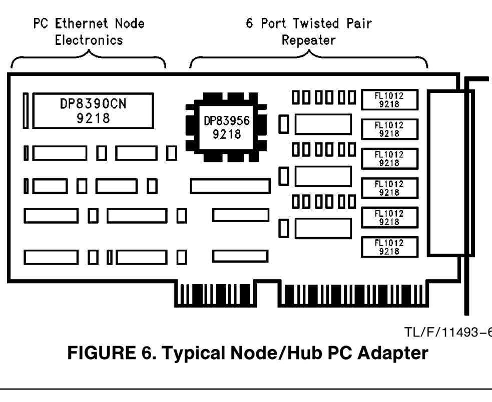
TL/F/11493–5

FIGURE 5. An Example of a 36 Port Modular Repeater

Like the Stand-Alone repeater this repeater usually implements LED status indicators, but usually does not provide sophisticated management. In some cases an add-in card for out of band management (including a CPU and RS-232 port) may be available, however most of the implementations desiring management are trending to add in the flexibility of the Managed Modular Repeater discussed later.

SIMPLE PC HUB CARD

The concept of a PC add-in card that includes the function of a repeater is relatively new, but (due to the prevalence of PCs) provides a lot of features and benefits when compared to other options. The basic idea is to add a repeater to an Ethernet adapter, thus creating a card that when added to a PC very inexpensively turns a PC into a central control point for a typically small network. A PC equipped with this card can be used as a server-hub, or just provide a hub at less cost than the Stand-Alone Repeater (primarily because the adapter hub does not need to have a case or power supply). A typical example is shown in *Figure 6*.



TL/F/11493–6

FIGURE 6. Typical Node/Hub PC Adapter

There are two major categories of repeater cards, a high end managed card (discussed later) and a low end simple card. The low end implementation typical implements 4–6 10BASE-T ports (6 RJ45 connectors is the maximum that can fit through the back slot of a PC), and possibly include either an AUI or 10BASE2 connection. Some implementations provide a slave repeater card (containing only the repeater) that can be cascaded to the master Ethernet adapter-repeater card. This allows some expansion capability.

In addition to low cost, the advantage of this application is that user friendly utilities can be written for the PC to enable some form of management to be implemented inexpensively (usually just the Basic Control objects are supported). The major disadvantage is that if the PC is switched off then the network goes down.

BASIC MANAGED REPEATER

One might think that a basic managed repeater without expandability would not have any application, however, there are two good applications for this repeater, and as costs for the management function drop the incremental price for added management functionality will become more popular. In one case, if the end user of a small or medium sized network is sophisticated enough he may desire a greater understanding of network health and thus need more thorough management capabilities.

Another popular application for this repeater is in a small semi-isolated work group in a sizable network. The work group itself may not require expandability, but since this work group is part of a large network then it is likely that this hub will be maintained by a central MIS organization. This organization will demand consistent hub maintenance to the rest of the network, and will require more sophisticated management than for a Stand-Alone Hub. This type of repeater looks much like *Figure 4*, but internally several component functions have been added.

Extensive management capabilities include the implementation of Performance Monitoring, Address Tracking and Basic Control MIB object tracking capabilities. Typically a CPU and a network interface controller provide the management function. This would allow the hub to be an addressable node on the network and the hub could be controlled remotely via the manager. This hub would require more memory and a larger power supply. Also the communications protocol, SNMP for example, running on this hardware platform. Typically this hub implements the IEEE 802.3 Hub Management Basic Control objects.

FULLY MANAGED PC HUB ADAPTER

This adapter hub is conceptually similar to the low cost PC hub card, except that two major features are added: 1) Extensive Management and Diagnostics are provided, and 2) Each card supports 12 ports by using a high density connector to get the cables out of the PC, and an additional breakout box to convert to 12 RJ45 connectors.

This card's application is in high end corporate servers, and has been spurred by Novell's creation and promotion of HMI (Hub Management Interface) which provides a driver level mechanism to gather IEEE hub management objects. Due to the large network environment a more sophisticated repeater is required as it is necessary to gather all IEEE hub management objects.

A server-repeater (Serpeater?) facilitates a number of possibilities in the corporate network environment. It enables very centralized total network services. A single box can provide not only file and print services, but can also provide routing, bridging and repeating. This potentially can ease network maintenance, and simplify configuration. However, as before the PC mechanically does not make a good repeater primarily due to the card slot form factor, and due to the limited expansion capabilities (usually it is difficult to add more than 48 ports to a server without using external repeaters.

FULLY MANAGED MODULAR REPEATER

For larger networks or workgroups all levels of in band network management are required. Like the Basic Managed Repeater, and the Fully Managed PC Hub Adapter, Performance Monitoring, Address Tracking and Basic Control capabilities need to be incorporated into the hub. This hub is shown in *Figure 7*.

Larger networks, 24–60 nodes, not only require full network management but now expandability is a very important issue. One can think of these repeaters as being very similar to the Simple Expandable Hub except that a high performance management agent is required and the expansion options tend to be more varied to support a large multi-vendor network.

MULTI-FUNCTION MODULAR COMMUNICATIONS RACK

A short conceptual jump from the Fully Managed Modular repeater is to support other communications technologies, such as Token Ring, FDDI, Routers, gateways, and potentially servers. These multi-function communications equipment is for only the large networks, so extensive, computing power is required. Because of the level of network management required of these repeaters, sophisticated yet proprietary management applications software is typically offered by the manufacturer. This software would run over standard protocols however.

BASIC RIC AND LERIC REPEATER FUNCTIONS

The previous section focused on the feature and function differences of the various repeater architectures, highlighting their advantages and disadvantages. However, each hub contains the same basic repeater functions as defined by the IEEE. This is key as repeaters from many manufacturers need to communicate with each other and Ethernet DTEs.

This following section describes the basic repeater functions that all repeaters must have. The description is given by using the RIC/LERIC architecture. It is possible to implement the repeater issuing different functional partitioning, however, the functions of a general repeater are basically the same. The block diagram of *Figure 8* shows the major functional blocks of a RIC or LERIC based repeater that implements the requirements of the IEEE and upon which the repeater products described earlier can be built.

It should be noticed what is *not* included in the repeater architecture. There is no complete MAC or Media Access Control unit. MACs are used by Ethernet controllers to implement the CSMA/CD protocol for gaining access to the media. Also, repeaters don't do address filtering or routing. These are done by gateways and bridges. Repeaters simply repeat the data that is received from one port and transmit it to all the others. The repeater has to re-time the received packets and remove accumulated jitter. The repeater must also not allow defective nodes to consume network bandwidth.

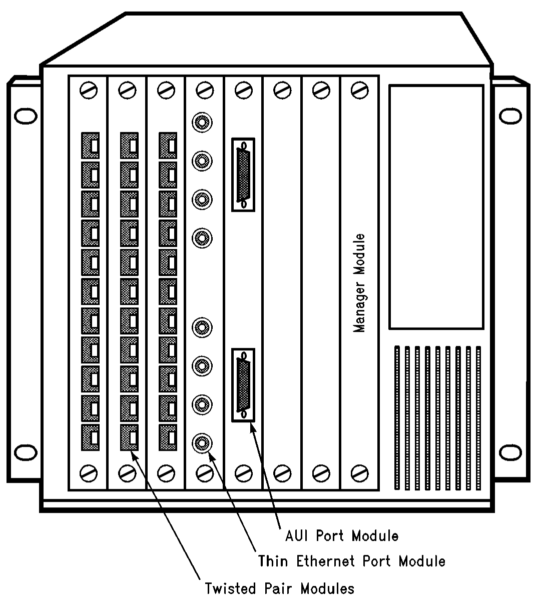


FIGURE 7. Typical Modular Repeater Including Options for Multiple Cable Media and Network Management

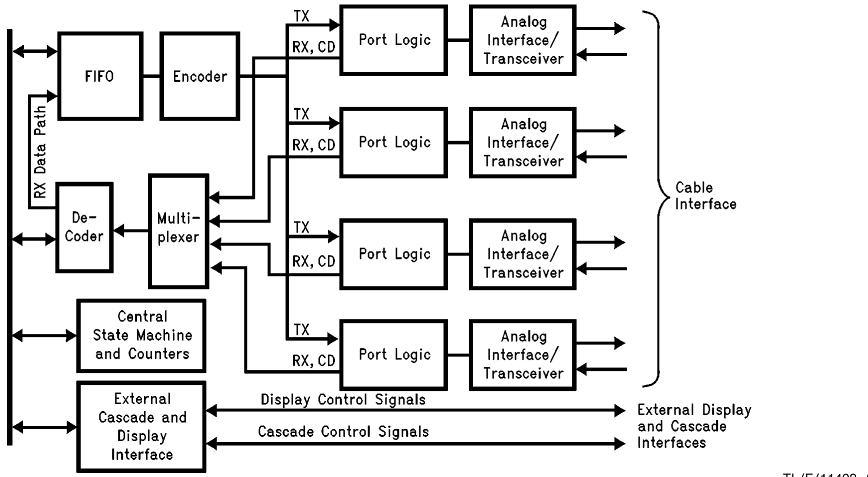


FIGURE 8. Simplified General Block Diagram of the Core Repeater Functions of the RIC and LERIC

PORT SPECIFIC FUNCTIONS

Within a repeater there are functions that are shared by all the ports and those that each port duplicates for itself. As the diagram shows, there are 5 functional blocks that are identical for each port.

Analog Interface/Transceivers. This block is not actually an 802.3 requirement. In a general repeater this function is required to connect the repeater to the media, and is generally incorporated into the repeater box, but it is not actually part of the repeater standard. Most integrated repeaters implement either a transceiver interface or all or part of a transceiver. In the case of the RIC/LERIC, this block includes all functional and electrical specifications to interface to a particular transmission media (coax, twisted pair, fiber). It should be noted that with the exception of the transceiver, everything about the repeater is independent of what media is attached to the ports. When the transceivers are for twisted pair, they monitor the link integrity of the attached segment.

Port Logic. This block performs many different functions. There are two different state machines for each port. One is called the Port State Machine, or PSM. This state machine is linked with all the other PSMs to perform port arbitration. This arbitration is needed to determine which port should be the source of data or collision information when multiple ports receive data simultaneously. The winning port is called Port_N or Port_M depending on the type of activity. Port_N is defined as the highest priority port experiencing receive or collision activity. Port_M is defined as the highest priority port that is last experiencing a collision. This state machine is also used to detect collisions and indicate them to the other ports. The second state machine implements the port auto-partioning algorithm. When a port experiences more than 30 consecutive collisions, this state machine prevents any further data on this port from being repeated on the network. This effectively blocks it off. The port is re-enabled when a packet is successfully received or if a packet is transmitted to it.

The port logic also monitors a port to determine if a transmission exceeds a specified limit, and if so turns off that port so it doesn't bog the network down. The port is re-enabled after a specified time period has elapsed since the transmission ended.

CENTRAL REPEATER FUNCTIONS

All repeaters tend to have some functions common to the individual ports implemented as a central function. The RIC/LERIC are typical implementations and implement the following blocks as a central function.

Multiplexer. This function multiplexes the packet from Port_N to internal functions in the repeater.

Decoder/FIFO/Encoder. The Decoder/FIFO/Encoder plays an important role in the recovering and re-timing the Ethernet data. As a signal travels from the DTE to the repeater several factors degrade the quality of the signal, and the repeater must remove these distortions before re-transmitting the data.

1. The signal transmitted down the Ethernet media accumulates jitter due to the different impedances, noise, and discontinuities in the cable.
2. The preamble of the receiving packet is shortened. This caused by the signal being attenuated and delays in the squelch circuitry being activated.

This block helps to eliminate these degradation. It has a phase lock loop which removes jitter. The packet is then sent to the FIFO. The FIFO buffers the data portion of a packet until a proper length preamble can be transmitted by the ports. The FIFO also compensates for data rate differences between the node and repeater. The encoder puts the packet back into manchester form, but now encoded without jitter and at the proper frequency.

Central State Machine and Counters. These functions form the heart of the repeater. They control the port logic and the majority of data and collision propagation operations as defined by the IEEE specifications. This block insures minimum packet fragment length and controls the FIFO to insure that the preamble is of the specified length. Collisions are also handled here. When a port is repeating a packet and senses activity on its RX± pair a transmit collision will result. The central state machine will transmit a jam pattern to all the ports to inform the attached nodes of a collision. This block also implements other IEEE defined timings and functions central to the repeater function.

Display Devices and Drivers. While not required by IEEE, some form of status display information can provide indication of repeater health. This block takes various signals from within the repeaters and makes them available to the display.

Cascade Logic. For a modular repeater this logic provides the key internal arbitration and data signals externally to facilitate the addition of additional repeaters/ports to the repeater system.

THE LERIC AND RIC ARCHITECTURES AND THEIR APPLICATIONS

The LERIC and RIC are National Semiconductor Corporation's solution to the implementation of IEEE 802.3 compatible multi-port repeaters. The LERIC and RIC offer all the features needed to address this marketplace. One of the most important features is the ability to support network management. The LERIC and RIC offer different levels of network management. As stated at the beginning, the LERIC is focused toward applications in small networks where basic management or no management at all is required. The RIC, on the other hand, is ideally suited for large networks where performance monitoring in addition to basic management capabilities are required.

THE LITE REPEATER INTERFACE CONTROLLER

The LERIC is a fully IEEE compliant repeater using as its core the general repeater architecture described previously. It adds all the features needed to be effectively used in its intended applications: the smaller networks where limited management is the only requirement. In these applications, Basic Control management is easily accomplished with the LERIC.

The LERIC, in addition to the basic repeater blocks discussed earlier has a number of specific feature blocks that are described in the following sections.

Six Twisted Pair Transceivers and AUI Port. 10BASE-T transceivers are integrated onto the LERIC to save board real estate. The transceivers meet the IEEE 802.3 10BASE-T specifications. The transceivers can be disabled, and turned into pseudo-AUI ports for connection to coax or fiber transceivers. While not fully AUI driver level compatible, they can drive a short distance on a PCB for connection to these alternate transceivers. The LERIC also has a single fully IEEE compatible AUI port that can drive a standard 50 meter AUI cable or can connect to a coax or fiber transceiver directly on the PCB. This port is typically used to enable the LERIC to connect to a network backbone.

CPU Bus. The LERIC has a bus so a CPU can access internal registers of the LERIC. One of these is a status register that indicates if any port is experiencing a reception, collision, partition, or if the LERIC is jabbering. In addition to the LERIC status register which indicates status for the entire repeater, each individual port has its own status register, called the Port Status and Configuration Register. Each port can be configured through this register. A port can be disabled and the squelch level be reduced to handle special cable conditions.

The CPU bus is multiplexed to provide the signals to perform the Mode Load self-configuration and is the pathway for the LED status signals as described below.

LED Display. The LERIC provides information to driver LEDs through the multiplexed operation of the CPU bus. Low cost 74LS259 addressable latches are used externally to latch the CPU bus and drive the signals to the LEDs.

The LEDs are used for visual monitoring of the repeaters status. There are two modes of LED display in the LERIC. In maximum mode, 5 LEDs are provided for each of the twist-

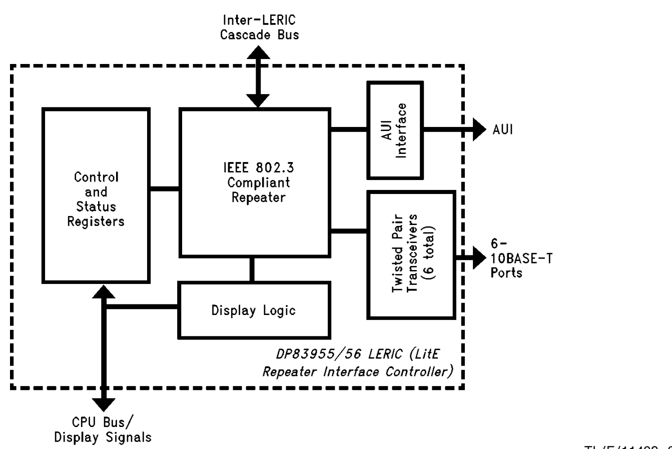


FIGURE 9. Simplified Block Diagram for LitE Repeater Interface Controller

ed pair ports to indicate reception, collision, partition, polarity, and link status. The AUI port has LEDs for collision, reception, and partition status. There is also and LED to indicate jabber status of the repeater.

Mode Load. An important feature of the LERIC is its ability to perform a hardware self-configuration. Simple pull-ups and pull-downs are attached to the CPU bus in a configuration suited for the particular application. When the mode load signal is asserted, the bit pattern defined by these resisters is loaded into the LERIC and it is configured. This operation is typically done for power-on configuration of the LERIC, but can also be used whenever LERIC needs to be reset and reconfigured. Options such as twisted pair or pseudo-AUI port definition, external PLL, LED display mode, and others are loaded here.

Inter-LERIC Bus. The Inter-LERIC bus is used for cascading multiple LERICs and interfacing to a network controller for In-Band hub applications. There is often the need to have more than 6 ports and/or a network controller so having a simple, but powerful way to expand is very important. The Inter-LERIC bus consists of three groups of signals:

- *Port Arbitration Signals*. These signals provide a way for multiple LERICs to arbitrate for Port_N and Port_M status. The port arbitration signals essentially connect the arbitration logic of the port state machines together.
- *Status Signals*. The status signals indicate receive data activity and collision status of the network and communicate it to the different LERICs.
- *Data Signals*. These signals actually transfer the repeated packet from the LERIC containing Port_N to all the other LERICs and to a network controller if there is one in the system. Packet data from the receiving LERIC is decoded from manchester and put into serial NRZ form before being driven onto this bus. The rest of the LERICs read the data and encode it back into manchester before transmitting the data to the ports.

There are two versions of the LERIC, and the major difference is the implementation of the Inter-LERIC bus. On the DP83955, the bus is designed with fewer signals intended for limited cascading primarily on a signal card. The DP83956 has the same bus as the RIC (DP83950) and therefore can be easily externally buffered and cascaded over large buses or many cards.

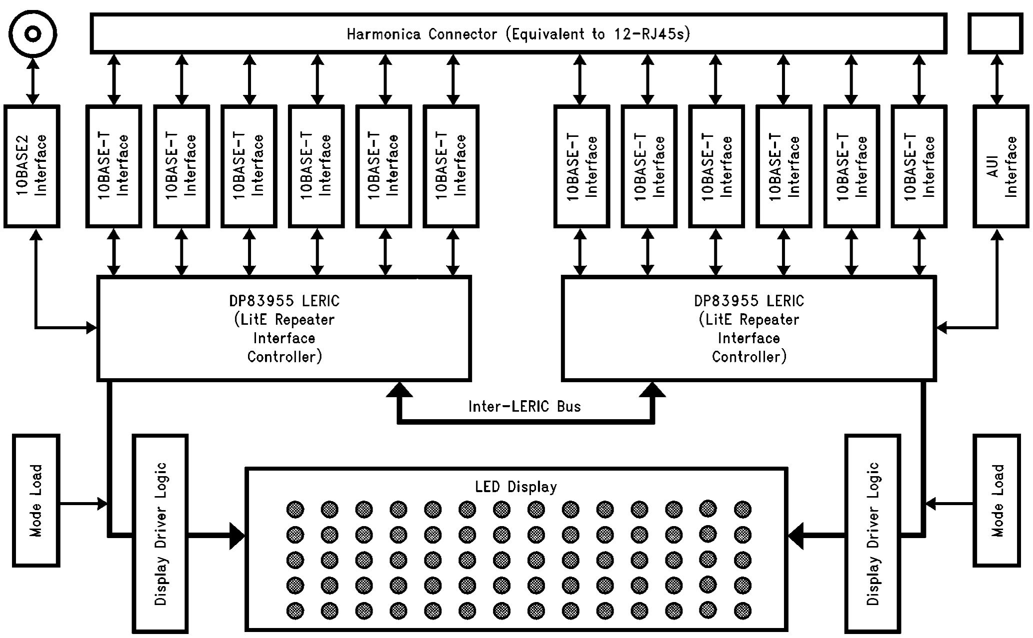
LERIC APPLICATIONS

The LERIC fits in designs at the lower end of the Port and Feature spectrum of *Figure 3*. These applications are described in the following.

Simple Stand-Alone Hub

This design is very straightforward. In the example of *Figure 10*, a 12+2 Hub, two LERIC's are used. These two chips are cascaded directly through their Inter-LERIC bus. The media interface to twisted pair is very simple requiring only a few buffers, filters and transformers. The status indication for each port is displayed via an LED array, this array is connected to each LERIC's CPU/LED bus, and feeds some 74LS259's which drive the LEDs.

This simple interconnection of 2 LERICs and minimal external logic enables the design of a very compact hub.



TL/F/11493–10

FIGURE 10. Simple 12 Port Twisted Pair Hub with both a Thin Cable and AUI Connection

Simple Expandable Hub

This application builds on top of the previous simple hub, and adding some buffer logic onto the Inter-LERIC bus. The biggest design change is really mechanical. Rather than a single PCB design as in the Stand-Alone Hub, this design is usually based on some form of card cage or plug-in slots.

Figure 11 shows a block diagram for a 6 port module that could be plugged into the card cage with other similar modules to make this a versatile setup.

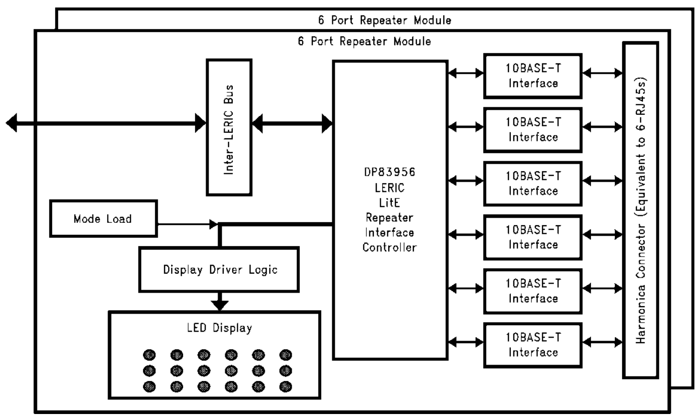
Simple PC Hub Card

This repeater takes advantage of the PCs power supply, enclosure and CPU. As mentioned this architecture takes advantage of the PC to provide a very flexible repeater and adapter card combination. The DP8390 Network Interface Controller with its buffer RAM and bus interface provides the MAC to the network and buffers packets to a local memory for later processing. This allows the card-PC to act as a typical network attached computer. This implementation also connects the LERIC's Registers to the PC bus, enabling PC based software to provide basic managed objects.

Typically this type of design has between 4–6 RJ-45 ports. Six is the maximum number of RJ-45s that can be accessed through the standard PC's back slot opening. The AUI port interface shown in *Figure 12*, is typically brought out a separate slot if needed.

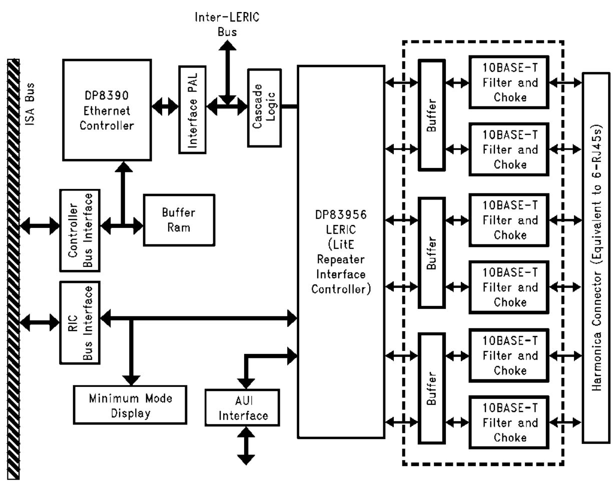
The cascade port is usually connected to other cards via a ribbon cable. When more ports are required, additional slave LERIC adapter cards can be cascaded to the main master card through the buffered Inter-LERIC bus (top of *Figure 11*).

Unlike previous examples, the display interface is typically very simple. Minimum mode display give some general purpose display which is typically used for installation diagnostics. (For run time diagnostics a software implementation can be developed to display the ''LED-like'' symbols on the PC's display.)



TL/F/11493–11

FIGURE 11. Module Hub with 6 Port 10BASE-T Modules



TL/F/11493–12

FIGURE 12. Simple PC Hub Card Block Diagram

Low End In-Band Managed Hub

There are many applications of the LERIC where it is focused at smaller networks under 24 ports where full network management isn't needed. This repeater configuration supports the Basic Control capability of an IEEE MIB. The LERIC is able to turn ports on and off and indicate their status to a requesting manager. Address Tracking is possible, by using the NIC in promiscuous mode. Performance Monitoring is not possible with the LERIC because it doesn't have the capability to gather all the required physical layer statistics.

As can be seen from *Figure 13* the block diagram for this type of hub is very similar to the PC Hub card except that a CPU and RAM/ROM are added, and the port restrictions of the PC do not apply. The internal registers of the LERIC are easily accessible by the host CPU so management information can be easily collected.

THE REPEATER INTERFACE CONTROLLER

The DP83950 RIC is a high end, feature rich device which implements all the required functions of an IEEE compatible repeater along with many additional features that enable it to gather all the mandatory, recommended, and optional IEEE capabilities for network management. The RIC is intended for networks requiring full network management now or the need for it in the future.

To compare the RIC and LERIC, they both have a cascading bus for expandability. In fact, the Inter-RIC™ bus and the Inter-LERIC™ bus are identical between the DP83950 and the DP83956, and can be connected together (The DP83955 Inter-LERIC bus is slightly different but still compatible).

Another difference between the RIC and LERIC is that the RIC contains 12 transceivers verses the LERICs 6. However, like the LERIC these 12 RIC ports can be selected to be configured as either pseudo-AUI port or twisted pair. The RICs internal twisted pair transceivers are identical to the LERICs.

Both the RIC and LERIC have the same modes of LED display. Like the LERIC, the RIC also can be configured with the Mode Load operation, but it is more likely to be configured by a CPU that typically resides in larger hub configurations.

By far the most outstanding difference between the RIC and the LERIC is their level of network management statistics gathering capability. Because the RIC is focused at the larger networks where full management is required, it has a much wider array of management components. There are two sources of network statistics in the RIC:

- Status, Event Record, and Event Counting registers, and Interrupts
- Management bus

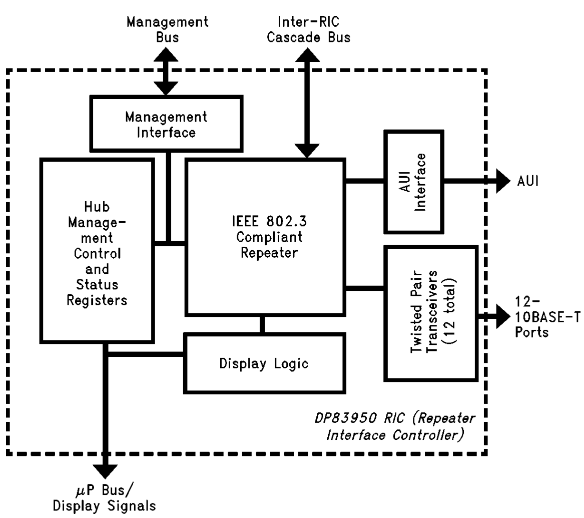
Internal Registers. Like the LERIC, the RIC has status registers that give repeater status and individual port status. In fact, these registers are very similar except the RIC provides more port status information. What makes the RIC different are the Event Record and Event Counting Registers, and the two interrupt pins. Each port has one each of these registers and they collect the important physical layer statistics that are needed by the IEEE Performance Monitoring objects.

Events in the status, Event Record and Event Counting can generate interrupts to the CPU through either the Real Time Interrupt (RTI) or the main Interrupt pin. This facilitates real time statistics gathering.

The Event Counting register counts a single network event on its every occurrence. One of 11 events are available to chose from which is done by software through a mask register. This function is particularly useful to count a rapidly occurring event, such as collisions. When the counters reach one of several chosen thresholds, they can interrupt the CPU.

The Event Record register is more flexible but requires more attention by the CPU as it provides real time status information. This register can be configured to log the occurrence of up to 8 events in a byte wide register. Not all 8 need to be logged and can be chosen through a mask register. Every time an unmasked event occurs an interrupt can be generated.

The other registers in the RIC allow software to quickly isolate which port is the source of activity without having to poll each register.



TL/F/11493–14

FIGURE 14. Simplified DP83950 Block Diagram

The Management Bus. Collection of a wide variety of network statistics is a major feature of the RIC, and the management bus is the RIC's most powerful pathway to communicate this information to an intelligent repeater system. The RIC couples to an Ethernet controller to form an intelligent, In-Band repeater. The management bus is similar to the data signals of the Inter-RIC bus. What makes the management data signals different from the Inter-RIC bus is that per packet statistics associated with the currently repeated packet are appended to the end of the packet on the management data signals, as shown in *Figure 15*.

The information sent on the management bus is contained in the seven additional bytes the RIC appends to the end of the packet, as shown in *Figure 16*.

These seven status bytes are on a serial data bus and are sent to main memory by adding a custom circuit, or more typically by a network interface controller. This can be accomplished using the DP8390 NIC or the SONIC™. There are advantages and disadvantages to all three approaches.

Designing a custom de-serializer circuit which converts the serial management data so that can be read by the host CPU takes design time but the interface can be tailored to the systems interface of the repeaters architecture. Since the repeater is In-Band, and Ethernet controller is still needed somewhere in the system.

Secondly, the NIC offers a low cost solution to buffering the management information to memory. A somewhat faster CPU (than in the first or third options) may be necessary to ensure that the NICs buffer does not overflow due to the large number of packets received by the hub.

The third solution is to connect the higher performance SONIC controller to the management bus. The SONIC provides signaling to enable the use of a special feature of the RIC-SONIC interface which is the ability to optimize packet storage and bus bandwidth by eliminating the unnecessary data field from packets (except for management packets which are addressed to the SONIC where the data field must be retained). This feature is called Packet Compression.

There are several advantages to the management bus:

- In a multi-RIC repeater, the management status bytes are mostly available from one source. This saves a processor from having to read data from a multitude of sources.
- CPU performance requirements may be reduced since using the management bus for gathering of network statistics and buffing from the CPU eliminates most of the real time processing required when statistics are gathered entirely by using the RIC's registers.
- The management bus records interframe gap time which allows the administrator to see if there are any nodes that violate this important IEEE spec.
- When using a SONIC controller, packet compression can be employed, and this can further reduce system overhead, by eliminating the buffering of packet data. The SONIC only has to buffer the 21 bytes (7 status + dest. address + source address + type/length field) in 6 32-bit write operations. This can be done very quickly, (<1 μs).

The management bus architecture is particularly cost effective for in band management hubs. These hubs will require an Ethernet controller to communicate to the Network Manager, and in this case the use of the management requires no addition logic to implement.

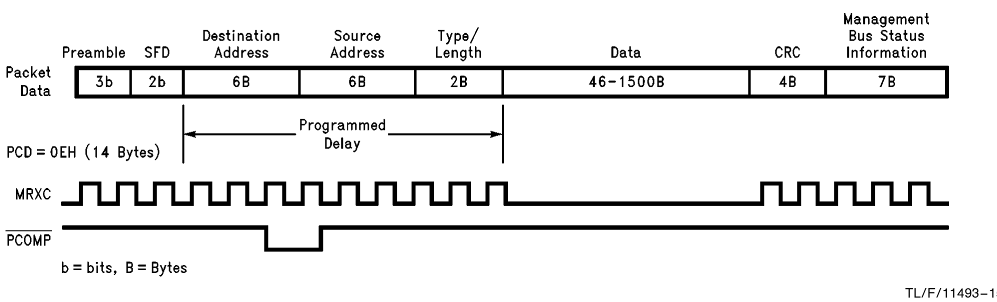
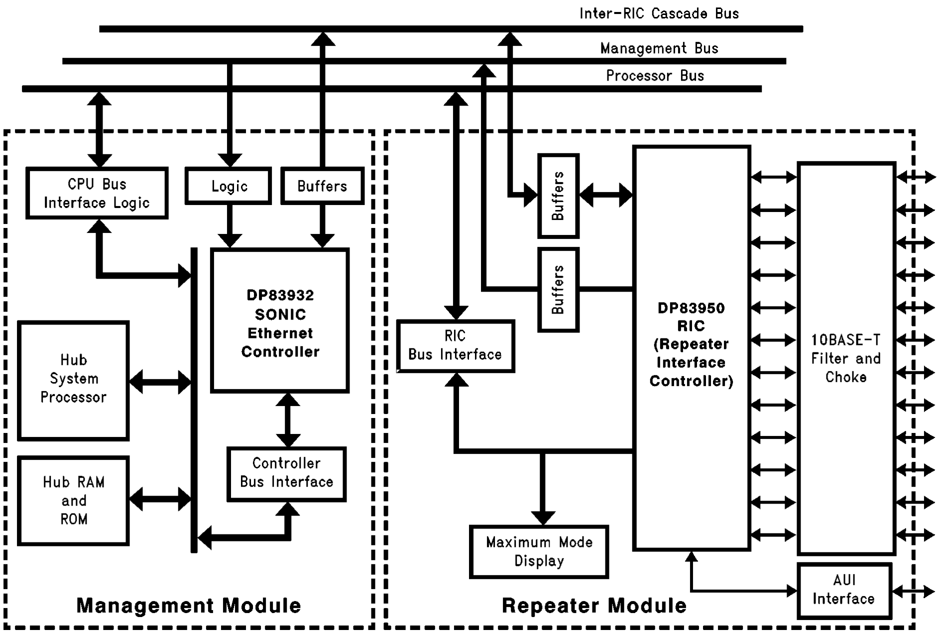


FIGURE 15. Signals Appearing on the Management Bus

Summary of Management Bus Statistics
RIC No. and Port No. Packet Received On
CRC Error, Frame Alignment Error, Tx Collision, Collision, Short Event, Late Collision, Non-SFD, PLL Error, FIFO Error, Jabber
Collision Bit Timer
Packet Data Byte Count
Repeater Byte Count
Inter-Frame Gap Bit Timer

FIGURE 16. Summary of Management Bus Information



TL/F/11493–16

FIGURE 17. Block Diagram for Managed Repeater Showing Multiple Repeater Cards and a Management Module

RIC APPLICATIONS

Like the LERIC, there are many applications for the RIC. The primary (though not only) applications for the RIC are in high end hub applications where full support of hub management IEEE objects are required. The large rack mounted system is an ideal application for the RIC for high end repeaters.

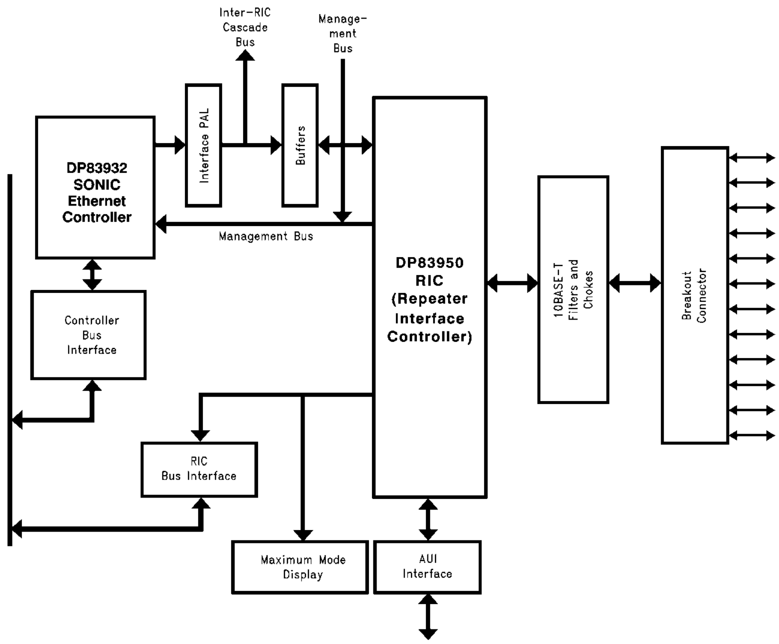
FULLY MANAGED REPEATER

For networks not quite so large but needing management, a fully enclosed module running SNMP with 12–24 ports implements a low cost hub yet provides all the management capabilities of larger systems. This is called the Fully Managed Hub. This system block diagram is very much the same as for the Modular Managed Hub, except that a single non-expandable 12–24 port PCB contains the repeater function, and Ethernet Controller, CPU and memory. Functionally, this system's block diagram is very similar to the Managed Modular Hub of *Figure 17*. Hence the functional description is the same as the modular managed repeater described next.

MANAGED MODULAR REPEATER

The modular managed repeater example is a rack mounted repeater, containing independent repeater modules. Since these repeaters could support up to hundreds of ports, it must be easily expandable. The modules are typically stacked vertically or horizontally in a chassis. Sophisticated In-Band network management is required and so an Ethernet controller with a CPU usually on a separate module is required. The ideal controller is the SONIC directly connected to the RIC. Expandability is very important so the hub can grow along with the network.

In *Figure 17*, the block diagram of the management module is shown on the left, and one of several repeater modules block diagram is shown on the right side. The backplane for this modular repeater is actually the center of the hub. This backplane usually consists of 3 buses. First, a CPU bus which allows the management module's CPU to control the repeater modules. Second, a management bus which is an extension of the RIC's management bus, and allows the management module's SONIC to access the RIC statistics information. Third, the repeater also has a repeater cascade backplane for connecting multiple repeater modules into a single logical repeater.



TL/F/11493–17

FIGURE 18. Block Diagram for Fully Managed PC Hub Card

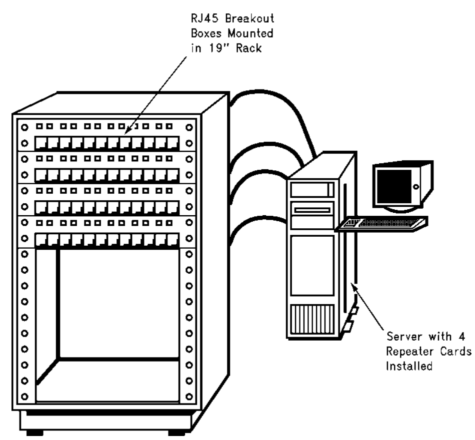
FULLY MANAGED PC ADAPTER

This repeater application has become popular since the development of Novell's Hub Management Interface (HMI) specification. This driver specification provides a standard software method to obtain all the network management capabilities of the larger, self-contained hubs, but hardware is much simpler and less costly (if you assume that the cost of the PC is not included). The block diagram of this adapter card is very similar to the LERIC/NIC solution except that a RIC is typically used in conjuction with a higher performance Ethernet Controller such as a 16-bit or 32-bit SONIC, as shown in *Figure 18*.

Since many servers are based on the EISA or Micro Channel bus, a 32-bit SONIC could act as a high performance bus master. An ASIC and/or other logic provides the interface between it and the system. On the network side, the SONIC's PLL/ENDEC is disabled and the management bus connected to the receive signals and the Inter-RIC bus connected to the transmit signals using a simple PLD incorporates some of the needed glue logic.

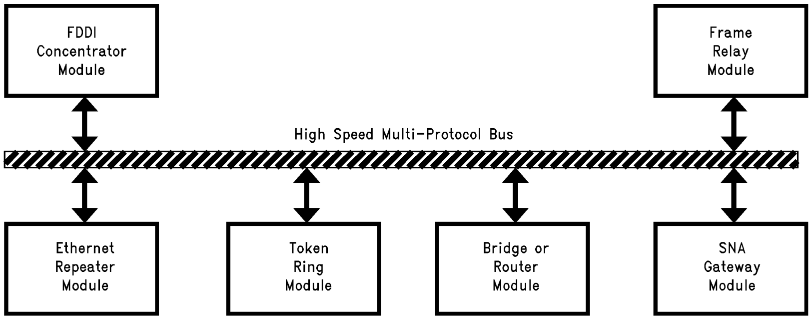
12 twisted pair ports of RJ45's are physically too large to fit into one PC expansion slot opening. So usually the port connection is made via a high density 50 pin (like a SCSI II) connector, and a cable connects to a breakout box, containing a 12 position RJ45 connector and typically the LED array.

The breakout boxes are usually placed on the floor or in some sort of standard rack, *Figure 19*. Typical configurations support up to 48 10BASE-T nodes with an AUI port for attachment to a 10BASE5 or 10BASE2 network. Expansion limitations are primarily due to the limited PC slot configurations.



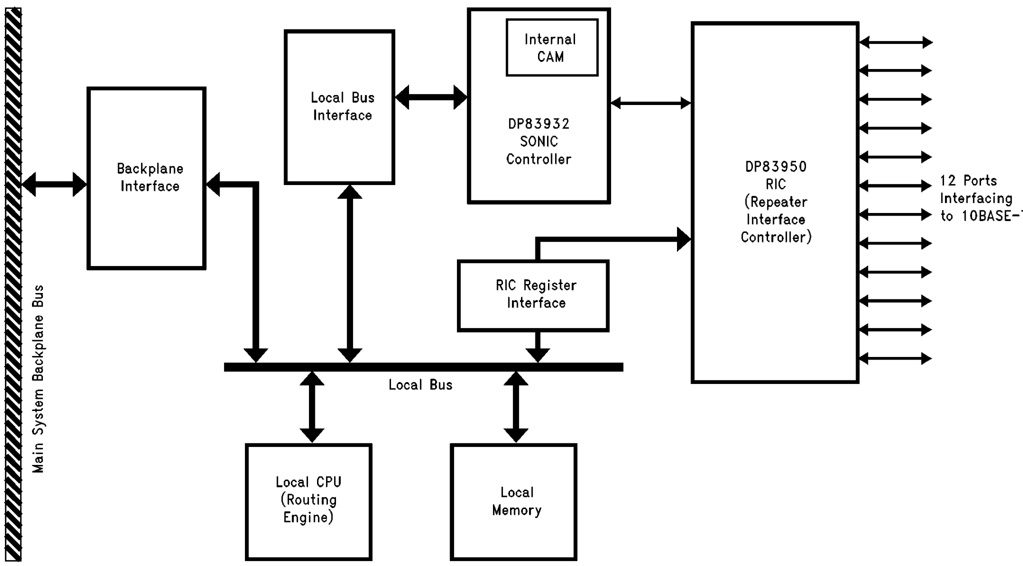
TL/F/11493–18

FIGURE 19. Breakout Boxes out of the File Server



TL/F/11493–19

FIGURE 20. Possible Modules for Communications Rack



TL/F/11493–20

FIGURE 21. Bridge/Router Combined with a Repeater (Using Hardware Address Filtering)

Vendor's offer a lot of flexibility in server configurations by offering slave adapters. These adapters are repeater boards without the controller. This allows the creation of single large repeaters with a single controller, or to use multiple controllers creating several networks connected by the server's bridging software.

Using Novell's Remote Network Interface, In-Band managed hubs can be located in other nodes besides the server. This allows repeaters to be distributed around the network where workgroups are more concentrated. Management can be done remotely from any node. Using this broad systems approach allows very large managed networks to be constructed at reasonable costs.

For expansion, additional RIC slave cards can be cascaded to the master card through the Inter-RIC bus and management bus. All of the RICs in this system are configured by software.

MODULAR COMMUNICATIONS RACK

For the purposes of this document, the Communications Rack is really a modular multi-function box (typically placed on a rack in a wiring closet) that in the ideal case, can support and LAN (or Wide Area Network) connection function. As shown in *Figure 20* this box could support not only repeater and management functions but bridge router, WAN connections, SNA Gateways, or possibly even file and printer server functions.

When using the RIC in this type of equipment, the architectures are very similar to previous modular repeaters, except that the bus supports more sophisticated functions, probably the rack's backplane is actually a high speed 16-bit–32-bit parallel data/control bus that routes network data between modules in a very sophisticated manner. The details of the architectural for such a box is beyond this paper, as it would involve discussions beyond applying the RIC or LERIC. However, there are a couple of interesting applications for the RIC within this box.

The most interesting one is the bridge/router-hub module, as shown in *Figure 21*. In this application, which does use the RIC-SONIC combination yet again, utilizes the SONIC'S internal CAM as an address filter. In this application a single RIC connects point-to-point to the RIC. Since only 12 nodes would typically be connected to the RIC, the SONIC's internal CAM can perform the address filtering. If a situation were such that the RIC would be connected to more than the 12 nodes, then either software or an external CAM would be necessary to do address filtering.

RIC AND LERIC REPEATERS FOR ANY APPLICATION

In this note, a wide variety of applications have been introduced in a general systems oriented overview.

A sampling of the breadth of possible hub/repeater applications has been presented as well as specifically highlighting the importance of network and Hub management as a required feature of many repeaters. Discussions of the operational characteristics of National's repeater family have shown how these repeaters have features that can be effectively utilized to build systems that address any possible Ethernet network repeater product.

The RIC provides a very feature rich IC platform that enables building fully managed very high functionality repeaters of various styles and architectures.

The LERIC is a very cost effective simple repeater IC that should appeal to simple non-managed repeater applications that are typically provided for small cost sensitive LAN applications.

With both these devices low end simple Velcro hubs, PC Hub Cards, Managed Hubs, Modular Repeaters all can be designed very easily and cost efficiently by selecting and using either the RIC or LERIC.

APPENDIX A.

IEEE 802.3 HUB MANAGEMENT IMPLEMENTATION

Management Criteria

A: Basic control capability Mandatory

B: Performance monitor Optional

C: Address tracking capability Optional

HUB MANAGED OBJECT CLASS

Object Name	Object Type	A	B	C	How Supported By RIC	How Supported By LERIC
Hub Attributes						
hubID	ATTRIBUTE GET	X			Software (Note 1)	Software
hubGroupCapacity	ATTRIBUTE GET	X			Software	Software
groupMap	ATTRIBUTE GET	X			Software	Software
hubHealthState	ATTRIBUTE GET	X			Software	Software
hubHealthText	ATTRIBUTE GET	X			Software	Software
hubHealthData	ATTRIBUTE GET	X			Software	Software
transmitCollisions	ATTRIBUTE GET		X		TXCOL on Mngmt Bus	External Logic on ANYXN
repeaterMJLPs	ATTRIBUTE GET		X		JAB bit on Mngmt Bus	LEDs
Hub Actions						
resetHubAction	ACTION	X			Software	Software
executeSelfTest1Action	ACTION	X			Software	Software
executeSelfTest2Action	ACTION	X			Software	Software
Hub Notifications						
hubHealth	NOTIFICATION	X			Software	Software
hubReset	NOTIFICATION	x			Software	Software
groupMapChange	NOTIFICATION	X			Software	Software
ResourceTypeID Managed Object Class						
resourceTypeID		X			Software	Software

Note 1: In the ''How Supported...'' columns, when Software is noted, this means that the Object is independent of hardware, and is an object that is collected and maintained by software or ROM firmware.

GROUP MANAGED OBJECT CLASS

Object Name	Object Type	A	B	C	How Supported By RIC	How Supported By LERIC
Group Attributes						
groupID	ATTRIBUTE GET	X			Software	Software
numberOfPorts	ATTRIBUTE GET	X			Software	Software

APPENDIX A. IEEE 802.3 HUB MANAGEMENT IMPLEMENTATION (Continued)

PORT MANAGED OBJECT CLASS

Object Name	Object Type	A	B	C	How Supported By RIC	How Supported By LERIC
Port Attributes						
portID	ATTRIBUTE GET	X			Software	Software
portAdminState	ATTRIBUTE GET	X			Ports' Real Time Status Register	Ports' Real Time Status Register
autoPartitionState	ATTRIBUTE GET		X		Ports' Real Time Status Register	Ports' Real Time Status Register
readableFrames	ATTRIBUTE GET		X		# of CLN bit active on Mngmt bus (no errors)	—
readableOctets	ATTRIBUTE GET		X		total # of RBY counts on Mngmt bus	—
frameCheckSequence-Errors	ATTRIBUTE GET		X		CRC bit active on Mngmt bus	—
alignmentErrors	ATTRIBUTE GET		X		FAE bit active on Mngmt bus	—
framesTooLong	ATTRIBUTE GET		X		RBY count on Mngmt bus	—
shortEvents	ATTRIBUTE GET		X		SE bit on Mngmt bus (no COL)	—
runts	ATTRIBUTE GET		X		RBY count on Mngmt bus (no SE)	—
collisions	ATTRIBUTE GET		X		Port Event Counters	External Logic Using DFS and LED Drivers
lateCollisions	ATTRIBUTE GET		X		Event Logging Interrupts	—
dataRateMismatches	ATTRIBUTE GET		X		ELBER bit on Mngmt bus (no COL)	—
autoPartitions	ATTRIBUTE GET		X		Event Logging Interrupts	Ports' Real Time Status Register
lastSourceAddress	ATTRIBUTE GET			X	Source address from Mngmt bus	Source Address from Ext. Controller
sourceAddressChanges	ATTRIBUTE GET			X	Software	Software
Port Actions						
portAdminControl	ACTION	X			Ports' Real Time Status Register	Ports' Real Time Status Register

National Semiconductor Corporation
2900 Semiconductor Drive
P.O. Box 58090
Santa Clara, CA 95052-8090
Tel: 1(800) 272-9959
TWX: (910) 339-9240

National Semiconductor GmbH
Livry-Gargan-Str. 10
D-82256 Fürstenfeldbruck
Germany
Tel: (81-41) 35-0
Telex: 527649
Fax: (81-41) 35-1

National Semiconductor Japan Ltd.
Sumitomo Chemical
Engineering Center
Bldg. 7F
1-7-1, Nakase, Mihama-Ku
Chiba-City,
Ciba Prefecture 261
Tel: (043) 299-2300
Fax: (043) 299-2500

National Semiconductor Hong Kong Ltd.
13th Floor, Straight Block,
Ocean Centre, 5 Canton Rd.
Tsimshatsui, Kowloon
Hong Kong
Tel: (852) 2737-1600
Fax: (852) 2736-9960

National Semiconductores Do Brazil Ltda.
Rue Deputado Lacorda Franco
120-3A
Sao Paulo-SP
Brazil 05418-000
Tel: (55-11) 212-5066
Telex: 391-1131931 NSBR BR
Fax: (55-11) 212-1181

National Semiconductor (Australia) Pty, Ltd.
Building 16
Business Park Drive
Monash Business Park
Nottinghill, Melbourne
Victoria 3168 Australia
Tel: (3) 558-9999
Fax: (3) 558-9998