Entertainment Services and
Technology Association

ESTA

Recommended Practice for Ethernet Cabling Systems in Entertainment Lighting Applications

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CP/96-1057r1

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.

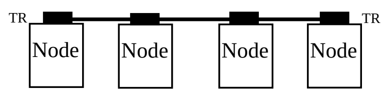

Figure 1 — Linear Topology

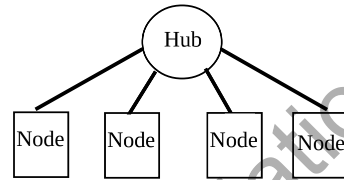

Figure 2 — Simple Star Topology

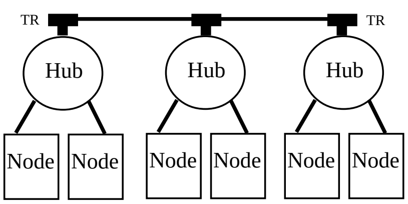

Figure 3 — Bussed Backbone Topology

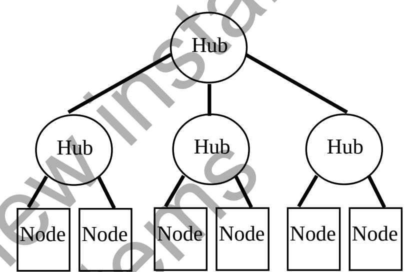

Figure 4 — Hierarchical Star Topology

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.

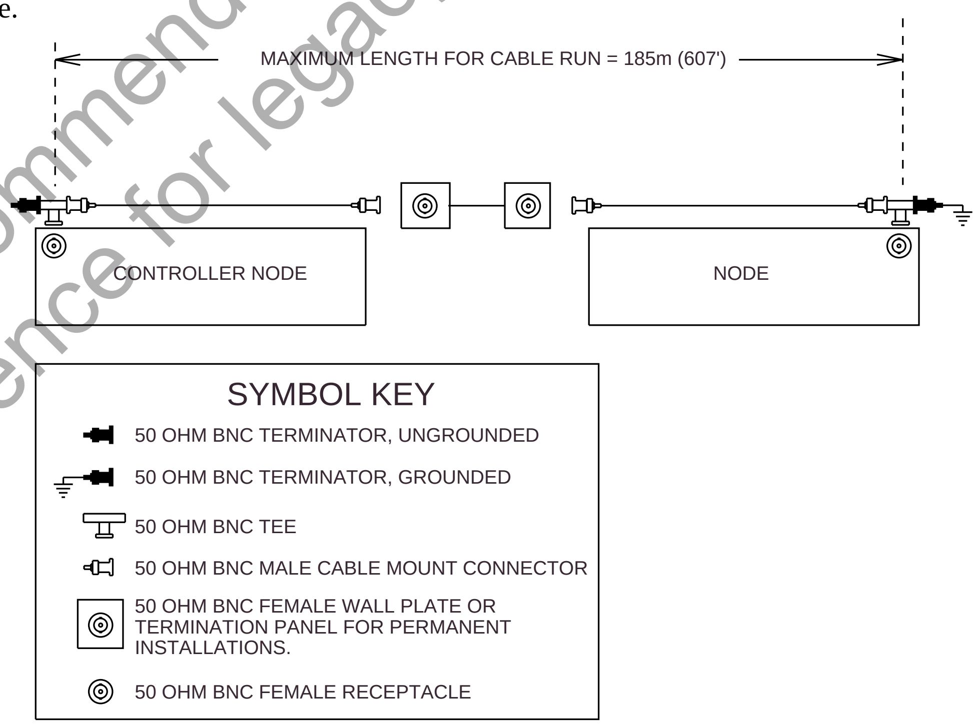

Figure 5 — Single Segment ThinNet System

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.

<u>Advantages of Single Segment ThinNet</u>

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.

<u>Disadvantages of Single Segment ThinNet</u>

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.

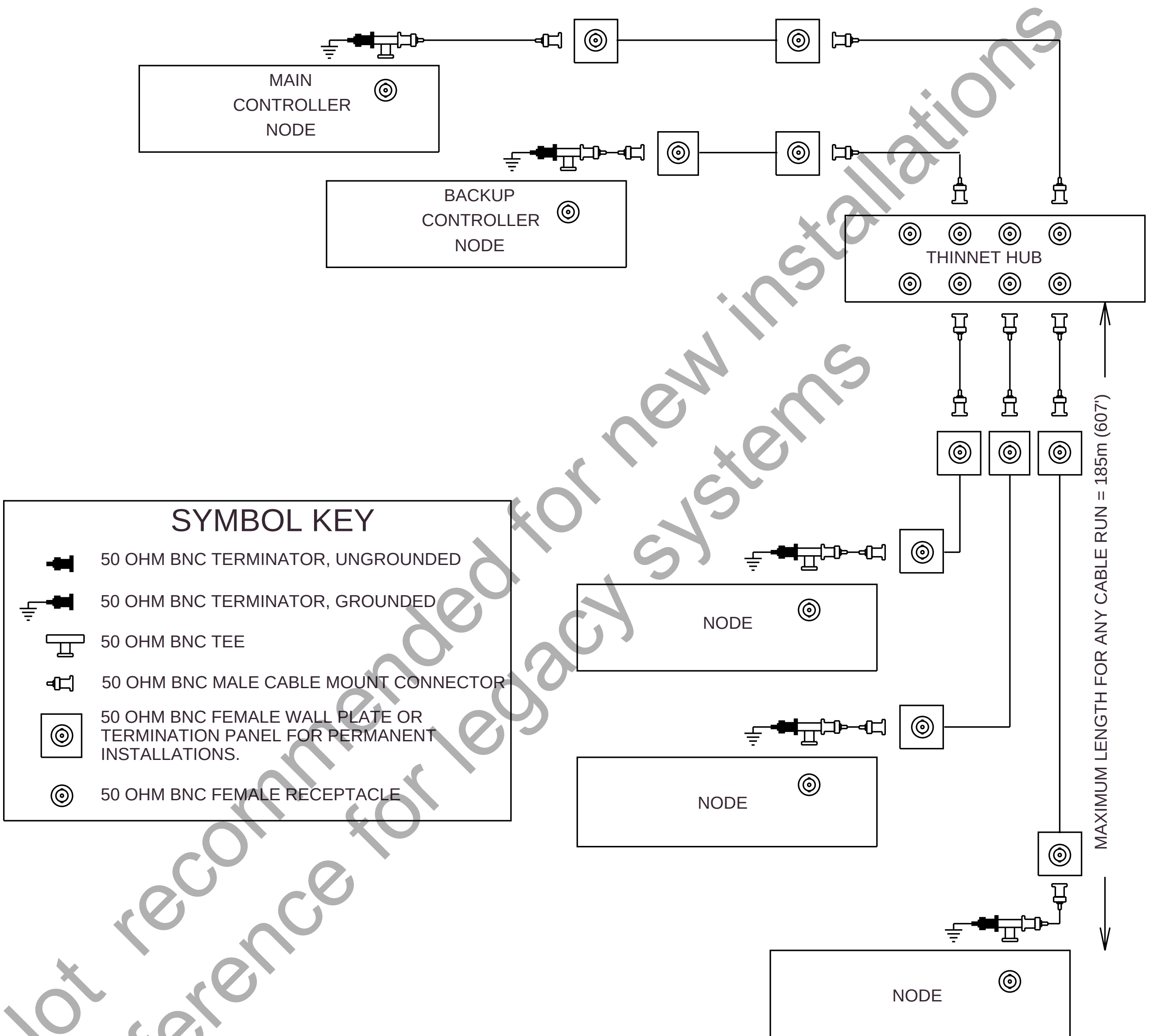

Figure 6 — Multiple Segment ThinNet System

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.

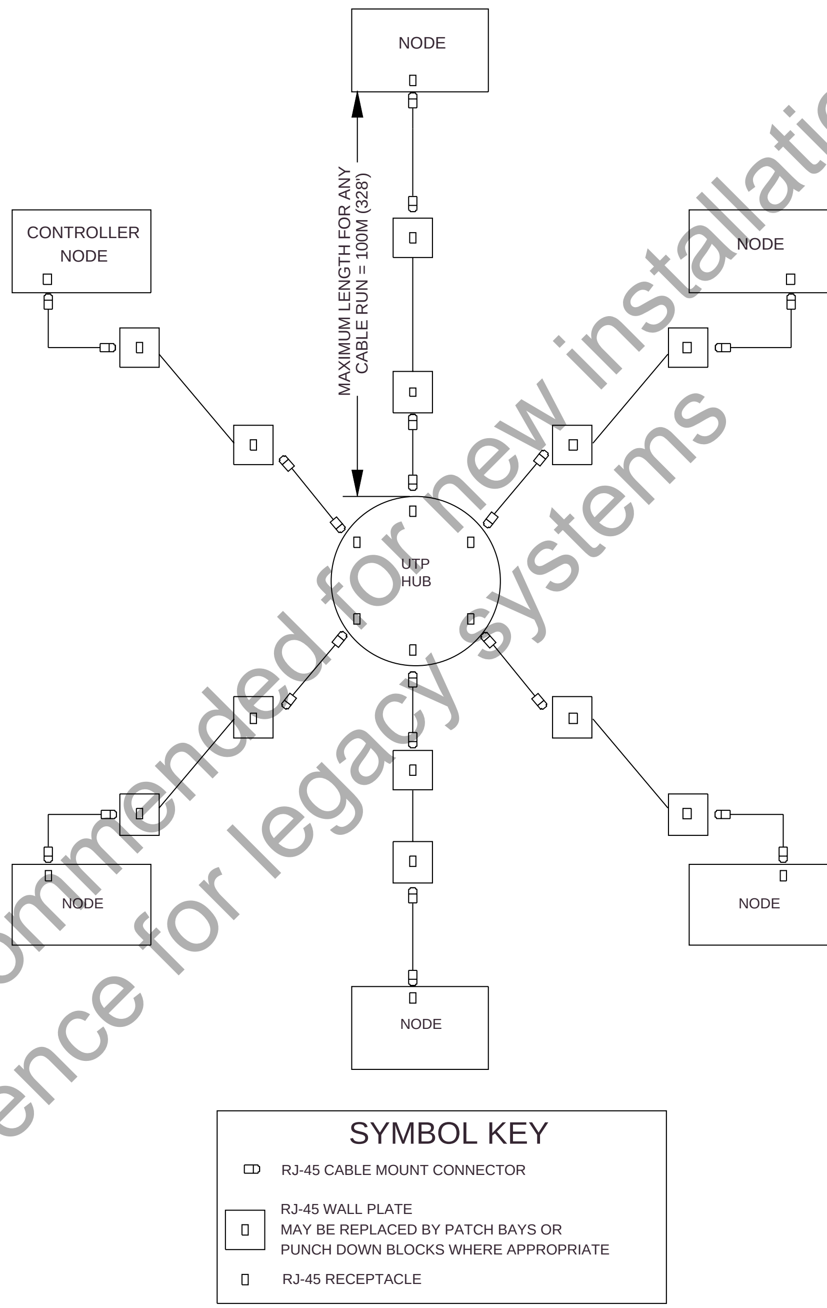

Figure 7 — Multiple Segment UTP System

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 inaequate 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.

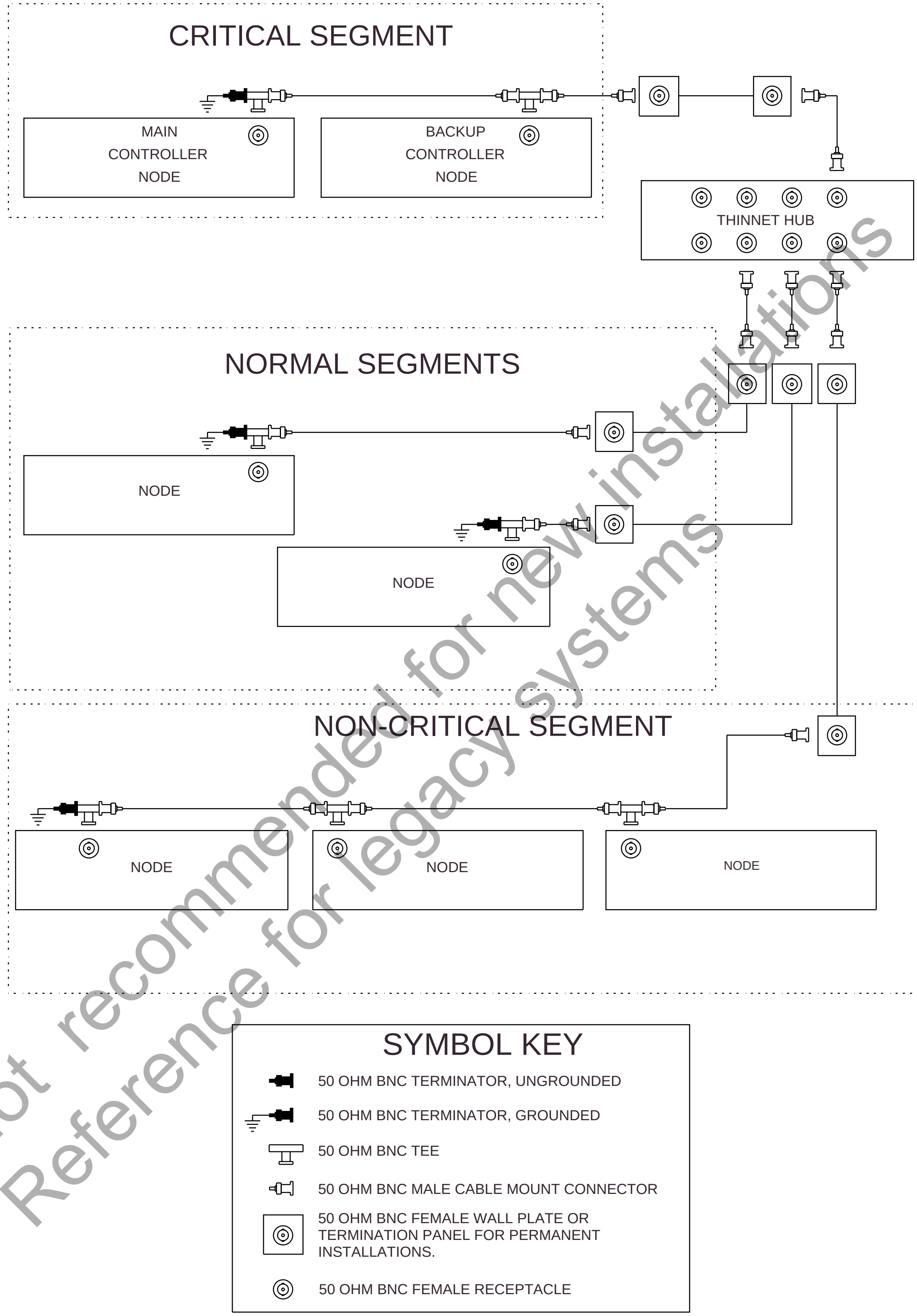

Figure 8 — Enhanced Multiple Segment ThinNet System

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.

<u>Advantages of Enhanced Multiple Segment ThinNet</u>

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.

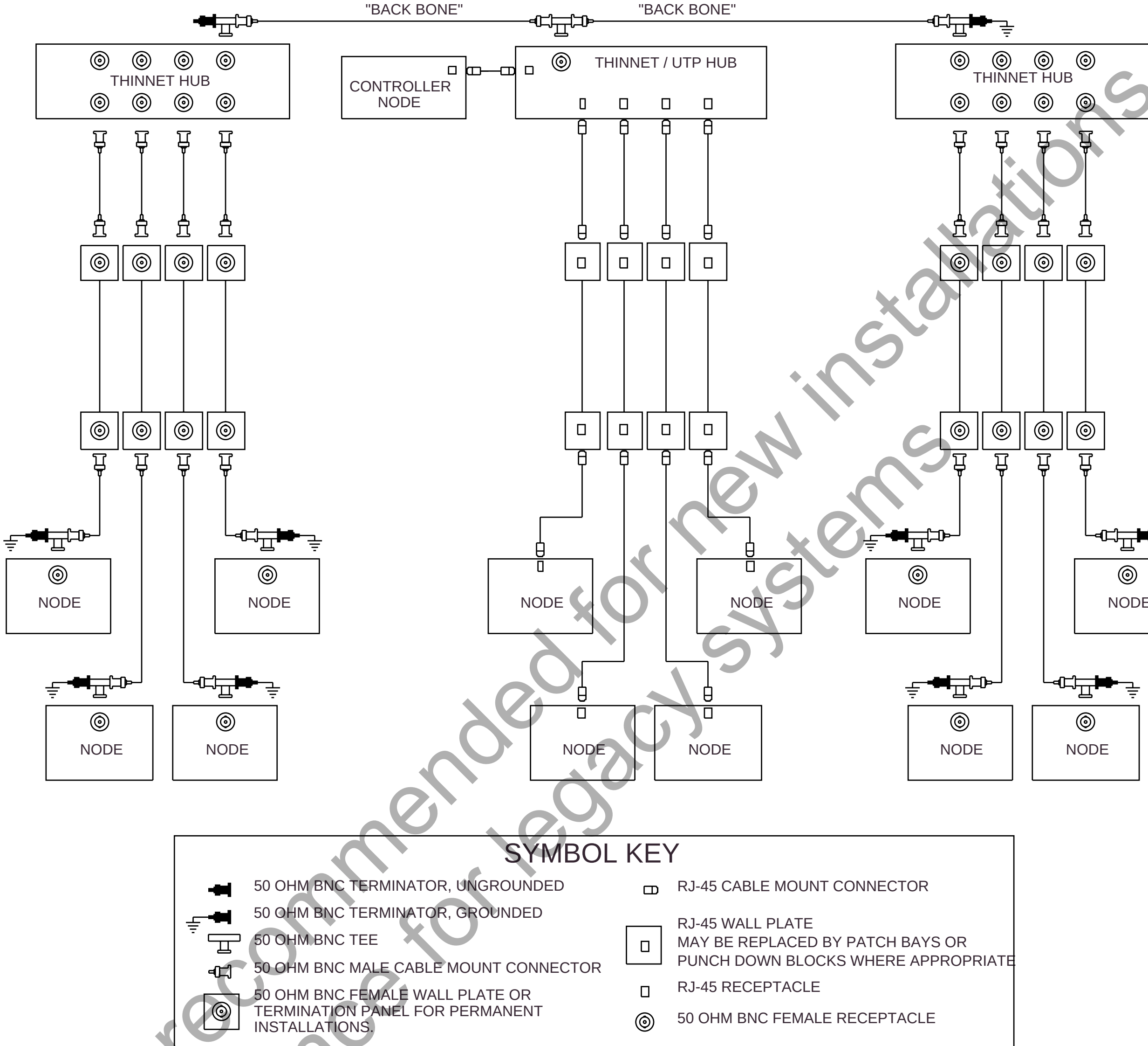

Figure 9 — Multiple Segment ThinNet Backbone System

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 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.

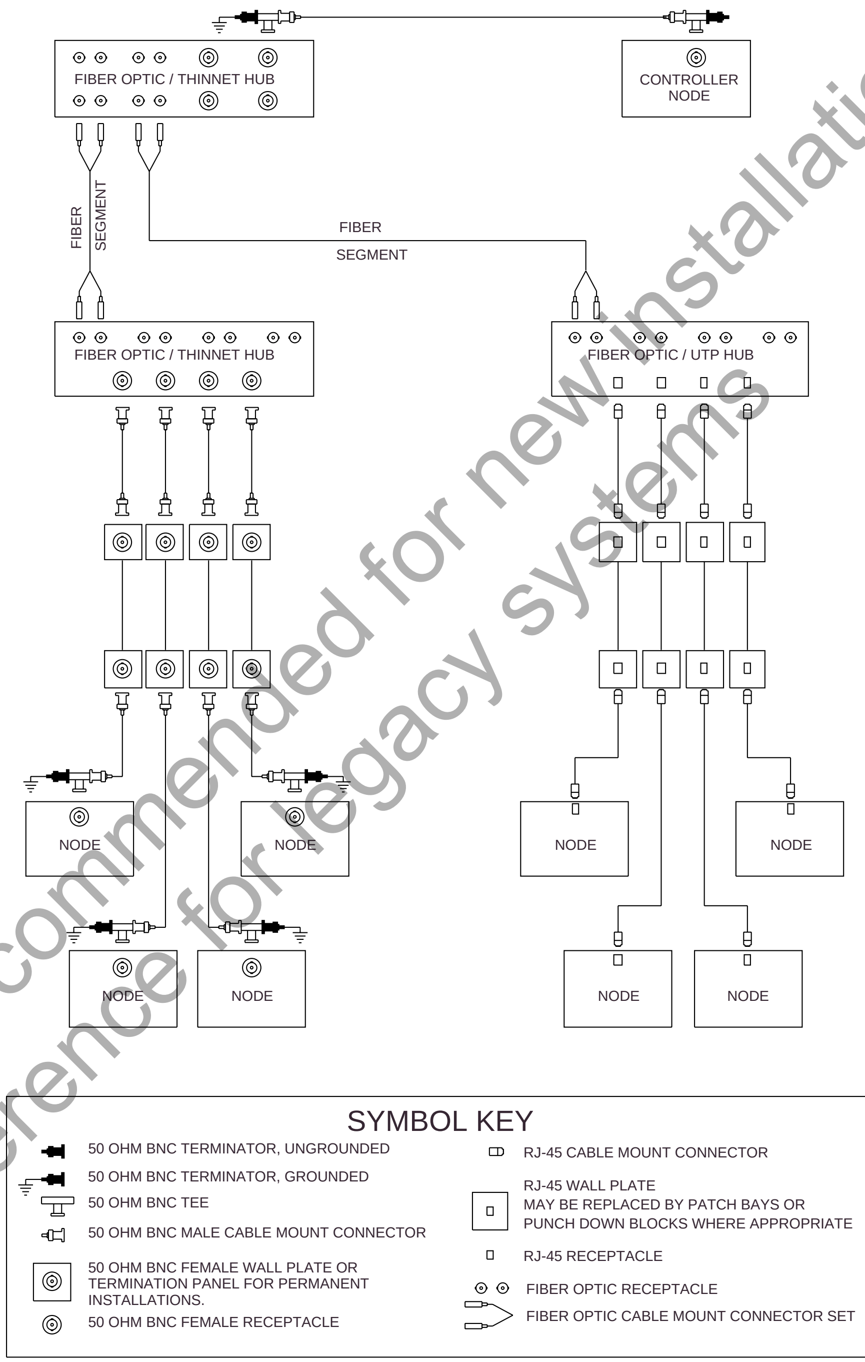

Figure 10 — Multiple Segment Fiber Optic System

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.

When ThinNet systems are used, follow the ESTA "Two-per Rule": you should plan for no more than two active devices per segment. This will help to prevent your entire system from having problems because one device has gone haywire. In some cases you may want to limit the number of devices to one per segment. In certain applications such as backbones (see section 1.2.5), it may be more appropriate to allow more than two devices per segment. This practice should be limited to devices whose operation is not critical for performance operations. Obviously, the determination of which devices are non-critical is subjective to each application. Devices that could be considered as not necessary for performance purposes might fall into this category.

Another concept to keep in mind is that of a Critical Segment (see section 1.2.4). Look at your topology and determine if there are two devices of central importance in the system. You will probably want to locate these devices on the same segment. This Critical Segment should not have any other interconnects or "T" connectors located along its run. This will insure that a faulty connector won't cause communication problems between your most important devices.

A backbone is a useful concept in the design of a larger network, and is normally a segment or several segments used to connect between the various physical areas. It should be physically well protected and should not usually contain any devices in order to maximize its reliability.

Basic Concepts to Keep in Mind while Designing Systems:

- If the system is larger than two devices, the use of a hub is highly recommended.
- Minimize connections. They are a major source of segment faults. Mid-segment interconnects should be avoided unless absolutely necessary.
- Limit the number of devices to two per segment (the Two-per Rule), except for non-critical devices.
- Identify a Critical Segment and design around it.
- Consider a backbone when devices are clustered at several separate locations.
- Think Reliability.

(A note about using equipment from different manufacturers): At the time of this booklet's printing there is no Ethernet protocol standard for lighting control communication similar to the DMX512 standard. It is not recommended that you connect Ethernet devices from different manufacturers on the same network until an applicable standard has been established (if one ever is). There are software issues that will determine whether coexistence on the same network will be feasible. As more testing is done on existing Ethernet control equipment, it may be determined that devices from different manufacturers can coexist on the same network. If you are considering designing a system in which you will be trying to interconnect equipment from different manufacturers, ESTA recommends that you contact all the manufacturers involved for information relating to the specific setup you are contemplating.

1.4 The 5-4-3 Rule

Network types may be combined in a virtually limitless variety of configurations as long as the final configuration complies with all Ethernet rules. These rules are summarized in what is referred to as the 5-4-3 rule. The 5-4-3 rule states that, between any two nodes in the network there may be:

- no more than 5 segments in series,
- no more than 4 hubs,
- no more than 3 coaxial segments (that is, segments attached to devices),
- a maximum distance between any node and any other node no greater than 1.5 km (0.9 miles).[1]

In a linear topology, as many as five segments (three populated and two unpopulated) can be joined by four hubs. Figure 11 shows how the rule applies.

For networks that need a more complex topology than described above, a bridge may be used to connect multiple networks. [1]

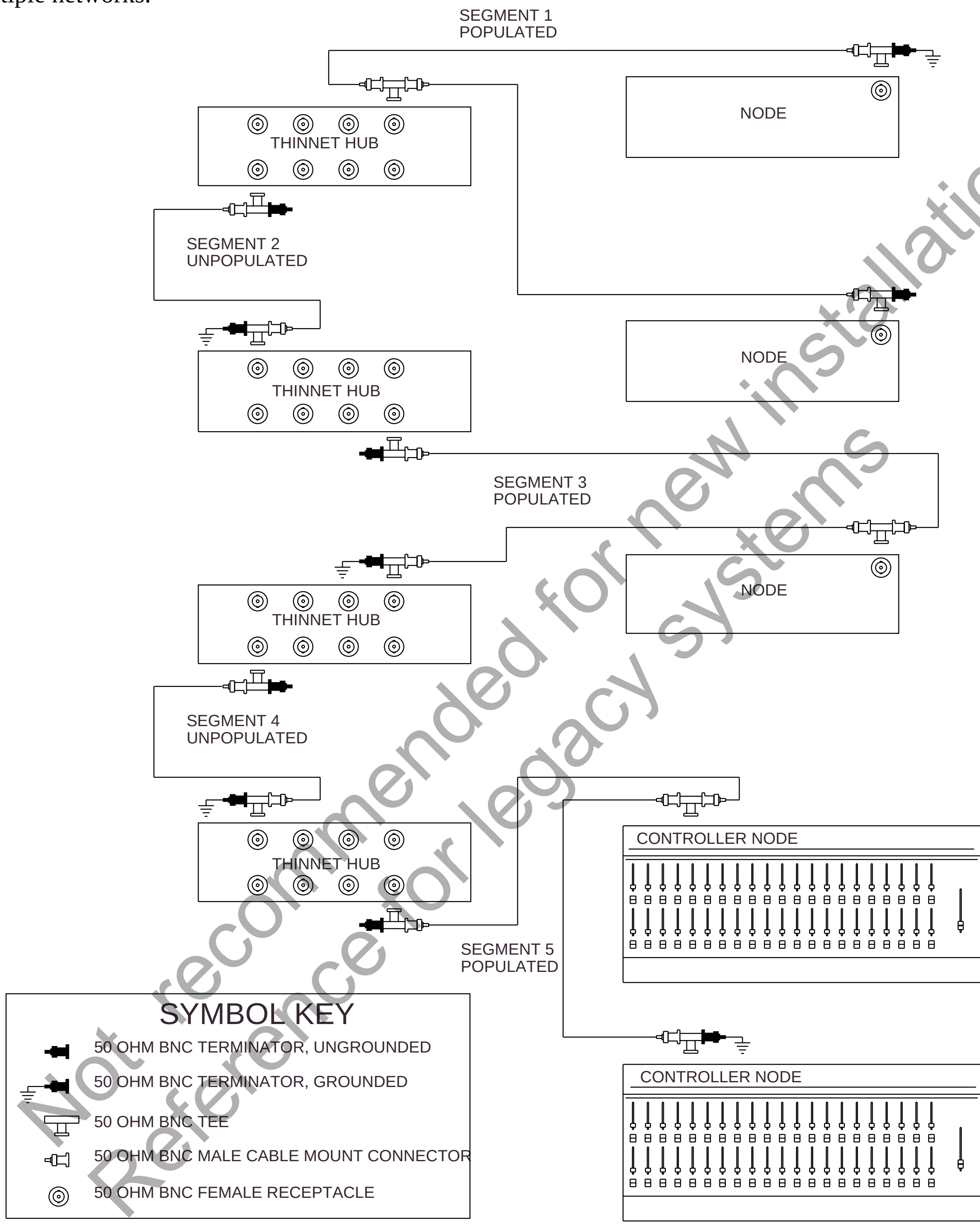

Figure 11— 5-4-3 Rule in a Network With 5 Thin Coax Segments

[1] Individual Ethernet technologies may impose additional length restrictions. Review the description of each technology you are using. Expert Ethernet system planners may be able to design systems with larger node-to-node distances. The knowledge required to do this is beyond the scope of this booklet.

Part 2: Management of Cable Length Considerations

Each type of Ethernet cable plan has specific segment length restrictions. These are not suggestions, they are firm rules; a network simply will not function if the cable length restrictions are violated. In a system which uses only portable cable, it is easy to comply with the length rules since the system installer knows with certainty the length of each portable cable because it can actually be seen.

In practical terms, these length rules present an interesting challenge in a permanent installation, since the majority of the cable is hidden in the walls. When one wants to connect a device to a wall plate, how does one know the length of cable hidden in the wall? For example, in a UTP system, if the length of permanent cable between the wall plate and the hub were 95m (312'), one could only use a 5m (16') portable cable to connect a node to the wall plate. On the other hand, if there were only 60m (197') of building wiring between the wall plate and the hub, then a 40m (131') portable cable would be allowed. This is further complicated by the fact that end users may be trying to use the cable plan after the system designer is nowhere to be found.[2]

Clearly, uncertainty concerning length of building wiring could result in problems. For this reason ESTA recommends the following approach:

When calculating allowable permanent building wiring lengths and network layout, it should be assumed that a portable cable of 10m (33') in length will be connected to every wall plate in the system. Wall plates should be located so that portable cables not longer than 10m (33') will be needed to place each network device at its desired operating location. When wall plates must be located more than 10m (33') from device operating locations, longer portable cables shall be utilized and wall plates shall be marked to indicate that use of longer portable cables is acceptable at this special location. Building wiring lengths shall be reduced if necessary to accommodate use of longer portable cables. In an Ethernet system that is installed to this ESTA recommended practice, users should be made aware through labeling and operating manuals that connection of a portable cable longer than 10m (33') could violate the Ethernet length rules, unless the wall plate clearly indicates otherwise.

Part 3: Labeling and System Identification

When a system or component failure occurs in an entertainment lighting system it seems that it usually happens at the most inopportune time. To assist the technicians in finding a quick resolution to the problem, clear and readily understood labeling of all Ethernet lighting system components will be of tremendous help. Labeling should be applied to all cables and hardware. Doing this will provide the technician the ability to systematically troubleshoot the system.

It is important that labeling be completely self-explanatory, without need for drawings or other data that might not be readily available on site. The ability to isolate and identify segments and hardware, as well as the lighting system to which they belong, can not be over-stressed. The system designer and installer should always keep in mind the time-critical nature of getting an entertainment lighting system back in operation.

ESTA recommends that the following guidelines be used for all entertainment lighting systems that utilize Ethernet cabling and components.

[2] Professional network installers have sophisticated test equipment that can measure the length of the cable in the wall. This requires disconnecting the cable segment at both ends. These testing devices are not now normally part of a stage electrician's tool kit.

3.1 Wall Plates Used in Permanent Installations

All wall plates used for permanently installed Ethernet lighting systems shall be permanently labeled with the following information:

- ♦ An indication that they are exclusive to a specific Ethernet lighting system
- ♦ An unique segment identifier (e.g., “Cable Run 22”)
- ♦ An indication of the maximum portable cable length allowed as described in Part 2 (e.g., “NNm (nn’) Max. Portable Cable”)

3.2 Hubs and Termination Blocks in Permanent Installations

All termination blocks and hubs in permanently installed Ethernet lighting systems shall be permanently labeled with the following information:

- ♦ Identification of the specific and exclusive Ethernet lighting system of which they are a component
- ♦ An unique identifier shall appear on each hardware component

3.3 Segment Cables

All segment cables shall be identified as follows:

- ♦ An exclusive and system specific Ethernet lighting system label shall be used at each termination of each segment
- ♦ The length of the segment cable

Part 4: Ethernet Hardware

Ethernet is in a state of continual development. At the time this recommended practice document was being prepared, two new Ethernet technologies were being developed by IEEE committees. ESTA will continually monitor new Ethernet standards. But, use of new Ethernet technologies cannot be recommended until sufficient practical experience has been gained by other computer technology sectors.

The IEEE 802.3 Ethernet standard describes several different kinds of Ethernet systems. The three systems recommended in this part of the booklet are *ThinNet, Unshielded Twisted Pair (UTP),* and *Fiber Optic* networks. Each of these types of Ethernet have advantages and disadvantages, and the system that you choose is likely to be based on the capabilities of your equipment, and on how you plan to use your system.

4.1 ThinNet Systems (10BASE2)

A ThinNet network (also called 10BASE2) is a network based on one or more linear topology segments, with nodes located along its length. Each segment may be up to 185m (607') in total length. A ThinNet cable must be at least 0.5m (1.6') long. The cable used is a special 50-ohm coaxial cable that is designed especially for ThinNet systems. There are lots of types of coaxial cable, so be sure that you specify one designed for use with the IEEE 802.3 10BASE2 standard, or you can buy RG-58AU or RG-58CU cable. A common mistake is to use the 75-ohm cable for composite video that may already exist in your installation. If you try to use 75-ohm cable it will work only by some miracle, and your system will have zero reliability, so don't even think about it.

ThinNet systems use special BNC connectors to connect cables and devices to the network. These are specially designed gold contact connectors, so again, you can't use your old video connectors and hope to build a reliable system. One way to assure that your system will be reliable is to verify that all of your parts are designed specifically for use with the IEEE 802.3 10BASE2 Ethernet standard, or meet the applicable military specification for the hardware.

4.1.1 Grounding in ThinNet

In the 10BASE2 specification, the signal is carried on the center conductor, and the braided shield is required to be grounded <u>at only one location</u> (one end) of each segment. If your network includes hubs, the hub may have been built to include the necessary grounding. Otherwise, you will need a special terminator that has a grounding wire attached to it.

Before purchasing special terminators, you should test for grounding in your hubs. Disconnect AC power from the equipment you are testing. Attach a BNC connector to one of the ports on your hub. Test for continuity between the metal exterior of the BNC connector and the ground pin of the power cord. If there is continuity, then the hub may be used for segment grounding. Note: The hub must be properly connected to earth ground for the system to be grounded.

The special grounded terminators can often be difficult to find. Most office network systems work fine without this ground attached. However, ESTA recommends that all ThinNet segments be properly grounded at one end.

You must take special care that other connectors on the segment do not touch any current-carrying conductors or other ground locations, since this could create ground currents through the Ethernet cable (which would certainly cause problems). Vinyl boots with Velcro fasteners are available that can be used to insulate the connectors used in ThinNet systems. In an emergency, insulating electrical tape can be used to insulate ThinNet connectors. Electrical tape should be replaced with proper insulators as soon as possible.

4.1.2 ThinNet Hardware Overview

ThinNet uses <u>50-ohm</u> coaxial cable, BNC connectors, and associated installation tools. BNC connectors are available in impedances other than 50 ohms, which should <u>never</u> be used for ThinNet applications. As a general rule, the cable, BNC connectors, and installation tools must all be matched for a successful connector installation.

4.1.2.1 ThinNet BNC Connectors

These are special male BNC connectors with a gold pin in the center that is attached to the center conductor of the coaxial cable. There are different types of these connectors, but the best are those that are attached to the coaxial cable using a special crimping tool. It is important to use the right crimping tool that matches the type of BNC connector you are using, or you will get an unreliable intermittent connection at this connector. To gain a reliable system, it is well worth spending the extra money to purchase the connector manufacturer's recommended crimping tool, rather than using an old crimper that you have in your tool box.

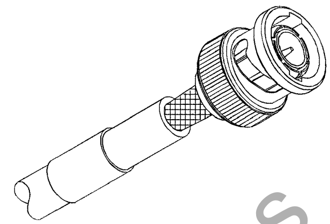

Figure 12 — BNC Ethernet Connector

The U.S. military specification MIL UG-88 BNC connector actually has a soldered-on center pin and a considerably more difficult assembly procedure, but when assembled correctly it provides the best connection. For entertainment applications, the crimp-on connector is recommended because it is more readily available, is easier to assemble, and will provide a reliable connection <u>if the manufacturer's procedures are followed using the correct crimping tool</u>. The BNC connectors used must match the specific cable type. You must use the correct combination of cable, connector, and crimping tool to insure a reliable connection. Incorrect selection of these items is one of the most common sources of ThinNet problems.

Great care should be taken when BNC connectors are attached to avoid letting any of the braided shield wires touch the center conductor, because this will cause a short in the wire, which will prevent the network from working.

4.1.2.2 Barrel Connectors

Barrel connectors have two female connectors for connecting two lengths of cable with male BNC connectors already attached to them. As with all Ethernet connectors, barrel connectors should have gold contacts to provide the best connection possible. Avoid using extra connectors if they are not absolutely needed. Every connection that exists in a cable segment can cause interference and is an extra point of risk for damage or malfunction.

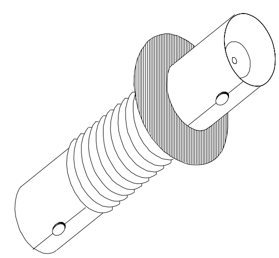

Figure 13 — BNC Barrel Connector

An exposed barrel connector has the potential to come into contact with a ground through any metal that it might touch. Since the shield should be connected to earth ground at only one end of the segment, you should insulate any exposed barrel connectors with some type of boot to prevent any contact with other metal. Failure to properly insulate a barrel connector could result in inadvertent and detrimental multiple earth grounding. Boots with Velcro closures and PVC insulated barrel connectors are available commercially for these reasons. In an emergency, insulating electrical tape can be used to insulate ThinNet connectors. Electrical tape should be replaced with proper insulators as soon as possible.

4.1.2.3 “T” Connectors

“T” connectors (or “tee connectors”) have two female ends for connecting two pieces of cable that have male BNC connectors attached (or one cable with a male BNC connector attached and a terminator). They also have a male BNC connector protruding at 90 degrees for direct connection to a node. They are also available with PVC insulation, although there is less chance of them coming into contact with other metal since they should not be resting on the ground like barrel connectors. The “T” connector should only be used to connect directly to the device’s BNC outlet. Never use any kind of a jumper cable, called a stub between the “T” connector and the BNC connector on the node however awkward the cable routing becomes. The stub will prevent the network from working! For the same reason, a “T” connector should not be used to create another “T”-connected segment.

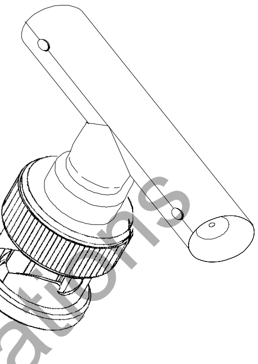

Figure 14 — BNC “T” Connector

4.1.2.4 50-Ohm Terminators

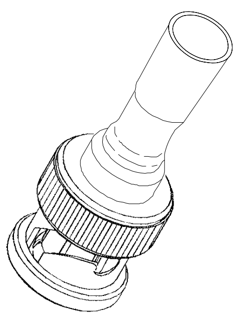

Figure 15 — BNC 50-Ohm Terminator

A terminator is a BNC connector that has a 50-ohm resistor inside connecting the shield to the center conductor. The resistor provides a cushion at the end of a segment to absorb propagating signals and prevent them from reflecting back up the wire and causing interference. Some 50-ohm terminators have an earth ground wire on them, but these are difficult to find. If your system uses a ThinNet hub, each output of the hub maybe internally grounded to the chassis ground of the hub. This can be quickly verified by making a continuity check between the power cord ground pin of the hub and the shell of the panel-mount BNC connector on each port of the hub. In cases where this internal grounding is present, use of grounding terminators is not required, since each segment must be grounded at only one point, which in this case is the hub itself (see section 4.1.1).

4.1.2.5 ThinNet Wall Plates

A ThinNet wall plate consists of a single bulkhead-mounted BNC connector. This connector shall be at the end of a segment from a ThinNet hub, unless it is at the end of a Single Segment System, as indicated in Figure 5. ThinNet wall plates must be constructed so that the outer shell of the BNC connector cannot come into contact with conduit ground. This is typically accomplished through the use of plastic wall plates or isolated BNC panel-mount connectors. Cable lengths between wall plates and hubs (and, by implication, patch cable allotments between wall plates and devices) must conform to the ESTA guidelines in Part 2. Wall plates must be labelled according to the ESTA guidelines in section 3.1.

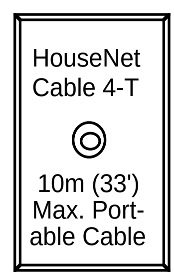

Figure 16
ThinNet Wall Plate

4.1.3 The Pros and Cons of ThinNet

Pros:

- Hardware is relatively durable and can withstand limited abuse
- Allows multiple nodes on a single segment in a linear topology as well as star topologies
- 185m (607') maximum length is suitable for most entertainment lighting systems
- Can interface with other Ethernet technologies

Cons:

- Requires a user-installed terminator
- Probably does not provide for future 100Mb/s Ethernet
- Electrical isolation between nodes is not as complete as with Fiber Optic: may not be suitable to bridge between equipment in totally different areas (i.e., areas that have no equi-potential grounding)
- ThinNet hubs are relatively expensive and not as readily available as UTP hubs
- Requires insulation of mated connector pairs with plastic boots or tape
- ThinNet is losing marketshare in the computer industry, and is not likely to be well-supported in the future.

4.2 Unshielded Twisted Pair (UTP) Systems (10BASE-T)

Unshielded Twisted Pair — also called UTP, twisted pair, or 10BASE-T — uses a central hub. Segments radiate from the hub, each connecting one node to the network. Each segment may be up to 100m (328'). Thus, the maximum distance between two nodes is 200m (656'), but only if the hub can be physically located exactly half way between the two nodes. To ensure upgradeability, ESTA requires that UTP cable must be four-pair, Category 5 wire, and must meet the ISO/IEC 11801 Class D link specification for 100-ohm cable. While two pair cable may be used for 10BASE-T systems, the installation of four pair Category 5 cable ensures the system is capable of a 100Mb/s upgrade.

4.2.1 Twisted Pair Hardware Overview

4.2.1.1 UTP RJ45 Connectors

UTP systems use 8-conductor RJ45 connectors to connect cables and devices to the network. The RJ45 male connector is a larger version of the RJ11 connector, which is commonly used on telephones in North America. This 8-pin connector is specified in standard IEC 603-7:1990, Part 7. Like its smaller cousin, the RJ45 is plastic, but it has eight exposed conductors at the front and bottom. A flexible plastic retaining tab, located on the top of the connector, holds the male connector in the female receptacle. The RJ45 connector is attached to a cable using a special crimping tool.

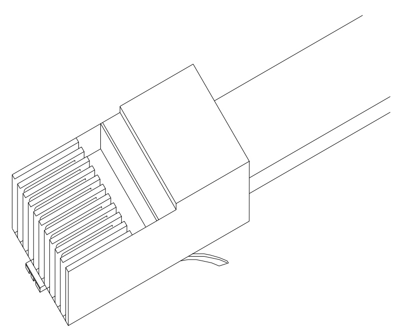

Figure 17 — UTP RJ45 Connector

While the RJ45 receptacle is rugged enough to survive many insertion and removal cycles, some question the ability of the plastic tab on the RJ45 male connector to survive similar use. On the other hand, the connectors and crimping tool are relatively cheap, making the repair of failed connectors a quick and inexpensive process. Also, the common office usage of UTP systems should simplify the purchase of spare or replacement cables and connectors. The best solution to the problem of broken connectors and cables is always to have at hand several spare UTP patch cables of appropriate lengths.

Equipment should be provided with RJ45 receptacles, rather than permanently attached UTP “pigtails” or cable stubs. Since UTP connections are always point-to-point, “T” connectors are not available for, or permitted in, UTP systems.

4.2.1.2 UTP Hubs

When UTP is used, a hub is required. The hub is active. It requires electrical power and it actively participates in network operations. If the hub’s power supply fails, the network will be inoperative.

Typically, a hub is little more than a “black box.” All but one of the face panels are featureless. The remaining face panel typically contains either 4, 8, or 16 RJ45 receptacles, a power LED, a 120V AC power connection, and a power switch. Some hubs include an LED near each RJ45 receptacle that indicates whether the far end is connected and powered up. This is often called the “linkbeat” indicator. It also is commonly found on transceivers and node ports.

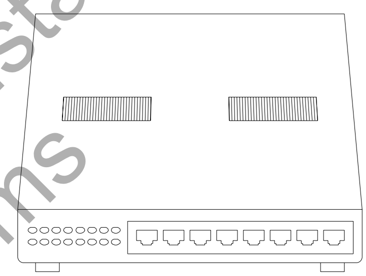

Figure 18 — UTP Hub

Some UTP hubs are designed to interface several UTP segments to a ThinNet or Fiber Optic segment. Such UTP hubs allow UTP technology to be integrated with a larger or more complex network. Other high-end hubs have multiple repeaters in a single chassis, and have embedded network management that lets you enable and disable individual ports, move ports between repeaters, and observe traffic and fault analysis statistics on each network.

There is a special case for the two-node UTP systems. Two UTP nodes may be connected together by a two-port passive UTP hub, described in Appendix A and available from lighting system manufacturers.

4.2.1.3 UTP Wall Plate Connectors

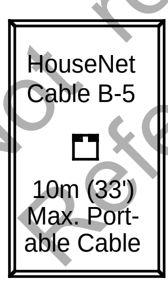

Figure 19
UTP Wall Plate

A UTP wall plate consists of a bulkhead-mounted RJ45 connector. For ease of labeling, only one connector per plate is recommended. This connector shall be at the end of a segment from a UTP hub. The permanent wiring of a UTP system should never be taken direct to a node or hub. Instead, it should end at a wall plate, terminal block, or patch bay, with connection to the node or hub via a UTP patch cable.

Cable lengths between wall plates and hubs must conform to the ESTA guidelines in Part 2. Wall plates must be labelled according to the ESTA guidelines in section 3.1.

4.2.2 Twisted Pair Topologies

All UTP configurations require a hub (see section 4.2.1.2). Conceptually, if not actually, the UTP node connections radiate outward from the centrally located hub. For these reasons, UTP configurations are usually referred to as star topologies.

By mixing UTP hubs with ThinNet or Fiber Optic backbones, you can create configurations with two or more interconnected star topologies. The UTP systems form the stars of the network and the ThinNet or Fiber Optic systems interconnect the stars.

4.2.3 Twisted Pair Pros and Cons

Pros:

- Connectors and cable are inexpensive, readily available and used in other network applications
- External termination is not necessary (termination is built in at nodes and hubs)
- Hardware and hubs are readily available and inexpensive
- Automatically partitions a segment if a failure occurs in that segment
- Will allow for future 100Mb/s Ethernet if 4-pair or Category 5 cable is specified at installation time. Four-pair, Category 5 cable and cable hardware is widely available, and is highly recommended.
- Can interface with other Ethernet types
- Cable and connectors are all insulated
- Tolerates most single device failures

Cons:

- Connectors and cables are not quite as robust as ThinNet
- Requires a hub (active or passive) even if only two nodes are to be connected (a non-standard two-port passive UTP hub, see Appendix A, can be used to link two UTP nodes)
- 100m (328') maximum length may be problematic for some entertainment lighting systems
- Does not allow additional nodes on a segment (no linear topologies)
- Electrical isolation between nodes is not as complete as with Fiber Optic: may not be suitable to bridge between equipment in totally different areas (i.e., areas that have no equi-potential grounding)

4.3 Fiber Optic Systems (10BASE-FL)

Fiber Optic Ethernet 10BASE-FL (10Mb/s) systems are not generally used for direct connections between nodes. Fiber Optic cable and hubs are more expensive than either ThinNet or UTP. Fiber Optic cable must be installed carefully in accordance with limited pulling force rules, bend radius limitations, and other detailed restrictions. Fiber Optic cable must not be bent more sharply than the recommended minimum bend radius, which makes using Fiber Optic cable in temporary installations more challenging.

Still, Fiber Optic is invaluable for situations where electronic emissions and environmental hazards are a concern. A common situation where these conditions threaten a network's integrity is when segments need to be routed between buildings. Lightning strikes can wreak havoc and even destroy networking equipment. Fiber Optic cables effectively insulate networking equipment from these conditions since they do not conduct electricity. Fiber Optic cable can also be used in areas where large amounts of electromagnetic interference are present. Fiber Optic links are also highly recommended between areas that have significant differences in ground potential, such as those areas that are serviced by AC power feeds from different transformers.

The Ethernet standards allows for Fiber Optic cable segments up to 1 km (0.6 miles) long. Fiber Optic systems can provide powerful backbones in permanent installations. Use of Fiber Optics should be considered when it is necessary to span distances greater than 185m (607').

The Fiber Optic cable should be 62.5 micron core/125 micron cladding (abbreviated 62.5/125 um) multi-mode graded index fiber with a modal bandwidth of at least 500 MHz/km. This is the standard for North American network cabling installations. Details about this optical fiber can be found in the TIA/EIA-568-A, or ISO/IEC 11801 building wiring standards. All 10Mb/s and 100Mb/s Fiber Optic Ethernet gear will work on this fiber.

4.3.1 Fiber Optic Hardware Overview

4.3.1.1 Fiber Optic Connectors

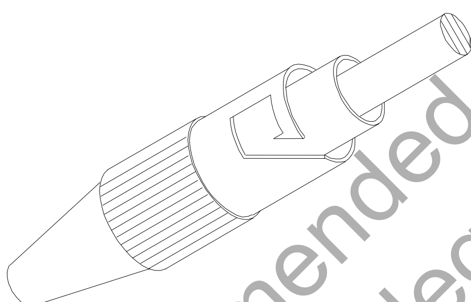

Figure 20
"ST" Type Fiber Optic connector

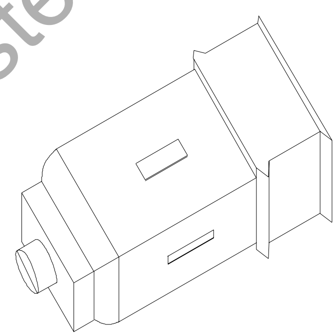

Figure 21
"SC" Type Fiber Optic connector

The "ST" type connector is a bayonet style simplex connector that is widely used in patch panels and hubs. It is a nice, rugged connector that is available from multiple sources. The "ST" type connector has one disadvantage; it is a simplex connector. Therefore, separate receive and transmit connectors are required for each segment. It is easy to confuse the two connectors, and cross plug them.

For this reason, "SC" connectors are generally recommended in a duplex configuration for Fiber Optic networks. A good combination is to use "ST" connectors behind wall plates, and for permanent installations, and to use "SC" connectors when connections are less than permanent.

4.3.1.2 Fiber Optic Hubs

Fiber Optic networks require hubs at both ends of the Fiber Optic cable. The hubs connect the optical fiber to other Fiber Optic, ThinNet, or UTP segments.

4.3.2 Fiber Optic Topologies

The only use for Fiber Optic hardware is as a backbone for and in combination with either ThinNet or UTP devices.

4.3.3 Fiber Optic Pros and Cons

Pros:

- Immune to electrical interference
- Not affected by many environmental hazards
- Hardware and hubs are readily available
- Allows for future 100Mb/s Ethernet (100BASE-FX)
- Can interface with other Ethernet technologies
- A segment can be up to 1 km (0.6 miles), or longer with proper engineering assistance
- Total electrical isolation between ends, which allows two nodes to be located in totally different electrical environments

Cons:

- Requires careful handling and protection of cables
- Point-to-point, does not allow additional nodes on a segment (no linear topologies)
- Not as suitable for direct connection to nodes
- Generally more costly than UTP and ThinNet
- User termination or alteration difficult
- Difficult to repair damaged fiber segments

4.4 ThickNet (10BASE5)

ThickNet is often referred to as the “frozen yellow garden hose,” because it uses a large diameter, low-loss coaxial cable. The cable is at least twice the diameter of ThinNet cable. However, its transmission loss characteristics allow segments of up to 500m (1640').

While some might see ThickNet as an attractive alternative to Fiber Optic backbones, some practical technological issues should be considered. ThickNet was the first Ethernet technology to be developed. It now is over fifteen years old (very old by computer industry criteria). Because of its costs (including but not limited to the cable cost), ThickNet no longer enjoys much usage or new product interest in the computer industry.

ThickNet is not recommended for use in entertainment venues.

Appendix A: Two-Port Passive UTP Hub

Two UTP nodes may be connected together without the use of a UTP hub. While this configuration does not allow for the network to expand, it does offer a very inexpensive way to connect two nodes.

Connecting two UTP nodes may be accomplished by using a two-port passive UTP hub or by the use of a cross-over cable. However, ESTA does not recommend the use of cross-over cables because it is very likely that a cross-over cable will be mistaken for a standard UTP portable cable. ESTA only recommends using a two-port passive UTP hub if an active UTP hub is not within the budget.

Two-port passive UTP hubs do have some advantages over an active hub. A carefully wired passive UTP hub will be more reliable than any active hub on the market; it is unaffected by power failures. A two-port passive UTP hub has fewer components than an active hub, and simple copper wires are about as reliable a connection as you could hope to find. Also, two-port passive UTP hubs are considerably less expensive than active hubs.

Pin	Pin
1	3
2	6
3	1
4	7
5	8
6	2
7	4
8	5

Figure 22
Two-Port Passive UTP
Hub Wiring Diagram

Two-port passive UTP hubs are not available from commercial Ethernet suppliers. Lighting system manufacturers may make them available as part of their product line. It is also possible to make a two-port passive UTP hub. A passive UTP hub can be made by using a terminal block with two RJ-45 connectors. Figure 22 shows the internal wiring of the two RJ-45 connectors.

Appendix B: About Ethernet

B.1 Why Use Ethernet?

Entertainment lighting is a small industry. Traditionally, we have borrowed existing technologies that were developed for other industries. As the computer industry grew, clever lighting technicians applied computers to the control of their lighting systems. Manufacturers began to use digital serial signals to communicate between their controlling computers and the SCR-based dimmers that ran their lights. Because fewer wires were required, serial communication reduced the amount of cabling needed to control lots of dimmers, so economic reasons largely drove the demand for serial technology.

Out of serial technology came the USITT 1986 DMX512 Digital Data Transmission Standard for Dimmers and Controllers. This standard allowed any manufacturer's console to "speak to" any other manufacturer's dimmers (in theory and usually in practice). Perhaps a similar Ethernet standard will exist someday, although that is not the subject of this document.

Ethernet is simply a new technology that we have borrowed from the computer industry. One of the most significant reasons to use Ethernet for communication is its ability to carry hundreds of times more information on a single cable than would be carried on a typical serial cable. First generation Ethernet operates at 10Mb/s (megabits per second). In comparison, DMX512 operates at 250Kb/s (kilobits per second). Furthermore, Ethernet technology is still evolving and Ethernet systems operating at up to 100Mb/s are appearing in some computer applications. This increase in bandwidth is almost essential when you consider the greater capacities of newer control systems being designed.

A second advantage in using Ethernet lies in its ability to accommodate connecting multiple devices in a single network, regardless of the information interchange relationships between the devices. Ethernet allows all devices in the network to communicate with each other. Ethernet also allows one or more groups of devices to set up private communication domains within a larger, single network. Ethernet even allows two devices to communicate solely with each other, ignoring all the other devices connected to the network. Ethernet also reduces the amount of cable required, so economic factors again will certainly drive the demand for this technology.

B.2 The Theory Behind Ethernet

Ethernet was first developed using a wiring scheme now called ThickNet. ThickNet evolved to ThinNet, which is fundamentally equivalent but uses a smaller, more flexible cable. The theory behind Ethernet is based on the coaxial cable used by ThickNet and ThinNet. You cannot properly appreciate the theory of Ethernet without first realizing that it assumes that a coaxial cable carries its signals.

Ethernet is used to operate a LAN (Local Area Network). A LAN allows multiple devices, or nodes, to either "listen" to or "speak" onto a central wire at any time. One analogy is to think of the coaxial LAN as a large pipe with portals along its length where different users can be located. The pipe is equivalent to the Ethernet coaxial cable. The portals are equivalent to the "T" connectors on the coaxial cable.

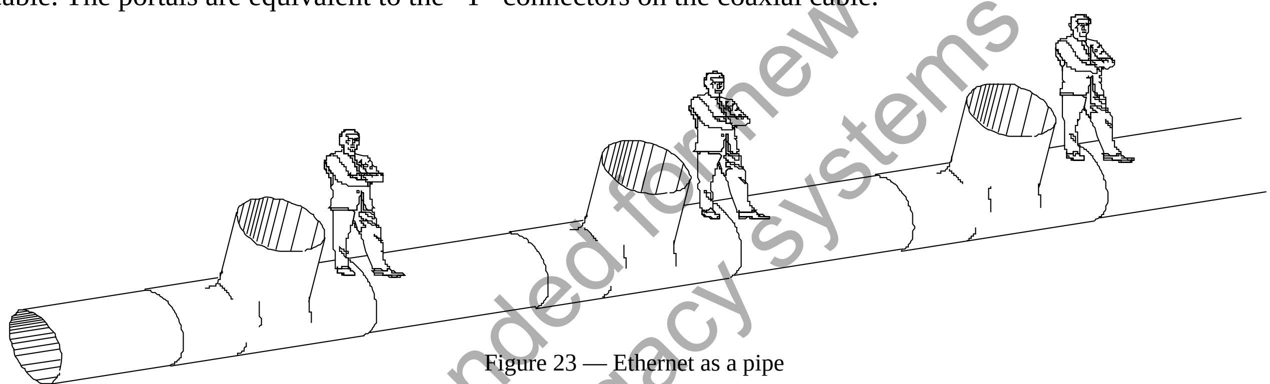

Figure 23 — Ethernet as a pipe

At any portal, you can hear what's being shouted into the pipe from any other location, or you can choose to shout your own message into the pipe for all others to hear. Now assume that you know who some of the listeners are. Before you shout your message into the pipe, you can shout who the message is meant for. Then all the other listeners can choose to ignore your message, while the listener(s) for whom your message is intended can receive and act on your message. To take it a step farther, the listener(s) who received your message can now shout back that they got your message and understood it, or that it was garbled and they would like you to shout it again.

This network arrangement (where all devices communicate on the same wire) is like a telephone party line, and requires that some rules be followed for the LAN to operate properly. After all, if everyone is talking at the same time, no one can understand what anyone else is saying. Nodes have to take turns sending messages. The inventors of Ethernet devised dramatic, new (to computers) rules for managing message traffic on the Ethernet party line. They called it the "Cocktail Party Algorithm."

Imagine that you are at a cocktail party, talking to a group of friends. In the same instant, Sally and Marvin try to say something. Noticing that someone else is talking, they both stop and wait for a new opportunity to speak. The time that Sally and Marvin each wait depends on their character, but it probably is not the same for both. So, the next time one of them talks she or he probably will be the only one talking.

In Ethernet terms, when two nodes try to send a message at the same time, a collision occurs. Electrically, their two signals combine to produce a higher voltage signal that all nodes can recognize as a collision. As required by the Cocktail Party Algorithm, any node that recognizes a collision stops sending and waits a random time interval before trying to send again. The random time interval is a computer way of representing the character differences between Sally and Marvin. Computer engineers say that the node is performing its back-off algorithm, backing-off its send operation. Collisions are a normal part of Ethernet network operation; they should not be thought of as errors. They are successfully retried quickly and result in only slight increases in the time required to send a message.

At a cocktail party, communications break down when too many people are trying to converse in the same group at the same time. Some two people are always trying to talk at the same time. A similar problem occurs in Ethernet networks. As more nodes are added to a given system, network traffic increases until collisions begin to occur. More nodes still may be added without causing any serious problems. However, a point eventually will be reached where so many nodes are trying to send messages so often that collisions are always occurring, back-offs are always being performed, and the time to send any single message approaches forever. This overload point can be reached with as few as three nodes, if all are trying to talk at the same time.

Another area where Ethernet can have limitations, particularly for entertainment lighting, is the non-deterministic nature of its back-off algorithm. Dimmer refresh requirements are fixed; in DMX512 dimmer data typically is refreshed at least 44 times per second. Typically, maintaining the same refresh rate is trivial for Ethernet. However, sufficiently large numbers of collisions can degrade the refresh rate, and there is nothing in the Ethernet standards to give dimmer data any special priority.

Most entertainment lighting systems assume that they can use all 10Mb/s of the Ethernet and frequently try to do so. This assumption simplifies design and production of the entertainment lighting equipment. However, it means that you must assume that entertainment lighting equipment from one manufacturer cannot share an Ethernet system with similar equipment from another lighting manufacturer or with ordinary office Ethernet devices.

Like all other signaling systems, Ethernet systems have cable length limitations. The specific cable length restrictions depend on the signaling technology and the quality of the cable. As Ethernet technologies have evolved over the years, several different methodologies and maximum cable lengths have been defined.

Like DMX512, most Ethernet communications cables need proper termination. When a resistance that matches the characteristic impedance of the cable is connected across both ends of the cable, the cable behaves as if it is infinitely long. Thus, signals simply disappear off both ends of the cable, as if they are continuing down an infinitely long wire. Signals that have an infinitely long wire to travel do not reappear (or get reflected) on the working part of the cable and so do not interfere with the data-carrying signals. Unlike DMX512, improperly terminated Ethernet cables never, ever work.

In some cases (such as Ethernet Fiber Optic cables), electrical termination is not required. In other cases (such as UTP), electrical termination is built into the transmitters and receivers. However, both ThickNet and ThinNet require user-installed proper termination at both ends of the cable.

This is a greatly over-simplified but fairly accurate description of the theory behind Ethernet. As noted previously, this description covers the original Ethernet theory. As Ethernet technology has evolved, slight changes have been made in some aspects of the theory. For example, UTP systems do not experience the on-wire collisions described above. However, UTP systems do exhibit the same cocktail party message collision properties described above; the collisions simply occur inside the hub or on a ThinNet segment down-stream from the hub.

Glossary

10BASE2: ThinNet Ethernet running on small diameter coaxial cable. (10 means 10Mb/s. BASE stands for baseband. 2 means 200m.)

10BASE5: ThickNet Ethernet running on large diameter coaxial cable. (10 means 10Mb/s. BASE stands for baseband. 5 means 500m.)

10BASE-FL: IEEE 802.3j physical layer specification for 10Mb/s Ethernet operating over two optical fibers.

10BASE-T: Ethernet running at 10Mb/s on unshielded twisted pair (UTP) cable. (10 means 10Mb/s. BASE stands for baseband. T means twisted-pair.)

100BASE-T: Ethernet running at 100Mb/s on unshielded twisted pair (UTP) cable. (100 means 100Mb/s. BASE stands for baseband. T means twisted-pair.)

100BASE-TX: IEEE 802.3u physical layer specification for 100Mb/s Ethernet operating over two pairs of Category 5 UTP or STP wire.

100BASE-T4: IEEE 802.3u physical layer specification for 100Mb/s Ethernet operating over four pairs of Category 3, 4, or 5 UTP wire.

100BASE-FX: IEEE 802.3u physical layer specification for 100Mb/s Ethernet operating over two optical fibers.

Two-Port Passive UTP Hub: A specially made two port RJ-45 terminal block that allows for two UTP nodes to be connected together without the need for a full UTP hub.

ANSI: American National Standards Institute — 11 West 42nd Street, New York, NY 10036. +1 212 642 4900. Fax: +1 212 398 0023. Email: info@ansi.org. WWW: http://www.ansi.org

AWG: American Wire Gauge. A system that specifies wire size. The gauge varies inversely with the wire diameter size.

Babble: An error condition caused by an Ethernet node transmitting longer packets than allowed. Sometimes babble is used interchangeably with jabber.

Backbone: An Ethernet segment having the sole purpose of connecting the hubs for other segments. A backbone often uses a different Ethernet technology than the one used by the segments radiating from the hubs that it connects (e.g., a ThinNet backbone can be used to connect two UTP star topologies).

Back-off: The action that a node takes when it recognizes a collision. The node stops trying to send a message, waits a random time interval, and then retries sending the message.

Baud: Unit of modulation rate equal to the number of signal elements per second, where all such elements are of equal length and each element represents one or more bits.

Bit: The smallest unit of data processing information. A bit (or binary digit) assumes the value of either 1 or 0.

BNC: Bayonet-Neil-Concelman. The connector type (named after its inventors) used for ThinNet 10BASE2 Ethernet coaxial connectors, “T”-connectors and terminators.

bps: Bits per second, units of transmission speed.

Bridge: A networking device that connects two LANs and forwards or filters data packets between them, based on their destination addresses. Bridges operate at the data link level and are transparent to protocols and to higher level devices like routers.

Bus: A LAN topology in which all the nodes are connected to a single cable, a linear topology. All nodes are considered equal and receive all transmissions on the medium.

Byte: A data unit of eight bits.

Category 5: The specification for UTP cable, connectors, and installation practices capable of running Ethernet at 10 and 100Mb/s.

Coaxial Cable: An electrical cable with a solid wire conductor at its center surrounded by insulating materials and an outer metal screen conductor concentric with the inner conductor — hence “coaxial”. Examples are ThickNet and ThinNet Ethernet cable.

Collision: The condition that occurs when two or more nodes attempt to send a message on a given network cable at the same time.

Concentrator: See Hub.

Critical Segment: A special ThinNet cable segment which connects critical devices (such as main and backup consoles) in a linear topology so that they continue communicating even if the hub connecting them to the rest of the network fails.

Crosstalk: Noise passed between communications cables or node elements.

Cross-Over Cable: A non-recommended cable that is the functional equivalent of a two-port passive UTP hub.

CSMA/CD: Carrier Sense Multiple Access with Collision Detection is the Ethernet media access method. All network nodes contend equally for access to transmit. If a node detects another nodes’s signal while it is transmitting it aborts transmission and retries after a brief pause.

Data Link: A logical connection between two nodes on the same network.

DMX512: USITT standard DMX512/1990 Digital Data Transmission Standard for Dimmers and Controllers.

EIA: Electronic Industries Association — 2500 Wilson Boulevard, Arlington, VA 22201. +1 703 907 7500. EIA and EIA/TIA documents can be purchased through Global Engineering.

Ethernet: The most popular LAN technology in use today. The IEEE standard 802.3 (or ISO/IEC 8802-3) defines the rules for configuring an Ethernet network. It is a 10Mb/s or 100Mb/s, CSMA/CD base band network that runs over thin coaxial, thick coaxial, twisted pair or Fiber Optic cable.

Fiber Optic Cable: A transmission medium composed of a central glass or plastic optical fiber filament surrounded by cladding and an outer protective sheath. It transmits digital signals in the form of modulated light from a laser or LED (light emitting diode).

Full-Duplex: Independent, simultaneous two-way transmission in both directions.

Header: The initial part of a data packet or frame containing identifying information such as the source of the data, its destination, the packet type and length.

Hub: A powered device with multiple ports used to connect together several Ethernet cable segments. The hub retransmits information received from a segment to all other segments, restoring signal timing and waveforms in the process. The hub isolates faulty cable segments from the other segments. Hubs are available with ThinNet, UTP or optical fiber interfaces. Technically defined as a “repeater set”.

IEC: International Electrotechnical Commission — IEC Central Office; 3, rue de Verenbe; P.O. Box 131, 1211 Geneva 20; Switzerland. +41 22 919 02 11. Fax: +41 22 919 03 00. If necessary, contacts from the USA should be made through ANSI. In the USA, IEC documents can be purchased through Global Engineering.

IEEE: Institute of Electrical and Electronic Engineers — 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331 USA, +1 800 678 4333, +1 908 981 0060.

ISO: International Organization for Standardization — ISO Central Secretariat; 1, rue de Varembe; Case postale 56; CH-1211 Geneve 20; Switzerland. +41 22 749 01 11. Fax: +41 22 733 34 30. WWW:http://www.iso.ch/. If necessary, contact from the USA should be made through ANSI. In the USA, ISO documents can be purchased through Global Engineering.

Jabber: Network error caused by an interface card placing continually corrupted data on the network. Sometimes jabber is used interchangeably with babble.

Kb/s: Kilobits per second (e.g., 250 Kb/s is 250,000 bits per second).

LAN: Local Area Network. A collection of nodes that communicate with each other using one or more interconnected cables and zero or more hubs.

Linear Topology: A network configuration in which a single cable run connects all nodes. All the nodes in a linear topology share the single cable for communications.

Mb/s: Megabits per second (e.g., 10Mb/s is 10,000,000 bits per second).

Multidrop: A network configuration in which multiple nodes are connected to the same network segment possibly in a linear topology.

Multi-port Repeater: See Repeater.

Network: A collection of nodes that communicate with each other using one or more interconnected cable segments and zero or more hubs.

Network Address: Every node on a network has a 48-bit address associated with it. This is a fixed hardware address, such as “AE-34-2C-1D-69-F1,” assigned by the node’s manufacturer. The address is made up of two fields, the Organizationally Unique Identifier (OUI) as defined in ISO/IEC 8802-3 sub-clause 3.2.3.1 and IEEE 802:1990 Clause 5, and the vendor assigned portion. There may be other addresses that the node will respond to, such as broadcast and multicast addresses. These are discussed in greater detail in the IEEE standards. The IEEE is a world-wide registration authority for OUI values.

Node: Any device communicating with another device on the network. All nodes have a network address. Hubs, concentrators, repeaters, etc. are part of the network but are not nodes. Typical entertainment lighting examples are consoles, remote video, etc.

Non-Critical Segment: A special ThinNet cable segment which connects non-critical nodes (such as remote video) in a linear topology.

Packet: A series of bits containing data and control information, including source and destination node addresses, formatted for transmission from one node to another.

Point-to-Point: A network configuration in which two devices are connected to each other by direct cables with no multidrops or linear topologies.

PLASA: Professional Lighting and Sound Association — 7 Highlight House, St. Leonards Road, Eastbourne, East Sussex, BN21 3UH, England, +44 1323 410 335. Fax: +44 1323 646 905. Email: info@plasa.org.uk. WWW: http://www.plasa.org.uk/plasa

Protocol: The encoding and data transfer formats used to move data between nodes on the network. Protocols are differentiated at the packet level by the value Ethernet Type Field. Xerox Corporation currently acts as the registration authority for Type Field values. Some lighting equipment manufacturers currently use unregistered and therefore incompatible protocols. The current contact for Type Field value registration is: Ethernet Registration Authority; Bldg. 801-27-C; Xerox Corporation; Webster, New York 14580.

Repeater: Technically, the core circuitry of a hub. Often used interchangeably with hub.

RJ45: The common name for the 8 pin modular plug and socket (IEC 603-7) used for UTP 10BASE-T Ethernet.

Segment: The Ethernet cable run between the terminators in a ThinNet network or the cable run between a device and a hub in a UTP network.

SQE: Ethernet defined signal quality test function frequently called “heartbeat”.

Star Topology: A network configuration in which cables from nodes are joined together with a hub.

Stub: A cable between the main trunk line of a network segment and a device. In Ethernet, a stub would be a cable between an Ethernet “T”-connector and a node. <u>There should never be a stub between a “T”-connector and a node.</u>

T-Connector: A T-shaped devices with two female and one male BNC connectors used to connect a node to a ThinNet cable segment.

Terminator: Used on both ends of a ThinNet (10BASE2) Ethernet segment, this device provides the 50-ohm termination impedance required for correct operation.

ThickNet: 10BASE5 Ethernet running on thick (13mm) 50-ohm coaxial cable.

ThinNet: 10BASE2 Ethernet running on thin (5mm) 50-ohm coaxial cable.

TIA: Telecommunications Industries Association — 2500 Wilson Boulevard; Arlington,VA 22201. +1 703 907-7700. Fax: +1 703 907 7727. TIA and EIA/TIA documents can be purchased through Global Engineering.

Topology: The arrangement of the nodes and connecting hardware that comprises the network.

Transceiver: The actual device that interfaces between the network cable and the node. Most transceivers are usually built into nodes but some transceivers (particularly for ThickNet) are external.

Twisted-Pair Cable: Inexpensive, multiple-conductor cable comprised of one or more pairs of 18 to 24 gauge copper wires. The pairs of wires are twisted to improve protection against electromagnetic and radio frequency interference and ensure a predictable characteristic impedance.

USITT: United States Institute for Theatre Technology — 6443 Ridings Road, Syracuse, NY 13206 USA, +1 315 463 6463. Fax: +1 315 463 6525. WWW: http://www.ffa.ucalgary.ca/usitt/

UTP: Unshielded Twisted Pair. The 4 pair cable used for 10BASE-T, 100BASE-T, 100BASE-TX, and 100BASE-T4 Ethernet.

Referenced Standards

IEEE Std 802-1990
IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture

ISO/IEC 8802-3:1996 (E) ANSI/IEEE Std 802.3, 1993 Edition
Local and Metropolitan Area Networks

ISO/IEC 11801:1995
Information Technology Generic Cabling for Customer Premises

TIA/EIA 568-A-1995
Commercial Building Telecommunications Cabling Standard

TIA/EIA Bulletin TSB67
Transmission Performance Specifications for Field Testing of Unshielded Twisted-Pair Cabling Systems

IEC 603-7
Detailed Specification for Connectors 8-Way Including Fixed and Free Connectors with Common Mating Features

USITT DMX512/1990
Digital Data Transmission Standard for Dimmers and Controllers

Standards Ordering Information

ISO/IEC - ANSI/IEEE joint standards and ANSI/IEEE standards are available from:

IEEE Standards
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
+1 908 981 1391
+1 908 981 9667 Fax
http://stdsbbs.ieee.org/

All ISO/IEC, IEC, ANSI/IEEE, and TIA/EIA standards are available from:

Global Engineering Documents
M/S B201
15 Inverness Way East
Englewood, CO 80112
+1 303 792 2181
+1 303 397 2740 Fax
http://www.ihs.com/global/

ANSI/IEEE and some ISO/IEC and IEC standards are available from:

ANSI
11 West 42nd Street
New York, NY 10036
+1 212 642 4900
+1 212 302 1286 Fax
http://www.ansi.org/

USITT standards are available from:

United States Institute for Theatre Technology
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Entertainment Services and
Technology Association

ESTA

Supplement to the Recommended Practice for Ethernet Cabling Systems in Entertainment Lighting Applications

CP/98-1005R3

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CP/98-1005r3

Warning: ESTA recommends against connecting control equipment from different manufacturers to the same Ethernet network. In addition, ESTA does not condone connecting non-entertainment nodes to an entertainment control network. The design details of most existing Ethernet control 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, CITT, VPLT, and APIAS 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: Camera Cranes; Control Protocols; Fog and Smoke; Photometrics; and Rigging.

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.

Contents

Figures

How to Use This Booklet

This booklet is intended to be a companion to the existing ESTA ***Recommended Practice for Ethernet Cabling Systems in Entertainment Lighting Applications***. It will add the additional information needed to guide the user through the different rules that apply to 100BASE-T system design and cabling installation.

Part 1 lists the ESTA recommended practices for Ethernet cabling in 100BASE-T environments. It includes one-line diagrams, descriptions of their use, and commentary about advantages or disadvantages. Part 2 lists ESTA recommended system labeling practices not covered in the original document. Part 3 describes Ethernet hardware that applies specifically to 100BASE-T cable installations. The Glossary has been duplicated from the original Recommended Practice booklet with some additions reflecting the new technology. Consequently, some of the terms in the glossary are not used in this booklet. This duplication allows the reader to use a single source for information rather than flipping between two documents.

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 control network utilizing 100BASE-T cabling. 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 control system into operation.

Introduction

Since the creation of ESTA's ***Recommended Practice for Ethernet Cabling Systems in Entertainment Lighting Applications*** document in 1996, Ethernet technology and cabling methods have improved. A new version of Ethernet is rapidly gaining market acceptance and cabling methods are getting better defined. The purpose of this document is to describe the changes that have occurred in the Ethernet industry and to amend the Recommended Practice to include the new Ethernet industry cabling standards.

The IEEE Std 802.3u:1995 version of Ethernet increases its data rate by a factor of ten to 100 Mb/s. Fast Ethernet, as it's known, (100BASE-T or 100BASE-FX) uses the same types of hub-and-spoke topologies used by 10BASE-T networks. It does not use, however, the bus topology as in ThickNet (10BASE5) or ThinNet (10BASE2) coax networks. Because of this cabling change, an additional document was required to augment the original ESTA Recommended Practice.

In the first Recommended Practice, there were a number of choices of cabling types and topologies depending on the nature of the installation. With Fast Ethernet, cabling decisions become easier, because the choices of technologies that support Fast Ethernet are fewer.

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. Companies who offer Ethernet systems also are very familiar with Ethernet design and practices.

In the broader entertainment industry, however, Ethernet is still a new, relatively 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 much less forgiving. Improper implementation of an Ethernet network is more likely to result in a non-functional network. With the advent of Fast Ethernet at 100 Mb/s, the implementation requirements become even more critical.

Part 1: Configuring Ethernet for Entertainment Control

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

1.1 Recommended Technologies

This Recommended Practice is based on the assumption that, because of its higher bandwidth, many manufacturers of control equipment will be adding 100 Mb/s Ethernet capability to their products. Therefore, unlike the original Recommended Practice which allowed older cabling technologies which were not 100 Mb/s compatible, this companion to the Recommended Practice narrows the recommended cabling technologies to the only two that are 100 Mb/s compatible.

The first is *unshielded twisted pair*, sometimes referred to as balanced twisted pair which is generically called *UTP*. UTP uses a cable containing four wire pairs, and RJ45 connectors (a larger version of the familiar modular telephone connector). UTP requires the use of a hub. The maximum UTP segment length from hub to node is 100m (328').

The cable and connectors used to carry 100 Mb/sec signals must be Category 5 compliant. These items are widely available from most electrical supply houses and computer shops. Category 5 UTP cabling can be used for both 10BASE-T and 100BASE-T installations. The cable terminations and workmanship of the installation must be Category 5 compliant as well.

The other Ethernet cable technology covered in detail in these recommendations is *Multi-mode Fiber Optic*, which is called 100BASE-FX. Fiber Optic cabling is a point-to-point technology which allows for very long runs of up to 2 kilometers, provides complete electrical isolation, and is principally used to connect between devices where segment lengths over 100m (328') are required. The most common fiber optic cable in use at this time is multi-mode 62/125 micron style with ST connectors. Many commonly available network devices accommodate this type of cable and connection. Other common connector types are Duplex SC and the FDDI MIC. This is an area of intense vendor activity and there are a large number of new higher density connectors coming to the market. One or more of them may become standard.

Through the use of these two technologies, the design of systems for nearly all entertainment venues can be addressed. The equipment and skills required to complete an installation using 100BASE-T and 100BASE-FX have become commonly available. This allows us to use off-the-shelf equipment and installation contractors who are equipped to handle the termination and testing of all of the network cables.

Two older technologies, *ThinNet* and *ThickNet*, are specifically <u>not recommended</u> for use in new installations. This is because they are not compatible with 100 Mb/s Ethernet, and support and hardware availability is rapidly diminishing. If you have an existing system which uses one of these technologies, refer to the original Recommended Practice document for further information.

1.2 Recommended Topologies

ESTA's recommended Ethernet cabling systems are based on the use of a "star" wiring topology in several different configurations. In a very small application, a two-port passive hub may be used to connect 2 nodes together. ESTA does not recommend this practice. If such an installation is required, Appendix A in the original Recommended Practice document illustrates how to make such a device. In the smallest of networks, a hub is required to connect nodes to one another. Figure 1 illustrates such a system. Figure 2 shows a generic medium-sized network in 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 shows a generic large-sized network in a hierarchical star topology which supports more nodes and greater distances between nodes than the simple star topology. Figure 4 shows an even larger network which uses Fiber Optic cable to cover extremely large distances.

Prior to permanently installing a cable plant in a facility, be sure to consult the manufacturer of the control equipment that is planned for the facility. This will insure that the cable selected will be compatible with the equipment it is designed to service.

In the following diagrams, the terms "vertical" cables and "horizontal" cables appear. These terms come from the cables used to wire a network in an office building. Usually the cables on each floor run horizontally to the workstations, while the backbone cables run between hubs, vertically from floor to floor.

1.2.1 Riser Diagrams for Recommended Topologies

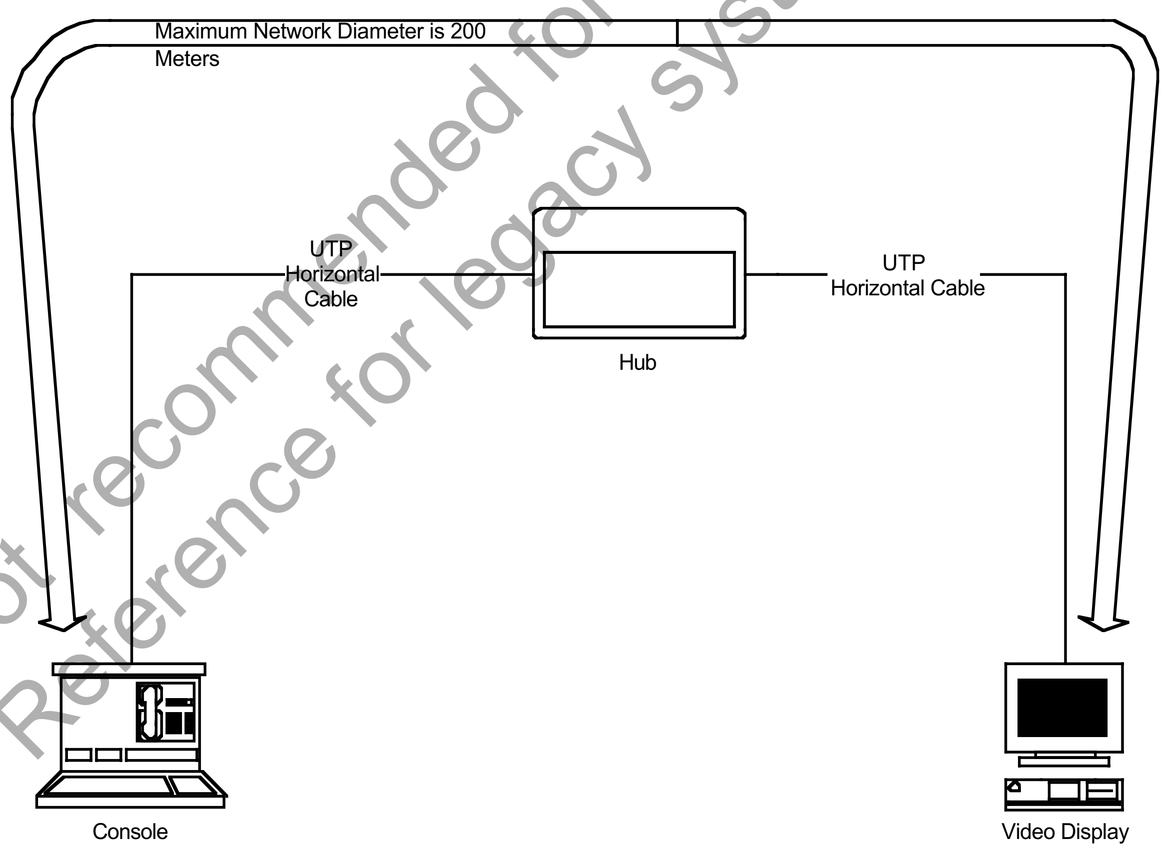

Figure 1 — A small network with 2 nodes

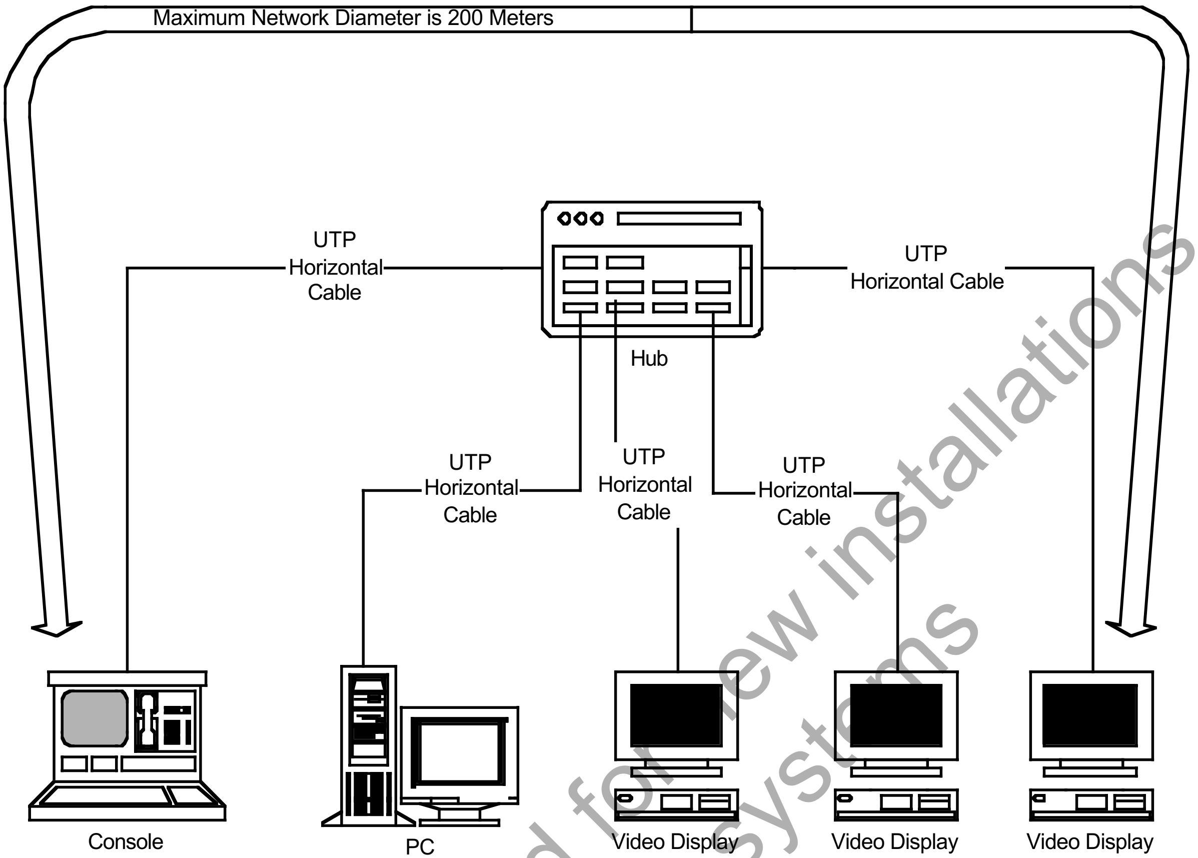

Figure 2— A medium-sized network using UTP cabling

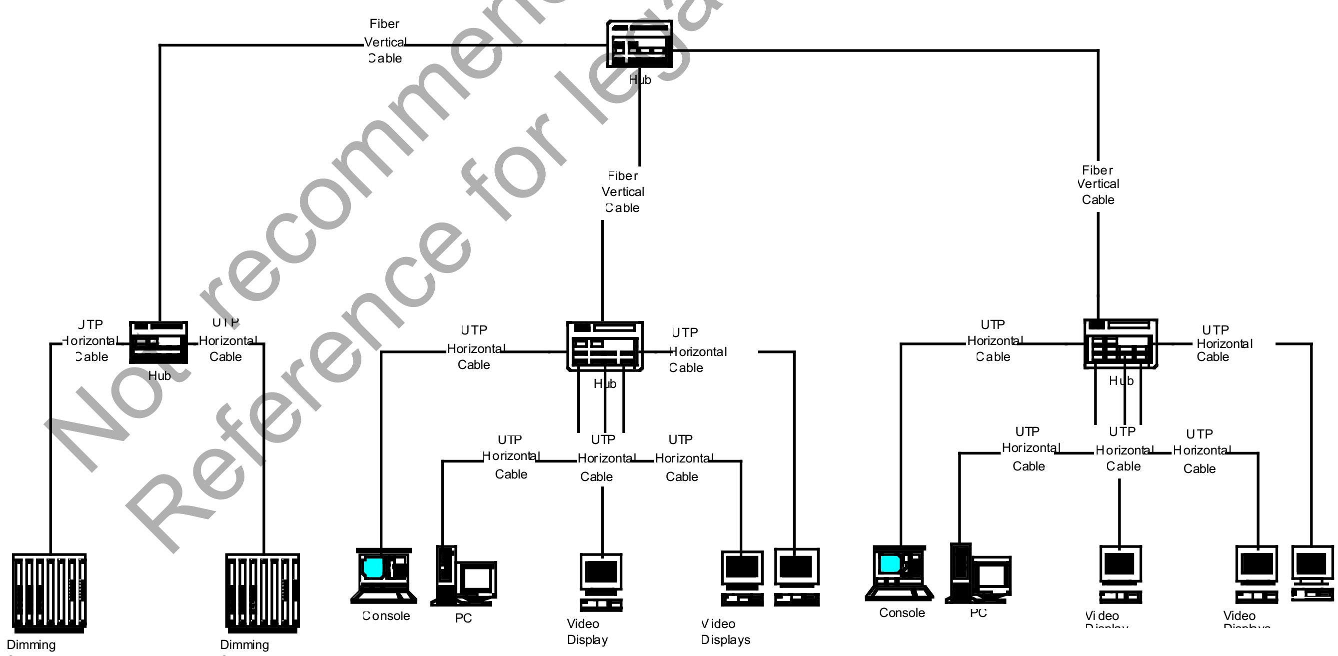

Figure 3 —A large network using both UTP and Fiber Optic cable

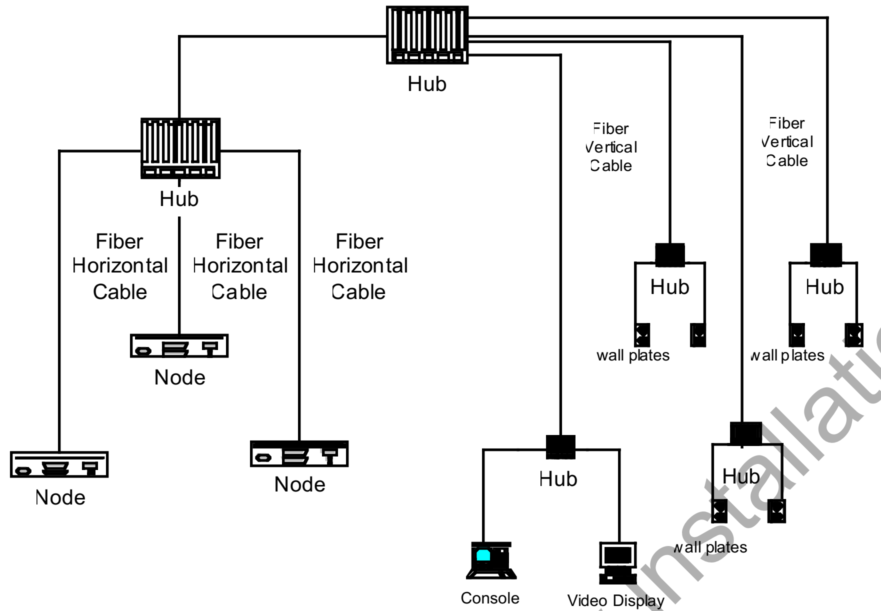

Figure 4 — A large network using Fiber Optic cable and some UTP

1.3 A Comparison of UTP and Fiber Optic Segments

Both UTP and fiber optic segments offer similar advantages compared to other older media such as ThinNet and ThickNet. For both UTP and Fiber Optic, the hub provides fault isolation between segments and insures that devices can be connected and disconnected without affecting the rest of the network. A properly-installed cable plant with either UTP or Fiber Optic cabling running 10Mb/s Ethernet can be readily upgraded to 100 Mb/s Ethernet in the future by the addition of appropriate 100 Mb/s nodes and hubs.

Fiber Optic cables do not usually plug directly into nodes; more often they are used as vertical segments inter-connecting UTP hubs, which in turn are connected to nodes. In special cases where a permanently installed node is hard-wired into a system at a distance of greater than 100m (328’), Fiber Optic may be used to overcome the distance limitation. In installations where hubs must be separated by very long distances, where cables may be routed underground or outdoors, or between devices powered by different power sources, Fiber Optic also provides an ideal solution.

The following sections outline the advantages and disadvantages of UTP and Fiber Optic cabling methods:

Advantages of UTP Segments

1. Cables and hubs are relatively inexpensive.

2. Correct installation of portable RJ45 cables and connectors is simple and familiar to users.

3. Since UTP is the most common cable plan for short-distance office networks, cable, RJ45 connectors, and hubs are very readily available and relatively inexpensive.

Disadvantages of UTP Segments

1. The maximum segment length for UTP is 100m (328'). This may be inadequate for some entertainment facilities.

Advantages of Fiber Optic Segments

1. Can connect hubs separated by distances of up to 2 km (1.2 miles). Under certain conditions, it may be possible to use Fiber Optic for distances of up to 15 km (9 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, and to induced-current damage from nearby lightning strikes.

3. Performs well in submersible or other environmentally hostile applications.

4. Provides complete electrical isolation between network equipment.

5. Many UTP hubs on the market have a single fiber port (100BASE-FX) for use as a backbone connection.

Disadvantages of Fiber Optic Segments

1. Fiber Optic cable, connectors, and hubs are more expensive than UTP.

2. Special tooling, training, and termination techniques are required.

3. Installation of Fiber Optic cable has more stringent requirements for maximum pulling force and minimum bend radius.

1.4 Recommendations for Designing Systems

When you set out to design an Ethernet system for entertainment 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 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.

A backbone is a useful concept in the design of a larger network, and is the segment used to connect between the various physical areas. It should be physically well protected. A network can have one or more backbone segments, or vertical cables.

The actual cable runs in most entertainment control applications are largely horizontal. Our systems are spread out, with long distances between nodes. Occasionally, applications require significant vertical cable runs between hubs due to distance requirements. This document uses the term “backbone” as a synonym for vertical cabling.

(A note about using equipment from different manufacturers): At the time of this booklet's printing there is no Ethernet protocol standard for lighting control communication similar to the DMX512 standard. It is not recommended that you connect Ethernet devices from different manufacturers on the same network until an applicable standard has been established. There are software issues that will determine whether coexistence on the same network will be feasible. As more testing is done on existing Ethernet control equipment, it may be determined that devices from different manufacturers can coexist on the same network. If you are considering designing a system in which you will be trying to interconnect equipment from different manufacturers, ESTA recommends that you contact all the manufacturers involved for information relating to the specific setup you are contemplating.

1.5 Network Design Rules

Network types may be combined in a virtually limitless variety of configurations as long as the final configuration complies with all Ethernet rules. The rules for 100BASE-T networks are summarized in what is referred to as the "Network Diameter Rule" for 100BASE-T.

1.5.1 The Network Diameter Rule for 100BASE-T & 100BASE-FX

For a 100BASE-T network the speed of signal transmission is 10 times that of 10BASE-T. Since the timing of the detection of a collision between nodes that wish to simultaneously transmit is the same, the maximum network distance between any two nodes is greatly reduced. The total area of a 100Mbps network that consists of interconnected nodes and only repeater hubs is called a "collision domain", and needs to be carefully planned to avoid exceeding critical timing parameters. In extremely large systems, there may be multiple collision domains. If this is the case, ESTA recommends that you consult with the manufacturer of the equipment you will be installing for detailed technical information on planning such a system. The following rules apply to a single collision domain:

- The maximum length of any Segment of 100BASE-TX shall not exceed 100m.
- The maximum distance between any two nodes (equivalent to the "diameter" of that network collision domain) connected by a Repeater hub using 100BASE-TX segments shall not exceed 200m, and shall not include more than one Repeater hub.
- The maximum distance between any two nodes connected by a Segment of 100BASE-TX and a Segment of 100BASE-FX, or two Segments of 100BASE-FX shall not exceed 250m.
- The maximum distance of a segment of 100BASE-FX (using multi-mode fiber) between two Switching hubs shall not exceed 412m for half-duplex hubs or 2km for full-duplex hubs. For more information regarding the application of these specialized types of hubs, consult with the manufacturer of the equipment you are considering.

1.5.2 Supplying Power to Remote Network Nodes

Entertainment controls often require network nodes to be powered from a central location thus alleviating the need to run separate high voltage cabling. Low voltage distribution from a central power source also allows the network cabling and the power supply cabling to share one electrical conduit under most local electrical codes. However, this practice provides little or no benefit if the remote device is to drive a video monitor, printer, or similar device which will require an A.C. mains voltage feed.

When a central low voltage power source is used, the cabling should be a minimum of two #16 AWG (1.43 mm^2) wires with individual runs for each device on the network. Each device should be separately protected, preferably at the central location where the power supply is mounted. Since each device is to be cabled to a central location where other network devices such as hubs are located, it is presumed that the maximum cable length for the low voltage supply will be 100 meters.

The centrally powered nodes should have a wide tolerance power supply to allow for voltage drop. Note: *Local codes may limit voltages and currents. This fact must be taken into account when specifying a new installation.*

In installations where line (mains) voltage is to be used to power remote nodes, it should be noted that the network cabling and the power wires must NOT be run in the same conduit.

Part 2: Labeling and System Identification Additions

The original Recommended Practice document outlined an effective system of documenting and labeling a network cabling plant. In addition to that, ESTA also recommends that each location that permanently houses a network hub (or similar device), have a laminated copy of the network riser diagram mounted in plain view. Figure 5 below shows an example of such a diagram.

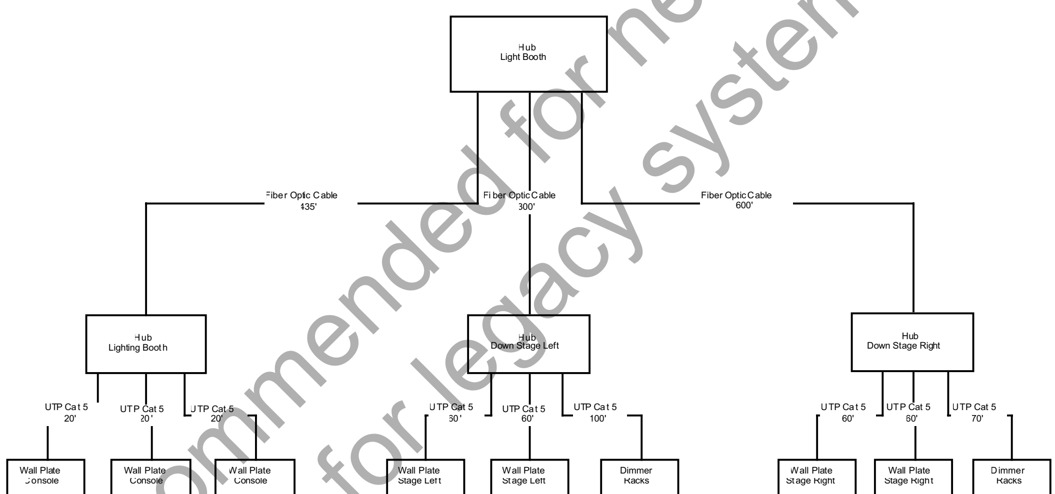

Figure 5 — An example of a network riser diagram

Part 3: Ethernet Hardware

Ethernet is in a state of continual development. At the time this Recommended Practice document was being prepared, other new Ethernet technologies were being developed by IEEE committees. ESTA will continually monitor new Ethernet standards. But, use of new Ethernet technologies cannot be recommended until sufficient practical experience has been gained by other computer technology sectors.

The IEEE 802.3 Ethernet standard describes several different kinds of Ethernet systems. The two systems recommended in this part of the booklet are Unshielded Twisted Pair (UTP), and Fiber Optic networks. Each of these types of Ethernet have advantages and disadvantages as described earlier in this booklet. The system that you choose is likely to be based on the capabilities of your equipment, and on how you plan to use your system.

3.1 Cable and Wire Management

As technology has improved and networks have become more commonplace, cable management hardware and software has become very inexpensive and more available.

ESTA recommends the use of Category 5 compliant patch panels in permanently installed systems adjacent to each hub or group of hubs in a system. This allows the user to permanently label a connector in the patch bay with its location and wire number. Short patch cords can then be used to connect the patch panel jacks to the hubs.

ESTA recommends that Category 5 cabling be installed using the T586B wiring standard. This is currently the most common wiring scheme in the computer industry. Connections are shown in the table below:

Pin Number	Wire Color
1	Orange/White
2	Orange
3	Green/White
4	Blue
5	Blue/White
6	Green
7	Brown/White
8	Brown

Figure 6 — T586B Connector Pin-out

Although patch panels are most commonly used to connect copper-wired Category 5 wall plates to hubs, there are fiber optic patch panels available as well. These products allow easy re-patching of fiber optic hubs. They also create an easy route for re-plugging in the event of a cable failure.

Regardless of the installation, network cables should be neatly installed and clearly labeled at both ends of the cable. Routing of cables inside cabinets should be done with an eye toward the future by leaving a service loop and by neatly bundling all cables.

3.2 100BASE-T network devices

Devices such as hubs which are used for 100BASE-T are nearly identical in appearance to their 10BASE-T counterparts. All 100BASE-T hubs, switches, etc. are clearly marked as to which speed they can operate. There are also hubs available which automatically detect whether they are connected to 100BASE-T or 10BASE-T nodes.

Because of this similarity in technologies, the end user can easily upgrade his existing 10BASE-T system to 100BASE-T by changing the hubs and the nodes to which they connect as such devices become available. The cabling plant installed in accordance with this Recommended Practice will be fully compliant with the 100BASE-T equipment.

Glossary

10BASE2: ThinNet Ethernet running on small diameter coaxial cable. (10 means 10Mb/s. BASE stands for baseband. 2 means 200m.)

10BASE5: ThickNet Ethernet running on large diameter coaxial cable. (10 means 10Mb/s. BASE stands for baseband. 5 means 500m.)

10BASE-FL: ISO/IEC 8802-3 (IEEE Std 802.3) physical layer specification for 10Mb/s Ethernet operating over two optical fibers.

10BASE-T: Ethernet running at 10Mb/s on unshielded twisted pair (UTP) cable. (10 means 10Mb/s. BASE stands for baseband. T means twisted-pair.)

100BASE-T: Ethernet running at 100 Mb/s on unshielded twisted pair (UTP) cable. (100 means 100 Mb/s. BASE stands for baseband. T means twisted-pair.)

100BASE-TX: IEEE 802.3u physical layer specification for 100 Mb/s Ethernet operating over two pairs of Category 5 UTP or STP wire.

100BASE-T4: IEEE 802.3u physical layer specification for 100 Mb/s Ethernet operating over four pairs of Category 3, 4, or 5 UTP wire.

100BASE-FX: IEEE 802.3u physical layer specification for 100 Mb/s Ethernet operating over two optical fibers.

Two-Port Passive UTP Hub: A specially made two port RJ-45 terminal block that allows for two UTP nodes at a maximum distance of 100 meters total, to be connected together without the need for a full UTP hub.

ANSI: American National Standards Institute — 11 West 42nd Street, New York, NY 10036. +1 212 642 4900. Fax: +1 212 398 0023. Email: info@ansi.org. WWW: http://www.ansi.org

AWG: American Wire Gauge. A system that specifies wire size. The gauge varies inversely with the wire diameter size.

Babble: An error condition caused by an Ethernet node transmitting longer packets than allowed. Sometimes babble is used interchangeably with jabber.

Backbone: An Ethernet segment having the sole purpose of connecting the hubs for other segments. A backbone often uses a different Ethernet technology than the one used by the segments radiating from the hubs that it connects (e.g., a ThinNet backbone can be used to connect two UTP star topologies).

Back-off: The action that a node takes when it recognizes a collision. The node stops trying to send a message, waits a random time interval, and then retries sending the message.

Baud: Unit of modulation rate equal to the number of signal elements per second, where all such elements are of equal length and each element represents one or more bits.

Bit: The smallest unit of data processing information. A bit (or binary digit) assumes the value of either 1 or 0.

BNC: Bayonet-Neil-Concelman. The connector type (named after its inventors) used for ThinNet 10BASE2 Ethernet coaxial connectors, "T"-connectors and terminators.

bps: Bits per second, units of transmission speed. Also abbreviated as b/s in this document.

Bridge: A networking device that connects two LANs and forwards or filters data packets between them, based on their destination addresses. Bridges operate at the data link level and are transparent to protocols and to higher level devices like routers.

Bus: A LAN topology in which all the nodes are connected to a single cable, a linear topology. All nodes are considered equal and receive all transmissions on the medium.

Byte: A data unit of eight bits, an octet.

Cable: A collection of individual wires contained within a single outer sheath.

Category 5: The specification for UTP cable, connectors, and installation practices capable of running Ethernet at 10 **and** 100 Mb/s.

Coaxial Cable: An electrical cable with a solid wire conductor at its center surrounded by insulating materials and an outer metal screen conductor concentric with the inner conductor — hence "coaxial". Examples are ThickNet and ThinNet Ethernet cable.

Collision: The condition that occurs when two or more nodes attempt to send a message on a given network cable at the same time.

Collision Domain: A set of nodes which share a single Ethernet LAN or segment.

Concentrator: See Hub.

Critical Segment: A special ThinNet cable segment which connects critical devices (such as main and backup consoles) in a linear topology so that they continue communicating even if the hub connecting them to the rest of the network fails.

Crosstalk: Noise passed between communications cables or node elements.

Cross-Over Cable: A non-recommended cable that is the functional equivalent of a two-port passive UTP hub.

CSMA/CD: Carrier Sense Multiple Access with Collision Detection is the Ethernet shared media access method. All network nodes contend equally for access to transmit. If a node detects another node's signal while it is transmitting it aborts transmission and retries after a brief pause.

Data Link: A logical connection between two nodes on the same network.

DMX512: USITT standard DMX512/1990 Digital Data Transmission Standard for Dimmers and Controllers.

EIA: Electronic Industries Association — 2500 Wilson Boulevard, Arlington, VA 22201. +1 703 907 7500. EIA and EIA/TIA documents can be purchased through Global Engineering.

Ethernet: The most popular LAN technology in use today. The IEEE standard 802.3 (or ISO/IEC 8802-3) defines the rules for configuring an Ethernet network. It is a 10Mb/s or 100 Mb/s, CSMA/CD base band network that runs over thin coaxial, thick coaxial, twisted pair or Fiber Optic cable.

Fiber Optic Cable: A transmission medium composed of a central glass optical fiber filament surrounded by cladding and an outer protective sheath. It transmits digital signals in the form of modulated light from a laser or LED (light emitting diode).

Full-Duplex: Independent, simultaneous two-way transmission in both directions.

Header: The initial part of a data packet or frame containing identifying information such as the source of the data, its destination, the packet type or length.

Horizontal Cable: Cabling used to connect Ethernet nodes to hubs. This is typically UTP cable. Also see Vertical Cable.

Hub: A powered device with multiple ports used to connect together several Ethernet cable segments. The hub retransmits information received from a segment to all other segments, restoring signal timing and wave-forms in the process. Hubs operate at the bit level and operate in a half duplex mode. The hub isolates faulty cable segments from the other segments. Hubs are available with ThinNet, UTP or optical fiber interfaces. Technically defined as a "repeater set". Hubs are more clearly defined in the 802.3 standard (Clause 9 for 10 Mb/s and Clause 27 for 100 Mb/s).

IEC: International Electrotechnical Commission — IEC Central Office; 3, rue de Verenbe; P.O. Box 131, 1211 Geneva 20; Switzerland. +41 22 919 02 11. Fax: +41 22 919 03 00. If necessary, contacts from the USA should be made through ANSI. In the USA, IEC documents can be purchased through Global Engineering.

IEEE: Institute of Electrical and Electronic Engineers — 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331 USA, +1 800 678 4333, +1 908 981 0060. http://www.ieee.org/

ISO: International Organization for Standardization — ISO Central Secretariat; 1, rue de Varembe; Case postale 56; CH-1211 Geneve 20; Switzerland. +41 22 749 01 11. Fax: +41 22 733 34 30.
WWW:http://www.iso.ch/. If necessary, contact from the USA should be made through ANSI. In the USA, ISO documents can be purchased through Global Engineering.

Jabber: Network error caused by an interface card placing continually corrupted data on the network. Sometimes jabber is used interchangeably with babble.

Kb/s: Kilobits per second (e.g., 250 Kb/s is 250,000 bits per second).

LAN: Local Area Network. A collection of nodes that communicate with each other using one or more interconnected cables and zero or more hubs.

Linear Topology: A network configuration in which a single cable run connects all nodes. All the nodes in a linear topology share the single cable for communications.

Mb/s: Megabits per second (e.g., 10Mb/s is 10,000,000 bits per second).

Multidrop: A network configuration in which multiple nodes are connected to the same network segment possibly in a linear topology.

Multi-port Repeater: See Repeater.

Network: A collection of nodes that communicate with each other using one or more interconnected cable segments and zero or more hubs.

Network Address: Every node on a network has a 48-bit address associated with it. This is a fixed hardware address, such as “AE-34-2C-1D-69-F1,” assigned by the node’s manufacturer. The address is made up of two fields, the Organizationally Unique Identifier (OUI) as defined in ISO/IEC 8802-3 sub-clause 3.2.3.1 and IEEE 802:1990 Clause 5, and the vendor assigned portion. There may be other addresses that the node will respond to, such as broadcast and multicast addresses. These are discussed in greater detail in the IEEE standards. The IEEE is a world-wide registration authority for OUI values.

Node: Any device communicating with another device on the network. All nodes have a network address. Hubs, concentrators, repeaters, etc. are part of the network but are not nodes. Typical entertainment control examples are consoles, remote video, etc.

Non-Critical Segment: A special ThinNet cable segment which connects non-critical nodes (such as remote video) in a linear topology.

Packet: A series of bits containing data and control information, including source and destination node addresses, formatted for transmission from one node to another.

Point-to-Point: A network configuration in which two devices are connected to each other by direct cables with no multidrops or linear topologies.

PLASA: Professional Lighting and Sound Association — 38 St. Leonards Road, Eastbourne, East Sussex, BN21 3UT, England, +44 1323 410 335. Fax: +44 1323 646 905. Email: info@plasa.org.uk. WWW: http://www.plasa.org.uk/plasa

Protocol: The encoding and data transfer formats used to move data between nodes on the network. Protocols are differentiated at the packet level by the value Ethernet Type Field. IEEE currently acts as the registration authority for Type Field values. Some entertainment equipment manufacturers currently use unregistered and therefore incompatible protocols. See IEEE in this glossary for contact information.

Repeater: Technically, the core circuitry of a hub. Often used interchangeably with hub. See hub for more detailed technical information.

RJ45: The common name for the 8 pin modular plug and jack (IEC 603-7) used for UTP.

Router: A device similar to a switch in that it forwards frames received on one port to a device on another port. A router operates using layer 3 protocol information in contrast to a switch which uses layer 2 frame information to make forwarding decisions.

Segment: The Ethernet cable run between the terminators in a ThinNet network or the cable run between a device and a hub in a UTP network.

SQE: Ethernet defined signal quality test function frequently called “heartbeat”.

Star Topology: A network configuration in which cables from nodes are joined together with a hub.

STP: Shielded Twisted Pair. A two pair, shielded cable. This is a 100 ohm cable originally developed for use in Token Ring topologies. STP is not used for most typical installations.

Stub: A cable between the main trunk line of a network segment and a device. In Ethernet, a stub would be a cable between an Ethernet "T"-connector and a node. **There should never be a stub between a "T"-connector and a node.**

Switch: Also referred to as a switching hub. A powered device with multiple ports used to connect together several Ethernet cable segments. Data received on one data port is routed only to ports which need that information rather than repeating the data to all ports like a hub does. Switches can operate in full duplex mode allowing greater system throughput.

T-Connector: A T-shaped devices with two female and one male BNC connectors used to connect a node to a ThinNet cable segment.

Terminator: Used on both ends of a ThinNet (10BASE2) Ethernet segment, this device provides the 50-ohm termination impedance required for correct operation.

ThickNet: 10BASE5 Ethernet running on thick (13mm) 50-ohm coaxial cable.

ThinNet: 10BASE2 Ethernet running on thin (5mm) 50-ohm coaxial cable.

TIA: Telecommunications Industries Association — 2500 Wilson Boulevard, Arlington,VA 22201. +1 703 907-7700. Fax: +1 703 907 7727. TIA and EIA/TIA documents can be purchased through Global Engineering.

Topology: The arrangement of the nodes and connecting hardware that comprises the network.

Transceiver: The actual device that interfaces between the network cable and the node. Most transceivers are usually built into nodes but some transceivers (particularly for ThickNet) are external and connected via an AUI cable.

Twisted-Pair Cable: Inexpensive, multiple-conductor cable comprised of one or more pairs of 18 to 24 gauge copper wires. The pairs of wires are twisted to improve protection against electromagnetic and radio frequency interference and ensure a predictable characteristic impedance.

USITT: United States Institute for Theatre Technology — 6443 Ridings Road, Syracuse, NY 13206 USA, +1 315 463 6463. Fax: +1 315 463 6525. WWW: http://www.usitt.org/

UTP: Unshielded Twisted Pair. The 4 pair cable used for 10BASE-T, 100BASE-T, 100BASE-TX, and 100BASE-T4 Ethernet.

Vertical Cable: Cabling typically used to connect hubs together. Vertical cables are often Fiber Optic cables to traverse large distances. Also see Horizontal Cable.

Wire: A single insulated conductor of electricity. Individual wires are grouped together to form a cable.

Referenced Standards

IEEE Std 802-1990
IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture

ISO/IEC 8802-3:1996 (E) ANSI/IEEE Std 802.3, 1993 Edition
Local and Metropolitan Area Networks

ISO/IEC 11801:1995
Information Technology Generic Cabling for Customer Premises

TIA/EIA 568-A-1995
Commercial Building Telecommunications Cabling Standard

TIA/EIA Bulletin TSB67
Transmission Performance Specifications for Field Testing of Unshielded Twisted-Pair Cabling Systems

IEC 603-7
Detailed Specification for Connectors 8-Way Including Fixed and Free Connectors with Common Mating Features

USITT DMX512/1990
Digital Data Transmission Standard for Dimmers and Controllers

Standards Ordering Information

ISO/IEC - ANSI/IEEE joint standards and ANSI/IEEE standards are available from:

IEEE Standards
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
+1 908 981 1391
+1 908 981 9667 Fax
http://stdsbbs.ieee.org/

All ISO/IEC, IEC, ANSI/IEEE, and TIA/EIA standards are available from:

Global Engineering Documents
M/S B201
15 Inverness Way East
Englewood, CO 80112
+1 303 792 2181
+1 303 397 2740 Fax
http://www.global.ihs.com/

ANSI/IEEE and some ISO/IEC and IEC standards are available from:

ANSI
11 West 42nd Street
New York, NY 10036
+1 212 642 4900
+1 212 302 1286 Fax
http://www.ansi.org/

USITT standards are available from:

United States Institute for Theatre Technology
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