

Entertainment Services and Technology Association



Recommended Practice for Ethernet Cabling Systems in Entertainment Lighting Applications

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Warning: ESTA recommends against connecting lighting equipment from different manufacturers to the same Ethernet network. In addition, ESTA does not condone connecting non-lighting nodes to a lighting network. The design details of most existing Ethernet lighting equipment and the need for large guaranteed communications bandwidths prohibit these situations.

Caution: IEEE still has an active committee modifying and improving Ethernet. The contents of this document represent the best understanding of ESTA at the time this document was written. Changes in the IEEE standard may obsolete parts of this document. ESTA will revise this document as appropriate.

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The ESTA Technical Standards Program

The ESTA Technical Standards Program was created to serve the ESTA Membership and the Entertainment Industry in technical standards related matters. The goal of the Program is to take a leading role regarding technology within the Entertainment Industry by creating recommended practices and standards, monitoring standards issues around the world on behalf of our members, and improving communications and safety within the Industry. ESTA works closely with the technical standards efforts of other organizations within our industry including USITT, PLASA and VPLT as well as representing the interests of ESTA members to ANSI, UL and the NFPA.

The Technical Standards Committee (TSC) was established by ESTA's Board of Directors to oversee and coordinate the Technical Standards Program. Made up of individuals experienced in standards making work from throughout our industry, the Committee approves all projects undertaken and assigns them to the appropriate Working Group. The Technical Standards Committee employs a Technical Standards Manager to coordinate the work of the Committee and its Working Groups as well as maintain a "Standards Watch" on behalf of members. Working Groups include: Control Protocols; Fog and Smoke; Truss and Rigging; and Safety and Loss Prevention.

ESTA encourages active participation in the Technical Standards Program. There are several ways to become involved. If you would like to become a member of an existing Working Group, as have over a hundred people, you must complete an application which is available from the ESTA office. Your application is subject to approval by the Working Group and you will be required to actively participate in the work of the group. This includes responding to letter ballots and attending meetings. You can also become involved by requesting that the TSC develop a standard or a recommended practice in an area of concern to you.

The Control Protocols Working Group, which authored this Recommended Practice, consists of a cross section of entertainment industry professionals, representing manufacturers, dealers and end-users. ESTA is committed to developing consensus-based standards and recommended practices in an open setting. Future Control Protocols Working Group projects will include updating this publication as technology changes and experience warrant, as well as developing new standards, data communication protocols, and recommended practices for the benefit of the entertainment industry.

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How to Use This Booklet

This booklet is structured in several different parts. Some parts contain general or overview information. Other parts contain detailed technical information or collected recommendations. Today some parts of this booklet may be uninteresting to you, but tomorrow those same parts may be invaluable.

Part 1 lists the ESTA recommended practices for Ethernet cabling. It includes one-line diagrams, descriptions of their use, and advantages or disadvantages commentary about them. Part 2 lists the ESTA recommended practices for determining cable lengths in permanent installations. Part 3 lists ESTA recommended labeling and system identification practices.

Part 4 describes specific elements of the Ethernet hardware commonly used in entertainment venues. There you will find pictures and descriptions of common Ethernet hardware. Part 4 also describes other Ethernet hardware that is not commonly used or recommended for entertainment venues.

Appendix B contains overview and background information about Ethernet. Read Appendix B to brush-up on the history and basic philosophy of Ethernet. At the back of this booklet is a brief glossary of Ethernet terminology.

Throughout this booklet segment length distance measurements have an accuracy of plus or minus 1m (3.3').

Scope

This booklet is intended to allow the reader to satisfactorily plan an entertainment lighting network. It is not recommended that you undertake the actual installation of the network, unless you have the technical skills and proper tools to do so.

This booklet is not a comprehensive discussion of Ethernet technology or a guide on how to connect your Ethernet equipment. It specifically is limited to information of interest to entertainment industry professionals. Please refer to the instructions provided by the manufacturer to learn how best to put your lighting control system into operation.

Introduction

For the last decade, most lighting systems have used USITT DMX512 digital data to connect control consoles to dimmers. In the last five years, other devices, such as color scrollers and moving lights, have also become DMX512 devices. DMX512 had become a de facto “control network” for much more than dimmers. Unfortunately, the proper means of distributing DMX512 signals around a theatre or other performance space, were not well understood by many users. Mostly this was because there was little information available to end users. This was finally overcome with the publication by PLASA and USITT of Adam Bennette’s book, *Recommended Practice for DMX512, A Guide For Users and Installers*, copies of which are available through either of these organizations.

Recently a new type of data network was introduced to the lighting industry to provide a high-performance way to connect consoles and remote devices such as designer’s remotes, remote video displays, remote consoles, and even dimmer banks. Unlike DMX512, which was developed specifically for lighting control, this data network comes from the computer industry. It is called Ethernet, and is the standard way to interconnect computers into local area networks (LANs). Most lighting companies have adopted a proprietary name for their Ethernet network. Some examples are ETC’s ETCNet™, Colortran’s ColorNet™, and Strand Lighting’s ShowNet™.

What is Ethernet? A detailed technical description is far beyond the scope of this document. Simply put, Ethernet is a communications network that operates at 10Mb/s (million bits per second), which is 40 times faster than DMX512. Ethernet is bi-directional; data may be sent and received from each connected unit (frequently called a node) on a network. There is no central controller in Ethernet. Each node “listens” to the network and waits for a quiet moment. When it finds one, it begins sending data.

Strictly speaking, Ethernet is not a standard. Ethernet was the name given to a manufacturer’s specification developed by Digital Equipment Corporation, Intel Corporation, and Xerox. The standard covering the Ethernet technology was developed by an IEEE (Institute of Electrical & Electronic Engineers) standards committee in 1983 and was adopted as IEEE Std 802.3. Later, a similar international standard was adopted as ISO/IEC 8802-3. Just as DMX512 differs from the Colortran manufacturer’s specification from which it was built, so IEEE 802.3 differs from Ethernet. However, the name Ethernet is a commonly used to mean IEEE 802.3 and its additions. This booklet continues that colloquial usage of the term Ethernet.

Because Ethernet (strictly speaking ISO/IEC 8802-3 or IEEE 802.3) is a world-wide standard, the types of cabling, connectors, and other network hardware are precisely defined and are commonly available. Professional network installers can be found in every city, and have the knowledge, skills and proper tools to install and test the network. The proper design and construction of Ethernet networks is well understood in the computer industry. Lighting companies who offer Ethernet systems also are very familiar with Ethernet design and practices.

In the broader lighting industry, however, Ethernet is a new, unfamiliar technology. While many of the rules for Ethernet distribution seem similar to those of DMX512, there are important differences. DMX512 can be somewhat forgiving of improperly constructed distribution. Ethernet is not. Improper implementation of an Ethernet network invariably results in a 100% non-functional network.

Part 1: Configuring Ethernet for Lighting

Now that you have decided to use Ethernet for your lighting system communication, you need to determine how to make Ethernet work well in your venue. Since there are limits on the lengths of wires, your first question must be, “How long is the longest end-to-end cable run?” The answer to that question will guide you in selecting the appropriate Ethernet technology (or technologies) for your system.

1.1 Recommended Technologies

Two principal Ethernet technologies are used in these ESTA recommendations. The first, unshielded twisted pair (UTP), is the technology principally recommended by ESTA. UTP uses a cable containing four wire pairs, and RJ45 connectors (a larger version of the familiar modular telephone connector), and has no user-installed terminators. UTP requires the use of a hub. (For the special case of connecting only two devices, see Appendix A). The maximum segment length from hub to node is 100m (328').

The other Ethernet technology covered in detail in these recommendations is ThinNet. ThinNet uses 50-ohm coaxial cable, BNC connectors, barrel connectors, “T” connectors, and terminators that users must install. ThinNet may or may not employ a hub. If a hub is not used, the maximum end-to-end length of a ThinNet segment is 185m (607'). ThinNet hubs permit this distance to be extended by joining several segments together. Hubs also isolate some nodes from failures on other nodes or their connective cabling.

Support for ThinNet in the computer industry is rapidly disappearing, especially as faster 100Mb/s Ethernet becomes popular. This faster Ethernet is not likely to be supported at all on ThinNet. ThinNet is included in this document so that users of existing cable plans can be familiar with the proper use of ThinNet technology. However, its inclusion does not mean that ThinNet is generally recommended by ESTA; disappearing support for this technology may mean decreasing availability of hardware and accessories.

As you can see, the connectors and portable cabling are very different for each of the principal recommended technologies. In general it is a good idea to use a single type of portable cable and wall plate connector in a facility. This allows easy movement of equipment to any physical point on the network.

1.2 Recommended Topologies

Ethernet cabling systems are based on the use of two particular wiring topologies. Figure 1 shows a linear topology, where the signal is connected from node to node to node to node. Figure 2 shows a simple star topology, where each node is connected to a central hub device by a dedicated cable. The resulting wiring diagram looks like the rays of a star. Figure 3 and Figure 4 show how these topologies can be combined. Figure 3 shows expansion of a simple star topology by addition of a linear backbone. Figure 4 shows a hierarchy of simple star topologies.

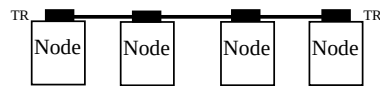


Figure 1 — Linear Topology

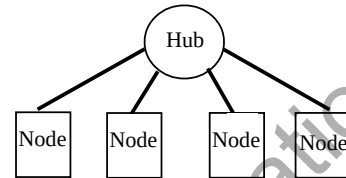


Figure 2 — Simple Star Topology

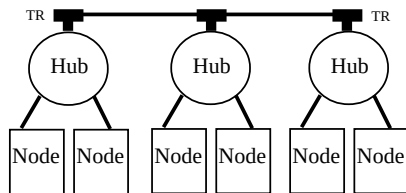


Figure 3 — Bussed Backbone Topology

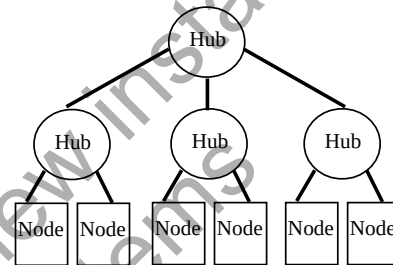


Figure 4 — Hierarchical Star Topology

The following one-line diagrams describe examples of different types of Ethernet cable plans. Prior to permanently installing a cable plan in a facility, be sure to consult the manufacturer of the lighting control equipment that is planned for the facility. This will insure that the cable plan selected will be compatible with the equipment it is designed to service.

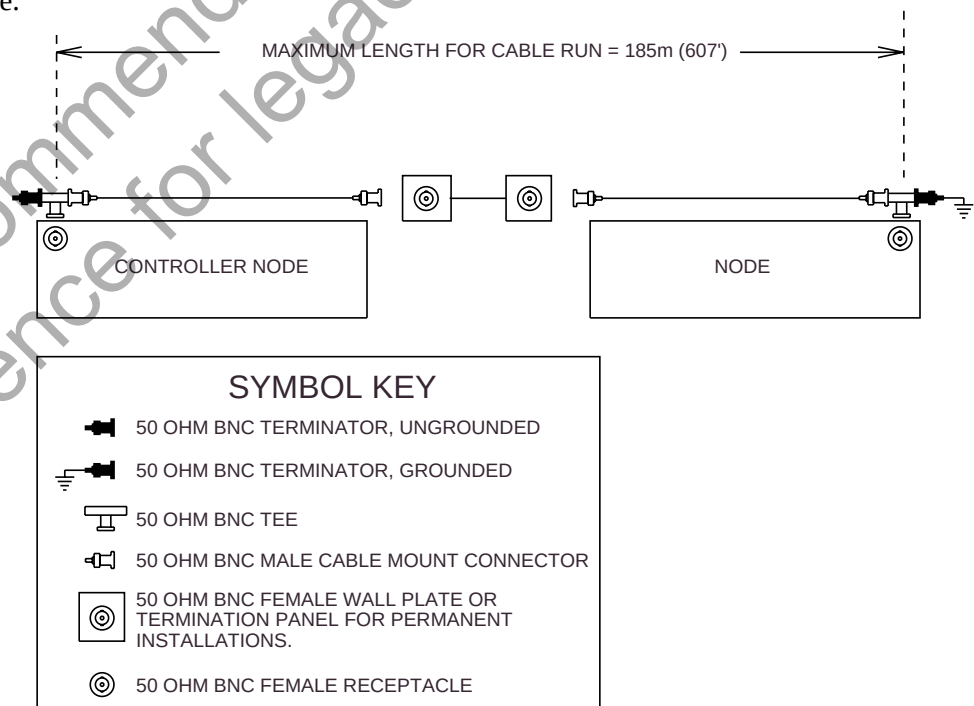


Figure 5 — Single Segment ThinNet System

1.2.1 Single Segment ThinNet

Figure 5 shows the simplest of all possible ThinNet systems: a single segment with only two devices and no hub. This type of system can only be recommended for Ethernet cable plans where it is definitely known that only two devices will be required, and that no further expansion is expected. Because it is often hard to predict whether or not a system will need to be expanded in the future, a preferred solution for permanent building wiring is one of the Multiple Segment ThinNet or UTP systems shown in other one-line diagrams.

The addition of more than two devices to this type of cable plan creates an inherently unreliable system; a fault anywhere on the network will cause all devices on the network to fail.

This cable plan is generally suitable for portable applications where only two devices will be used. A good example would be a touring system where a control console and a video node at the Designer's Table are the only two Ethernet devices.

Advantages of Single Segment ThinNet

1. ThinNet coaxial cable allows segment lengths up to 185m (607'), which is ideal for many entertainment industry applications.
2. BNC connectors are robust, well suited to entertainment industry applications, and readily available.
3. Cable and connectors are of relatively low cost.
4. For a network with only two devices, the lack of an active hub makes a simple and economical installation.

Disadvantages of Single Segment ThinNet

1. To maintain reliability and fault tolerance, only two devices should be used on a single segment system. Larger systems should use the multiple-segment arrangements described in other one-line diagrams.
2. The network requires a BNC "T" connector and terminator at each end. Terminators can get lost or forgotten. The network will not function at all without proper termination.
3. BNC connectors have metal shells. In order to follow the proper grounding rules of ThinNet mated pairs of cable connectors must be protected by plastic boots or tape against inadvertent earth grounding.

1.2.2 Multiple Segment ThinNet

Figure 6 shows a ThinNet system where each segment of the network is connected through a ThinNet hub. The hub provides fault isolation between segments and insures that devices can be connected and disconnected without affecting the rest of the network. This topology is ideal for a cable plan where wall outlets in the facility may or may not have nodes connected at any given time.

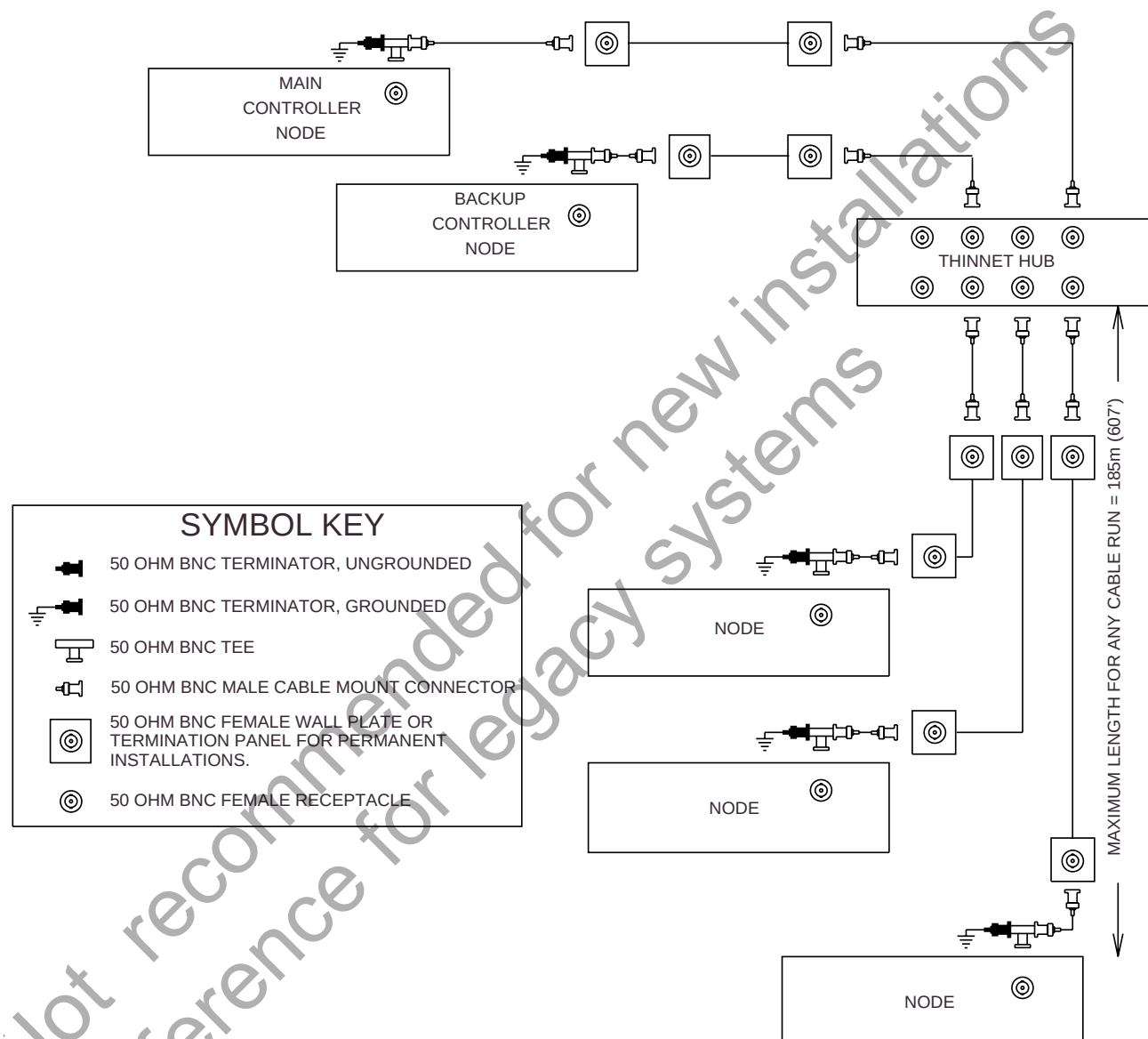


Figure 6 — Multiple Segment ThinNet System

Advantages of Multiple Segment ThinNet

1. The star topology of this system provides excellent tolerance to faults on the network. A shorted or cut cable, missing terminator, or damaged node cannot disable the entire network, only a single segment. In a star topology, the partitioning effect of the hub also provides the ability to connect/disconnect nodes at will on a live network.
2. ThinNet coaxial cable allows segment lengths up to 185m (607'), which is ideal for many entertainment industry applications.
3. BNC connectors are robust, well suited to entertainment industry applications, and readily available.
4. Cable and connectors are of relatively low cost.

Disadvantages of Multiple Segment ThinNet

1. Support for ThinNet in the computer industry is rapidly disappearing, especially as faster 100Mb/s Ethernet becomes popular. This faster Ethernet is not likely to be supported at all on ThinNet. Inclusion of ThinNet in this document does not mean that it is generally recommended by ESTA; disappearing support for this technology may mean decreasing availability of hardware and accessories.
2. Unlike UTP, there are no known plans to upgrade ThinNet to speeds in excess of 10Mb/s. It is likely that some entertainment industry manufacturers will adopt the higher performance of 100Mb/s UTP Ethernet (see section 4.2) at some point in the future. In large, permanently installed cable plans where the cost of cable installation is significant, a 10Mb/s restriction could be viewed unfavorably.
3. Cost of the hub is higher than comparable UTP hubs by at least a factor of four.
4. The hub is an active device; it requires power to operate. A hub failure can disable the entire network. In critical applications, the network design must allow for this (see the "Critical Segment" discussion in section 1.2.4).
5. Each segment requires a BNC "T" connector and terminator at each end. While some hubs have internal terminators, at least one "T" and terminator will be required on the end of each segment. Terminators can get lost or forgotten; a segment will not function at all without proper termination.
6. For a fully partitioned cable plan, a dedicated run of cable is required to the hub for each segment.
7. BNC connectors have metal shells. In order to follow the proper grounding rules of ThinNet (see Section 4.1.1.), mated pairs of cable connectors must be protected by plastic boots or tape against inadvertent grounding.

1.2.3 Multiple Segment Unshielded Twisted Pair

Figure 7 shows a UTP system where each segment of the network is connected through a UTP hub. The hub provides fault isolation between segments and insures that devices can be connected and disconnected without affecting the rest of the network. This topology is ideal for a cable plan where wall outlets in the facility may or may not have nodes connected at any given time.

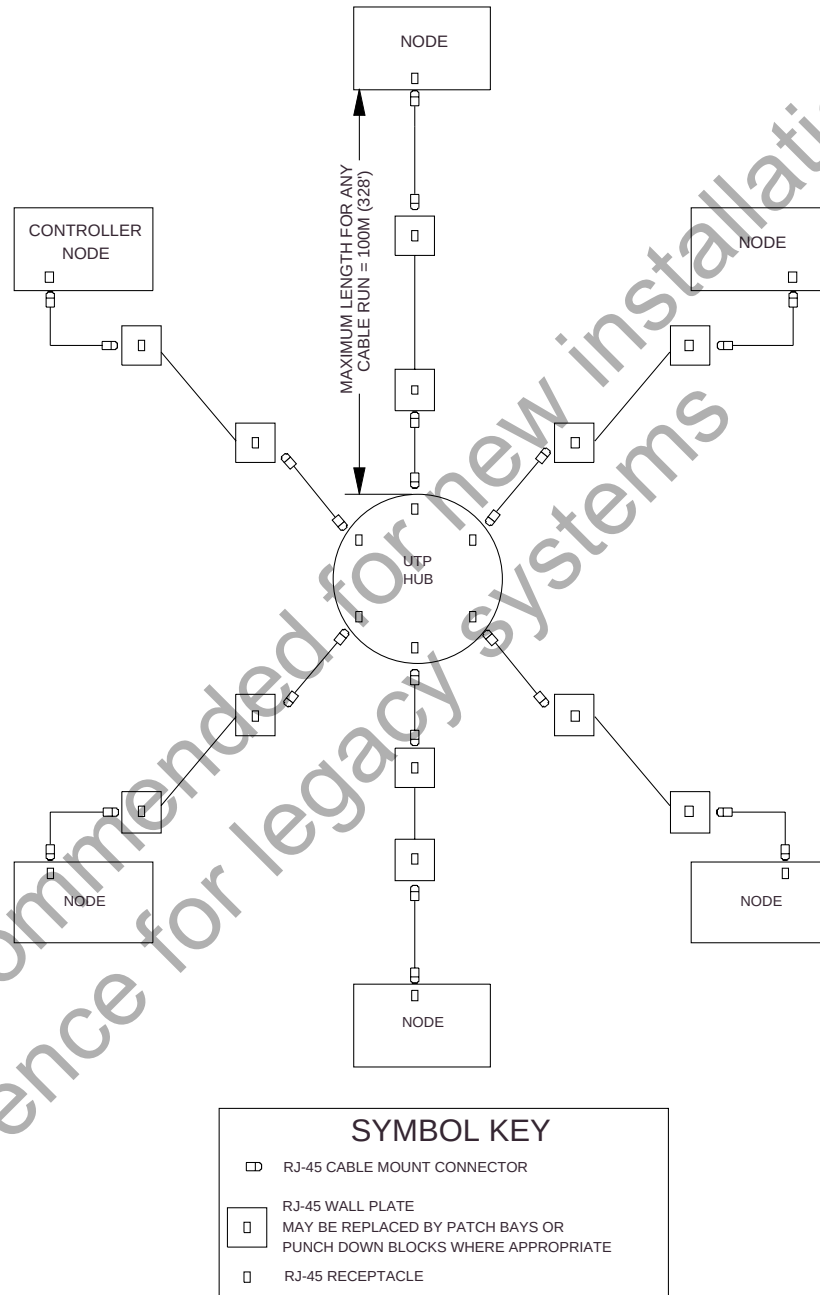


Figure 7 — Multiple Segment UTP System

Advantages of Multiple Segment UTP

1. The star topology of this system provides excellent tolerance to faults on the network. A shorted or cut cable, or damaged node cannot disable the entire network, only a single segment. In a star topology, the partitioning effect of the hub also provides the ability to connect/disconnect nodes at will on a live network.
2. Correct installation of portable RJ45 cables and connectors is simple and familiar to users. There are no external terminators to forget, as in a ThinNet system.
3. RJ45 connectors are plastic; they do not need additional protection against inadvertent earth grounding of mated pairs.
4. Since UTP is the most common cable plan for short-distance office environments, cable, RJ45 connectors, and hubs are very readily available and inexpensive. Hubs are typically one-quarter the cost of those for ThinNet, and are much more widely available.
5. A UTP cable plan installed with the proper type of cable (4-pair Category 5) can be readily up-graded to 100Mb/s Ethernet in the future by the addition of appropriate 100Mb/s nodes and hub.
6. Since UTP is transformer-coupled at each end, it avoids ground loop problems.

Disadvantages of Multiple Segment UTP

1. The maximum recommended segment length for UTP is 100m (328'). This may be inadequate for many entertainment facilities.
2. The RJ45 connector was designed with a relatively small number of mating cycles in mind. Failure of the plastic connector latch is possible over many mating cycles. In addition, the latch of the connector protrudes and may be subject to damage when dragging a cable or bundle of cables.
3. A multi-port hub is an active device; it requires power to operate. A hub failure can disable the entire network.
4. A dedicated run of cable is required to the hub for each segment.

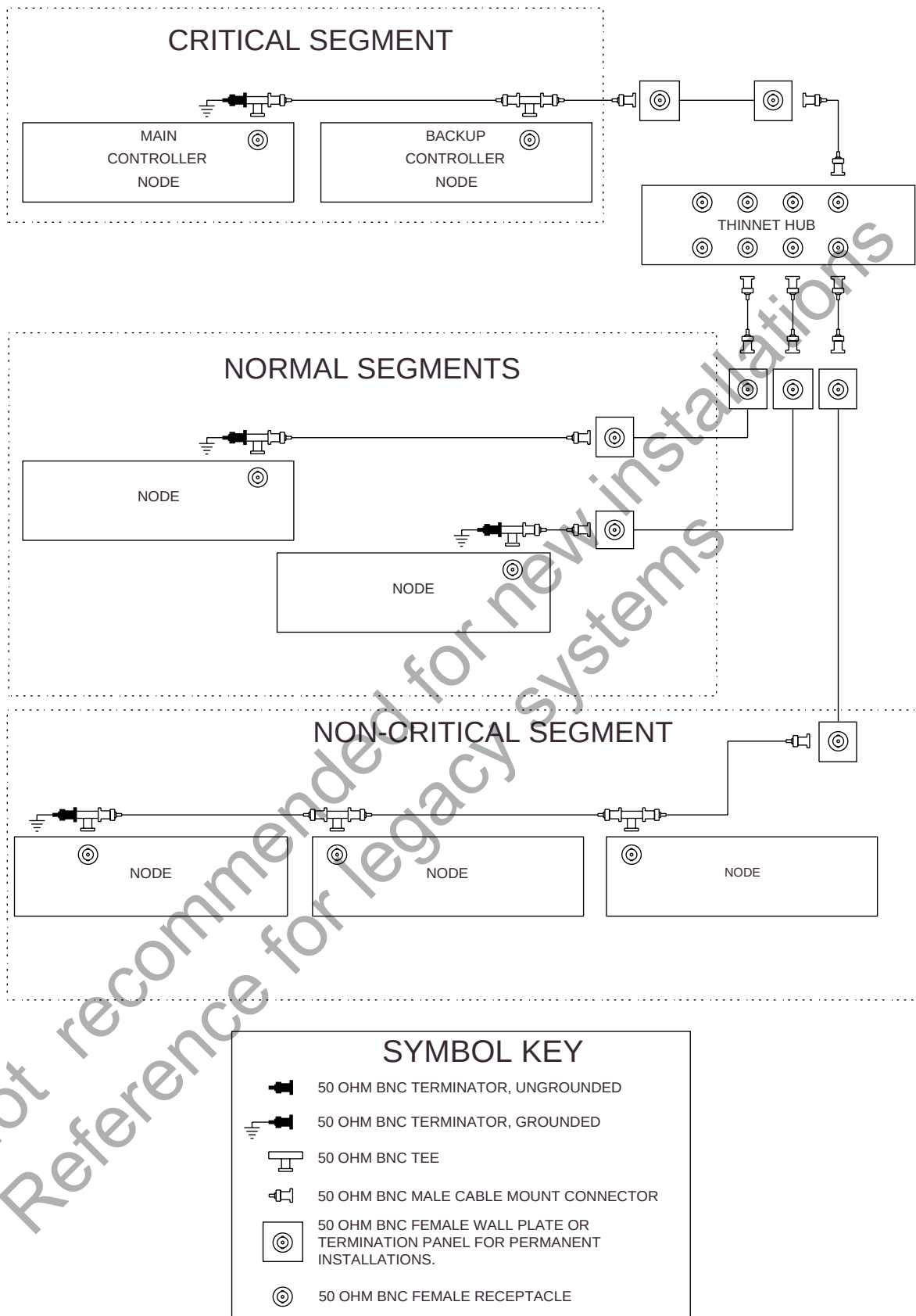


Figure 8 — Enhanced Multiple Segment ThinNet System

1.2.4 Enhanced Multiple Segment ThinNet

Figure 8 shows a ThinNet system similar to the Multiple Segment system that Figure 6 shows. It provides all of the advantages of that system. However, in certain cases, it may be desirable to connect multiple pieces of equipment onto a single segment using portable cables in a linear topology. These cases are:

- A. The Critical Segment — In cases where two nodes absolutely must communicate, even in the event of a hub failure, they may be connected together on a single segment in a linear topology. An example where this arrangement might be desirable is that of a main and backup lighting controller, both in the same room in close physical proximity, and carefully protected from physical disconnection. This example assumes that dimmer control data is not being sent via Ethernet.
- B. One or more Non-Critical Segments — For simple convenience or economy, it may be desirable to connect multiple nodes on a segment in a linear topology, especially when loss of all of those nodes is not critical to operation of the system. For a rehearsal situation, multiple nodes (perhaps for many video displays) could be connected onto a single outlet in a linear topology using portable cable.

Use of a linear topology for Critical or Non-Critical segments should only be accomplished through the use of portable cables. The installation of a multi-node connection linear topology in permanent building wiring is specifically not recommended. When a user is presented with a wall outlet, he/she must be confident that it is at the end of an Ethernet segment, and is not part of a linear topology that is hidden in the permanent building wiring.

Note: The use of a linear topology is specifically allowed within a rack or other equipment enclosure on a Critical or Non-Critical Segment; the prohibition against linear topologies in permanent wiring described above does not apply to wiring within equipment enclosures.

When a linear topology is used, no more than 30 nodes can be placed on a segment. Also, the maximum portable cable length shown on the wall plate (see section 3.1) applies to the sum of the lengths of the portable cables used to create the linear topology.

Advantages of Enhanced Multiple Segment ThinNet

1. The star topology of this system provides excellent tolerance to faults on the network. A shorted or cut cable, missing terminator, or damaged node cannot disable the entire network, only a single segment. In a star topology, the partitioning effect of the hub also provides the ability to connect/disconnect nodes at will on a live network. (As for Multiple Segment ThinNet)
2. The addition of a Critical Segment allows for continued operation of critical nodes within the Critical Segment even in the event of a hub failure.
3. The addition of one or more Non-Critical Segments eliminates the need for dedicated segments for non-critical nodes, thus simplifying the cable plan and reducing hub requirements in an economical manner.
4. ThinNet coaxial cable allows segment lengths up to 185m (607'), which is ideal for many entertainment industry applications. (As for Multiple Segment ThinNet)

5. BNC connectors are robust, well suited to entertainment industry applications, and readily available. (As for Multiple Segment ThinNet)
6. Cable and connectors are of relatively low cost. (As for Multiple Segment ThinNet)

Disadvantages of Enhanced Multiple Segment ThinNet

1. Support for ThinNet in the computer industry is rapidly disappearing, especially as faster 100Mb/s Ethernet becomes popular. This faster Ethernet is not likely to be supported at all on ThinNet. It is likely that some entertainment industry manufacturers will adopt the higher performance of 100Mb/s UTP Ethernet at some point in the future. Inclusion of ThinNet in this document does not mean that it is generally recommended by ESTA; disappearing support for this technology may mean decreasing availability of hardware and accessories. (As for Multiple Segment ThinNet)
2. Cost of the hub is higher than comparable UTP hubs by at least a factor of four. (As for Multiple Segment ThinNet)
3. The hub is an active device; it requires power to operate. A hub failure can disable the entire network. In critical applications, the network design must allow for this (see “Critical Segment” discussion above). (As for Multiple Segment ThinNet)
4. Each segment requires a BNC “T” connector and terminator at each end. Even with hubs that have internal terminators, at least one “T” and terminator will be required at the last node on each segment. Terminators can get lost or forgotten; a segment will not function at all without proper termination. (As for Multiple Segment ThinNet)
5. For a fully partitioned cable plan, a dedicated run of cable is required to the hub for each segment. (As for Multiple Segment ThinNet)
6. BNC connectors have metal shells. In order to follow the proper grounding rules of ThinNet (see Section 4.1.1), mated pairs of cable connectors must be protected by insulated boots or tape against inadvertent earth grounding. (As for Multiple Segment ThinNet)

1.2.5 Multiple Segment ThinNet Backbone

Figure 9 shows a ThinNet backbone system. This type of system is generally used to service multiple clusters of nodes, where each cluster is separated by a long distance. Hubs for the clusters of nodes can be either UTP or ThinNet.

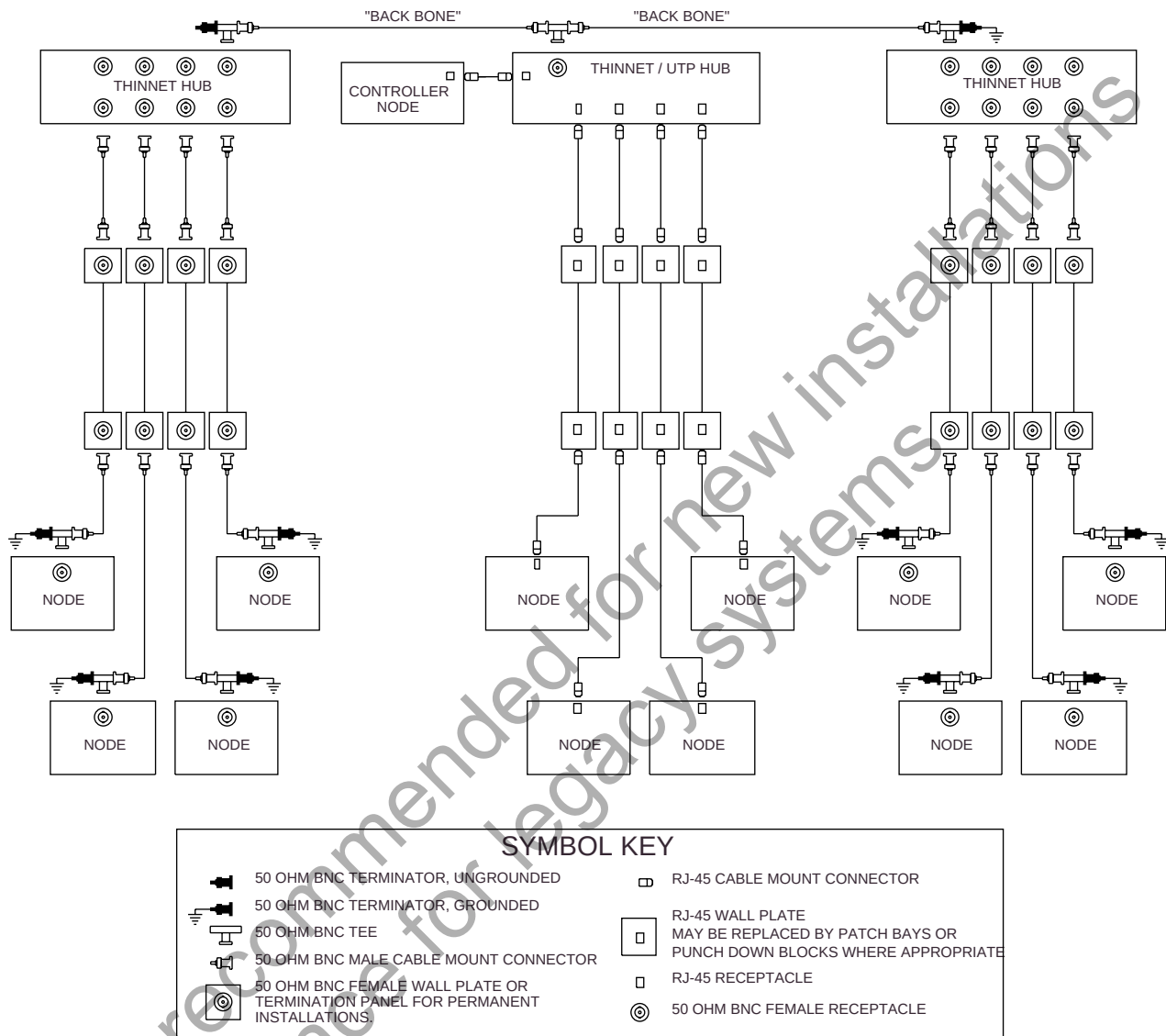


Figure 9 — Multiple Segment ThinNet Backbone System

Note that the figure shows a UTP hub in the middle of the backbone and a ThinNet hub at the either end. This is simply to show that both UTP and ThinNet hubs can be serviced by a ThinNet backbone. It is not recommended that both UTP and ThinNet hubs and wall outlets be used in the same facility, since this would require two different sets of portable cables, which would not be interchangeable.

The use of a ThinNet backbone in combination with UTP hubs combines the cost advantages of UTP with the distance advantages of ThinNet.

1.2.6 Multiple Segment Fiber Optic

In cases where hubs must be be separated by very long distances or cables will be routed underground, Fiber Optic provides an ideal solution (as Figure 10 shows). Fiber Optic is a point-to-point technology, with only one transmitter and one receiver on each segment. It is immune to RF interference and lightning strikes, and can be used for distances of up to 1 km (0.6 miles). Fiber Optic cables do not generally plug directly into nodes; they are used to connect UTP or ThinNet hubs, which in turn are connected to nodes.

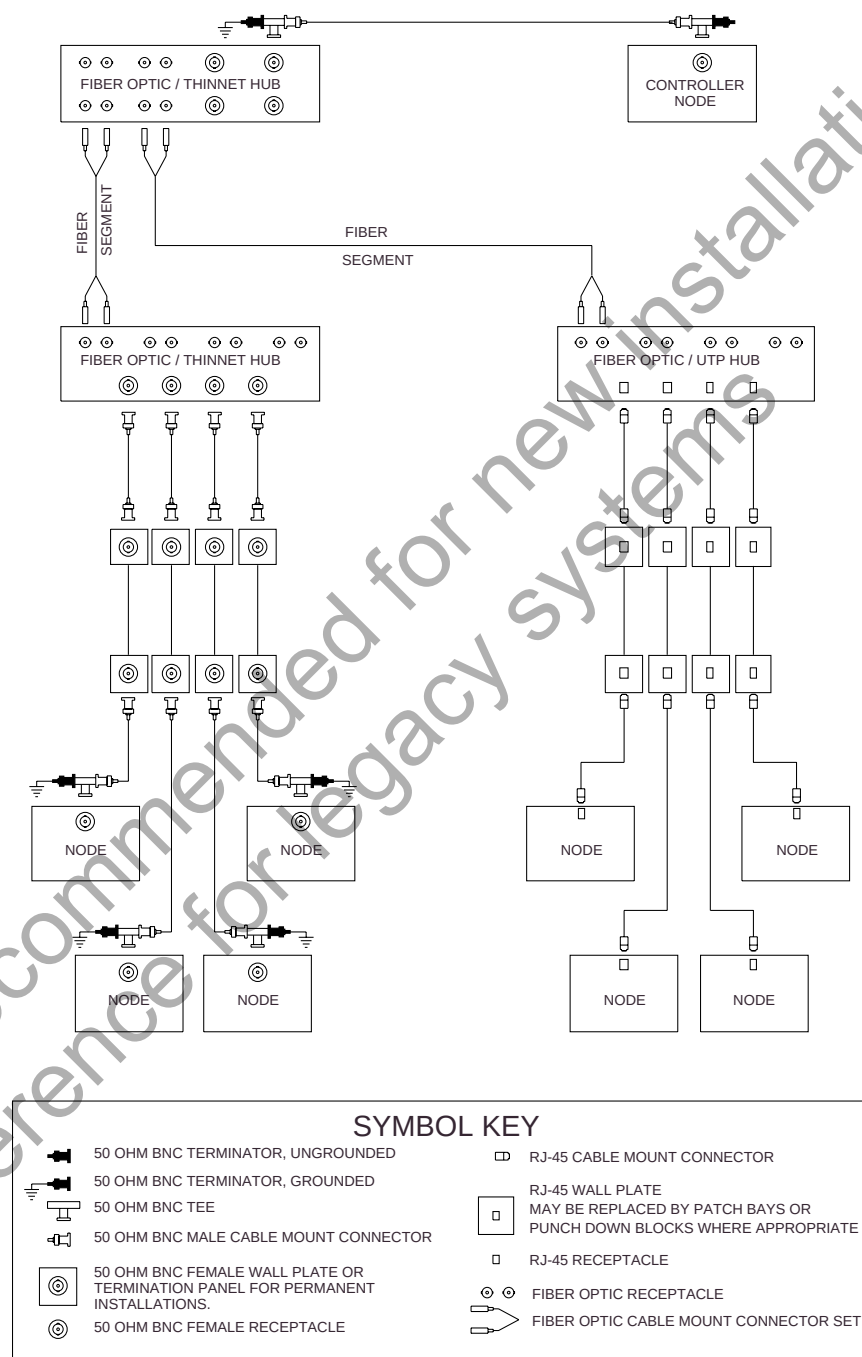


Figure 10 — Multiple Segment Fiber Optic System

Advantages of Multiple Segment Fiber Optic

1. Can connect hubs separated by distances of up to 1 km (0.6 miles). Under certain conditions, it may be possible to use Fiber Optic for distances of up to 2 km (1.2 miles), while still complying with the rules of the IEEE 802.3 standard. Users should seek qualified engineering assistance for such applications.
2. Immune to electrical or RF interference.
3. Immune to induced-current damage from nearby lightning strikes.
4. Performs well in submersible or other environmentally hostile applications.
5. Provides complete electrical isolation between network equipment.
6. Many UTP hubs on the market have a single fiber port (10BASE-FL) for use as a backbone connection.

Disadvantages of Multiple Segment Fiber Optic

1. Fiber Optic cable, connectors, and hubs are costly.
2. Special tooling, training, and termination techniques are required.
3. Installation of Fiber Optic cable has stringent requirements for maximum pulling force and minimum bend radius.
4. Can only be used in a point-to-point topology, multi-drop is not allowed.

1.3 Recommendations for Designing Systems

When you set out to design an Ethernet system for entertainment lighting control, you need to consider how it needs to be different from a typical office LAN. Because we are putting on shows, our required level of reliability is probably higher than that required in most offices. If your office LAN goes down, you have to wait for the system to reboot to continue working. If a lighting control system goes down during a performance, well..., we all know what that means. As a result, we must set higher design standards for these systems.

In general, UTP systems are more economical and easier to configure, but they may not have the distance capabilities that you require. For systems with more than two devices, one way to insure system reliability is through the use of hubs. Since hubs isolate faulty segments from operating segments, they can add a lot of reliability.

Support for ThinNet in the computer industry is rapidly disappearing, especially as faster 100Mb/s Ethernet becomes popular. This faster Ethernet is not likely to be supported at all on ThinNet. ThinNet is included in this document so that users of existing cable plans can be familiar with the proper use of ThinNet technology. However, its inclusion does not mean that ThinNet is generally recommended by ESTA; disappearing support for this technology may mean decreasing availability of hardware and accessories.