ABSTRACT

This document examines the elements of the local area network: vertical distribution cabling, horizontal distribution cabling, and access devices. It discusses their relationship to the University of Michigan backbone network, and their separate impacts on network performance. It considers the costs associated with upgrading each element in general terms, and indicates areas where tradeoffs may be made. It includes a limited discussion of design considerations for specific applications (such as voice over internet protocol, or VoIP).

This document is not intended to be a complete and detailed engineering guide for local area network design. Rather, it is intended to be an overview of the various components of the network, their impact on network performance, and the issues to be considered when contemplating LAN installations or upgrades.

ELEMENTS OF THE LOCAL AREA NETWORK

The Local Area Network (LAN) refers to the system of electronic devices and cabling that connects individual hosts (computers, printers, etc.) in a unit to each other and to the University of Michigan backbone network. The backbone network in turn provides connections to other hosts within the University, and to the internet.

The Distribution Layer Switches are the physical presence of the backbone network in each building. They are connected to two different backbone switch-routers so that the failure of a single distribution layer switch will not cause the failure of the backbone network connection to the building.

Vertical Distribution Cabling provides connections between the backbone distribution layer switches and local wiring closets. Vertical distribution cabling may be fiber optics (preferred) or any of several types of copper cabling.

Access Layer Switches are provided by individual units. They are typically located in wiring closets and are connected to the distribution layer switches via the vertical distribution cabling. They provide network connectivity to the hosts in their area. Other devices, such as uninterruptible power supplies or power over ethernet devices may be associated with the access layer switches for particular applications.

Horizontal Distribution Cabling provides connections between the access layer devices and the local hosts. It typically terminates at a patch panel in the wiring closet at one end, and at the wall jack in offices and classrooms at the other end. Various types of patch cables and drop cables are used to complete the connections to the access layer switch and the local host, respectively.

Elements of the building’s infrastructure, such as raceways (cable trays and conduits), wiring closet ventilation, and electrical power affect the functioning of all of these elements and may constrain your design.
HORIZONTAL DISTRIBUTION CABLING

The horizontal distribution cabling may limit the maximum data rate available to individual hosts. It is typically very expensive to upgrade and should be considered a long-term investment. When horizontal distribution cabling is upgraded, raceways may also need replacement as well.

The types of horizontal distribution cable commonly found in University of Michigan buildings, and their data-rate capabilities, are:

*Category 5e* is the current recommended type for new cabling. Installed according to specifications, this cable type will support data rates up to 1 gigabit per second.

*Category 5* was the recommended standard until fairly recently. It will support data rates up to 100 megabits per second. Most category 5 cable can be re-terminated according to category 5e specifications to support 1 gigabit per second.

*Category 4* cable is relatively uncommon. It will support data rates of no more than 10 megabits per second.

*Category 3* cable is still quite common, especially in buildings that have not been renovated within the past 20 years. It too will support data rates of no more than 10 megabits per second.

Both the cable and its terminations must be compliant with the standards in order to work at the listed data rates. This is not the case in every University building, depending on the policies in effect at the time the building was wired. Category 5 cable, for instance, may be terminated to category three specifications in order to provide two 10 Mb/s ethernet circuits per cable. Current wiring standards call for TIA 568B terminations (all four pairs terminated) to support data rates up to 1 Gb/s.

Horizontal distribution cabling may be no longer than 100 meters, measured from the access layer device to the host, including all patch cables and drop cables. It is important to note that this distance is the length of the cable, not the “line of sight” distance from the wiring closet. For practical purposes this means that the cable installed “in the walls”, i.e. between the patch panel and the wall plate, may be no longer than 90 meters. New buildings are designed with this standard in mind, but older buildings might exceed it. Although this distance standard has been part of the ethernet over twisted pair (ETP) standard from the beginning, older hubs and repeaters have been more tolerant of out of specification cabling than modern switches are. If you suspect that this condition may apply in your building the longest cable runs should be measured electronically to determine whether they are within specification. If they are not your alternatives are to construct new wiring closets and rewire the out-of-spec locations to the new closets, install proprietary ethernet technology for long distance wiring, or install wireless ethernet. Each of these options has unique costs, performance tradeoffs, and
infrastructure requirements, a complete discussion of which is beyond the scope of this document.

ACCESS LAYER DEVICES

The access layer devices typically have the shortest service life of all of the LAN elements discussed here, and they are the most easily replaced. We recommend that all access layer devices provide a minimum set of capabilities, but you may forgo more advanced capabilities with small penalty if you are facing budgetary constraints.

Nearly all currently available access switches provide connectivity to the hosts at either 10 or 100 megabits per second. The data rate used is automatically negotiated between the switch and the attached host. If you have category 3 or category 4 horizontal distribution cabling it will not operate properly at 100 megabits per second. In this case you will have to configure your access layer switches to operate at 10 megabits per second only.

RECOMMENDED MINIMUM STANDARDS FOR ACCESS LAYER DEVICES

- Use managed switches, never hubs
- Provide one switch port per host (avoid small hubs and switches in offices)
- Remote management over the ethernet network, including SNMP V2
- Available secure management interface, such as Secure Shell (ssh) (ssh-v2 or higher preferred, using encryption better than DES)
- IEEE 802.1Q/p VLAN support
- Support for standard spanning tree (STP-802.1d), rapid configuring spanning tree (STP 802.1w), multiple instance spanning tree (MISTP-802.1s)
- IGMP (V2) snooping (for multicast applications, such as video on demand). IGMP V3 is becoming more widely supported, and offers more robust multicast capabilities.)

SUGGESTED ADVANCED CAPABILITIES FOR ACCESS SWITCHES

- Support for IEEE 802.1x to provide network level authentication. IEEE 802.1x with dynamic VLAN assignment to support Policy Based Networking.
- Four layer 2 priority queues (for VoIP installations, and for streaming video applications.)
- Ability to rewrite layer 3 type of service (TOS) or DifServ code point (DSCP) for ports.
- Ability to rate-limit traffic by type (unicast, multicast, broadcast)
- Power over ethernet (PoE) to support VoIP telephones and wireless access points. Add-on devices are also available and are equally satisfactory. The IEEE 802.3af standard is gaining acceptance; but incompatible devices still exist on campus and in the marketplace, so careful selection of compatible power sources and end devices is necessary.
- Support for IEEE 802.1t spanning tree enhancements
• Per VLAN spanning tree (PVST)
• DHCP relay (with support for option 82, switch port mapping.)
• Link aggregation (IEEE 802.3ad) for higher uplink bandwidths.
• Radius and/or TACACS+ authentication for management access.
• SNMP V3 management for higher security environments
• Netflow/sflow export
• Syslog logging capability.
• DHCP snooping, IP source verification, and dynamic ARP inspection to prevent various “man in the middle” attacks.

RELIABILITY CONSIDERATIONS

If your network will be used for voice services over internet protocol (voice over IP, or VoIP) you should insure the highest possible reliability, because the voice telephone is usually peoples’ first recourse in an emergency.

Uninterruptible Power Supplies (UPS) are essential for VoIP. You may also consider them for switches connected to departmental servers, to allow time for “graceful” shut down in the event of power failure. If you have wireless access points connected to your switches you may also want to consider UPS, since wireless users will typically be using battery powered laptop computers. (This assumes that the wireless access points will also be powered from an uninterruptible source, such as a PoE device connected to the UPS.)

New construction projects often include a diesel or gas generator to provide power to emergency circuits. For critical applications, such as VoIP, it may be possible for this generator to provide power for network switches as well, reducing the size and cost of the UPS required. This option should be discussed with the architects and facilities planners early in the construction planning process.

Redundant power supplies are available for large chassis-based switches. Since power supply failure is perhaps the most common failure mode this can be a significant enhancement to reliability.

Dual homing to the distribution layer switches involves connecting each access switch to both distribution layer switches, insuring continued connectivity in the case of a distribution switch failure. Particularly if you are using stacked switches, connecting the first and last switches in the stack to different distribution layer switches will prevent failure of a single switch in the stack from interrupting connectivity to the remaining switches. You may need to upgrade the vertical distribution cabling to achieve dual homing.

WIRING CLOSET CONSIDERATIONS

Wiring closets in older buildings are often small and unventilated. Fortunately manufacturers are aware of the prevalence of these conditions and good quality switches
are surprisingly robust. Forced air ventilation or mechanical cooling is desirable but may not be necessary if the heat load is small. Louvers inserted into wiring closet doors will sometimes provide sufficient ventilation in marginal situations. (Alterations to wiring closets must conform to code requirements for fire and smoke protection. Check with the Fire Marshall before proceeding.)

Avoid storage of ladders, custodial supplies, salt, corrosives, flammables, etc. in wiring closets. If you are in a high security environment access control for wiring closets should be part of your security design.

**VERTICAL DISTRIBUTION CABLEING**

The data from all of the hosts connected to an access layer device is transmitted to the campus backbone network via the vertical distribution cabling. For this reason, inadequate vertical distribution cabling can have a significant effect on your network’s performance. Fortunately it is often possible to upgrade the vertical distribution cabling at a reasonable cost. If you are installing new vertical distribution cabling you should install enough to support dual homing (see above), since the extra material cost is usually only a small part of the total cost. Various types of vertical distribution cabling are commonly encountered at the University:

*Fiber optic cable (recommended)* is capable of the highest data rates. Multi mode fiber is usually adequate for connections wholly with the building, whereas single mode fiber is required for longer distances. It seems likely that future high data rates will require single mode fiber. We recommend that both types be installed.

*Category 5e, 5, 4, or 3* tie cables are subject to the data rate limitations discussed above under horizontal distribution cabling.

*Telephone riser cable* was commonly used for early ethernet installations. This cable is will support at best 10 megabits per second, deteriorating over time. This cable type is not replaced, because it is also used for voice telephony. New vertical distribution cabling for ethernet networks should be installed in parallel with the existing telephone riser. New raceways may be required, but usually are not.

**REFERENCES – GUIDELINES FOR NEW CONSTRUCTION**

The University of Michigan’s Plant Extension department publishes extensive guidelines for new building construction. The section relevant to telecommunications building entrance and raceway may be found at:

http://www.plantext.bf.umich.edu/desguide/tech/16/16740.pdf

the section referring to wiring closet design is at:

http://www.plantext.bf.umich.edu/desguide/sba/sba_c.pdf
THE UNIVERSITY OF MICHIGAN BACKBONE NETWORK

The backbone network consists of six switch/routers connected in a partial mesh and located in various buildings around campus. These switch/routers provide VLAN connectivity between buildings and layer 3 interconnectivity for the entire campus. They are in turn connected to the other backbone networks on campus and to the public internet and Internet II via MERIT/MichNET. The distribution layer switches in each building provide connectivity between the building LANs and the backbone core.
University of Michigan Backbone Network Conceptual Diagram