



WHY STRUCTURED CABLING ?

In order that we may understand why Structured cabling has become the de facto standard for building communications infrastructure we must first look at some history and this white paper draws on the historic developments in Ethernet technology since it is the most prevalent LAN technology. The principles expounded hold equally true for other protocols.

Modern Ethernet networking equipment is designed around the concept that each device in the network has a dedicated media connection to a central "hub". Whether the LAN bandwidth is shared among all the stations as is the case with standard hubs or dedicated to each one (switched technology), a given cable is allocated for use by a single device. This was not always the case. The original design assumed a common, shared medium: coaxial cable.

To thousands of people who began to learn about and use LAN technology in the 1990s, the use of structured wiring and twisted-pair cabling is commonplace and it is hard to understand why anyone would build a large LAN using any other wiring technology. Why didn't we design Ethernet to use twisted-pair in the first place? Why was Ethernet originally designed around coaxial cable (and a fat, expensive and hard-to-work-with cable at that)? There are three reasons:-

It is easier to design a high-speed LAN using coaxial cable than twisted-pair. While it may be easier to install or configure a LAN using twisted-pair wiring, it is much easier from the perspective of the equipment (transceiver) designer to have a coaxial cable as the underlying transmission medium. Coaxial cable has several important advantages as a medium for high-speed communications systems:

- It is much less susceptible to noise ingress (EMI susceptibility) than twisted-pairs. It is also less prone to radiate (EMI emissions) in violation of regulatory restrictions.
- The inherent bandwidth capacity of most coaxial cables far exceeds that of even the best twisted-pairs. Coaxial cable has much lower signal attenuation; thus designing a receiver is easier, since there will be more signal present than for other media. Perhaps more important, the attenuation does not degrade as much at higher frequencies. Thus the need for complex equalisation circuitry at the transmitter and/or receiver is avoided.
- The impedance of a coaxial cable is controlled much better than on twisted-pairs, thereby making it easier to design transceiver circuitry.

10 Mb/s Ethernet is currently considered the slowest of the popular LANs. But at the time of its introduction, 10 Mb/s Ethernet was the fastest commercial LAN available. It was reasonable to assume that a high-grade communications medium like coaxial cable was necessary, even if it was physically inconvenient. This seemingly incongruous statement is valid for the following reasons.

- Coaxial cable has inherently better signal transmission characteristics than does twisted-pair, yet coaxial cable is used only for 10 Mb/s Ethernet while twisted-pair is used for 100 Mb/s systems.
- Many sites are migrating (or have already migrated) from coaxial based systems to newer, twisted-pair systems. This seems absurd if coaxial cable is a superior medium.



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The answer lies in the fact that the advantages of the twisted-pair medium have nothing to do with its electrical or transmission characteristics. Indeed, the prime disadvantage of twisted-pair is its electrical performance. However, this is outweighed by the advantages discussed later. Also, it is important to note that when Ethernet was being designed, 10 Mb/s was considered a very high-speed communications channel.

A shared medium is perfect for a shared-bandwidth LAN. When 10 Mb/s Ethernet was first designed, there was no consideration of switched LANs, hub-centric systems, bridges, and so on.

A LAN was a shared-bandwidth communications channel, and coaxial cable in a bus topology was an appropriate means for implementing such a channel. So, given that coaxial cable was a good choice for electrical reasons, there was nothing about the topology of coaxial cabling that negated this choice. Figure 1 refers;

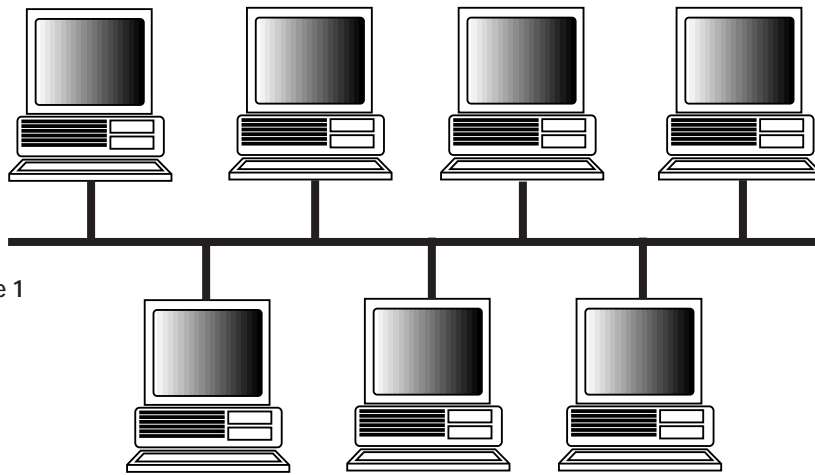


Figure 1

The Transition to Structured Wiring

It is a well known phenomena that events in one segment of the communications industry can ripple changes to seemingly unrelated disciplines. During the 1980s the US telephone industry underwent a major wave of deregulation, most easily noted by the break-up of the nation-wide Bell System telephone monopoly. One element of the new regulatory environment was that customers were to be allowed to own their own telephone equipment, at least on their own premises. Formerly, all telephone equipment, right up to the desk set, was owned and controlled by the Bell monopoly. Thus deregulation created the market opportunity for Private Branch Exchange (PBX) equipment and the private ownership and control of the inside wiring. This deregulation has been mirrored in most European countries.

On top of this, the 1980s ushered in the era of digital telephony, with 64 kb/s encoded signals used to communicate voice, rather than raw analogue signalling. The digital telephone systems allowed numerous features and functions to be added to private telephone systems, thus further enhancing the competitive environment.

For most large (and many small-to-medium) organisations that were installing private digital telephone systems, standards and structure in the wiring system were needed. Many early wiring systems were proprietary and designed by a specific vendor. As the industry matured, the need was recognised for wiring standards that allowed a building to be wired in a generic manner, without considering what equipment would be later selected and installed. Over the years, standards have matured and been refined to accommodate the new LAN technologies, but the original driving force was the deployment of PBX equipment for digital telephony.



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The important development from the perspective of LAN deployment in offices was that, for proper operation of digital telephone systems, a higher grade of cable was needed, higher than that traditionally used for analogue telephone. Analogue telephone is highly tolerant of wide variations in cable types and topologies. Such systems operate perfectly well over untwisted-pairs (for example "silver satin" flat cable), and cope with problems of uncontrolled impedance and marginal connections. Digital telephone systems required a more controlled wiring environment, at least for the longer cable runs. This led to the development of "data grade" cable (later standardised as Category 3 twisted-pair). With data-grade cable and a better controlled environment, it became possible to design high-speed LANs that ran over telephone cable.

A comprehensive discussion of structured wiring systems is beyond the scope of this paper, but is important to note the key characteristics of the standard structured wiring system, especially as they relate to their use in Ethernet LANs. Figure 2 refers;

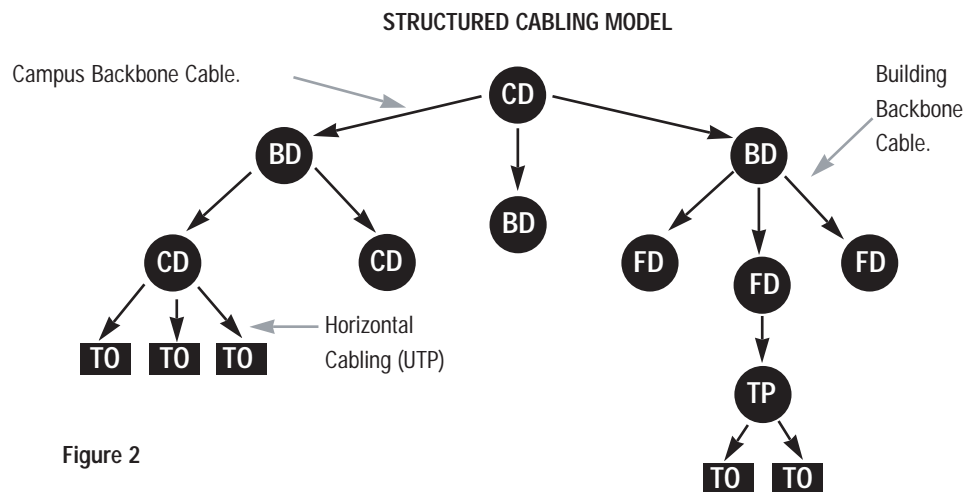


Figure 2

- Each work position (desktop) is provided with at least one dedicated cable that runs from the work position to a wiring closet. This cable is used exclusively by devices at that work position and is not shared or daisy-chained to any other work position. Each cable is typically 4 unshielded twisted-pair (UTP); good practice provides (and international standards dictate a minimum of two such cables to each work position. The wiring used from the closet to the work positions is often called the horizontal distribution, since it usually runs parallel to each single floor.
- The horizontal distribution cable may be one of a number of different types. "In the old days" thin coaxial cable and shielded, 150 W, twisted-pair (Type 1 STP) were common for LAN applications, with Category 3 UTP used for voice. Today, Category 5 UTP is employed for both LAN and voice, with some legacy Category 3 UTP remaining.
- The maximum distance for the horizontal distribution is 100m, including allowances for patch cables, wall plate-to-computer cables, and so on.
- Structured wiring implies the presence of a hub device, which is typically located in the wiring closet in which the horizontal distribution terminates.
- Wiring closets are interconnected through the vertical distribution, so named because the wiring generally runs vertically between floors. The vertical distribution may also employ a variety of cable types. "In the old days," thick coaxial cable, 150W STP, and optical fibre were common for LAN usage, with Category 3 UTP used for voice. However 62.5/125 mm optical fibre is most commonly used for LANs, with UTP, typically low grade multipair, used for voice.



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- The maximum distance for the vertical distribution varies with the cable type remaining at 100m when UTP is used but may be up to 500m when 62.5/125mm optical fibre is used.
- The wiring system maintains (or at least attempts to maintain) controlled electrical characteristics, including constant impedance, minimal Crosstalk, and elimination of stubs. This is a function of the cable and wiring components and also of controlled installation practices; the wiring standards define both.

Over time, developers of wiring systems and standards recognised the need for computer communications in addition to the telephone systems, the original driving force. The EIA/TIA 568 series of standards and ISO 11801 are generally recognised as the controlling documents for building structured wiring systems. We have come full circle. That is, while the standards may originally have been driven by the needs of digital PBX systems, today the more stringent requirements are those of high-speed LANs. Most of the current activity within the wiring standards organisation focuses on supporting the needs of every-increasing LAN speeds. Equally important, within most user organisations the LAN has become as critical a resource as the telephone system. This increased visibility has allowed the improvement of wiring systems beyond the needs of digital telephony, with LAN applications being the primary consideration.

Advantages of Structured Wiring

A structured wiring system offers something never possible when Ethernet was first developed: a stable wiring infrastructure capable of supporting high-speed LAN communication, with:

- Controlled electrical characteristics of the cables and wiring system
- A star-wired topology, with dedicated media for each device
- Every cable terminating in a wiring closet, in which LAN hub and cable interconnection equipment can be placed.

Telephone systems have used star-wired topologies for more than one hundred years, with good reason. While formal specifications for structured wiring that is compatible with both high-speed LANs and digital telephone systems have emerged only recently, the advantages of a star-wiring topology are clear.

- **Ease of executing moves, adds, and changes to the configuration.** This is unquestionably the primary advantage of a structured wiring system. In most organisations, there is a constant need to add users, shift users from one location to another. With a bus or daisy-chain topology (as used in coaxial Ethernet systems), any change to the configuration could require rewiring (including climbing into ceiling voids or removing permanent walls to access the cables) and network disruption (while devices are added). With a structured wiring system, every work location is prewired, thus eliminating the need for new wiring when users are added.

More importantly, the configuration of the network is done at a patch panel in the wiring closet and does not require access to either the user's end of the connection or the horizontal cable itself. In this manner, reconfiguration, even as extensive as a wholesale move of an entire work group, can be executed quickly, in one location, without disrupting other users of the network.

- **LAN technology independence.** Using standards for structured wiring, we have designed a multitude of LAN technologies that operate over this common medium. "In the old days," a decision to use a given medium implied the network technology choice, and vice versa. Installing 50 W coaxial cable implied the use of Ethernet, 150W STP mandated Token Ring, and so on. There was a tight interdependence between the medium and the technology.



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This is no longer true with structured wiring standards. The same infrastructure can support Ethernet (at a variety of data rates), Token Ring, Local Talk, FDDI/CDDI, R232/422, ATM, and so on. We no longer have to make the technology decision at the same time that we choose the wiring system. The same system supports multiple technologies and multiple data rates within the same technology. This allows us both to use, without rewiring, different LANs in different areas of the organisation that are appropriate to the needs of the individual work group and to migrate among technologies and data rates as those needs change.

- **Single Point Fault isolation.** Since each device attached to the network has a dedicated medium connection, any fault, either with the user's device, the user's port on the network concentrator, or the wiring system itself, can be isolated to that individual user. With shared media such as coaxial cable, a single fault could disrupt multiple users, or an entire LAN.
- **Ease of network management.** With all of the user's connections and the network hub devices located in a single location (the wiring closet), network diagnosis, testing, and repair become greatly simplified. Test equipment and network monitoring tools can be either installed semi-permanently in the wiring closet or built directly into the network hub equipment. The wiring closet becomes the obvious point from which to test user devices, network devices, and the wiring system itself. Most repairs can also be made from this central location.
- **Network equipment security.** All of the network-critical equipment - patch panels, LAN hubs, switch routers, and so on - are located in a single area that can be physically controlled. Simply put, one can lock the door and prevent unauthorised access to all the single-points-of-failure in the LAN.

It is interesting to note that even from the beginning, the developers of Token Ring technology recognised the benefits of structured wiring. Token Ring (IEEE 802.5) systems are never wired as a physical ring, but rather as a physical star. This allows Token Ring to take advantage of many of the benefits of star-wired systems discussed previously. The benefits, especially of unitary fault isolation, are especially important in Token Ring, since the local topology permits a large class of device faults to cause total network disruption. By using star wiring and a centralised means of granting permission to join/leave the physical ring, one could minimise the impact of device faults.

The benefits of structured wiring however do not come without penalties.

- Dedicated media is more expensive than shared media. The cost of a structured wiring system is much more expensive than that of a shared, coaxial medium. While the cost-per-unit-length of UTP is lower than that of coaxial cable, there is much more cable required, since each device gets a dedicated "home run" cable from the work location to the wiring closet. After the costs of cable installation are added in (such costs can run an order-of-magnitude greater than the cost of the cable itself), the cost of a LAN based on structured wiring far exceeds that of shared-media systems.
- **A LAN based on dedicated media is more expensive than one based on shared media.** In a shared media system, there is no need for any hub equipment. A hub of some sort (that is, repeater or switch) is always needed when using structured wiring.
- **UTP is not a good transmission medium for high-speed communications systems.** Most structured wiring systems use UTP for the horizontal distribution. UTP is excellent in terms of cost (per unit length), ease of installation, size and weight, availability of common tools and connectors, and so on. But when one is considering media for the foundation of high-speed communications systems, UTP is not ideal. Granted, modern Category 5 UTP is vastly superior to earlier cables, especially the uncontrolled telephone wiring of the pre-1980s. However, it is still extremely difficult to design a multi-megabit-per-second communications system that operates reliably over 100m of twisted-pair cable. Coaxial cable would make the design task (and therefore the equipment cost) much lower than that of a UTP based system.



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However, the user benefits of structured wiring systems using UTP (especially in greater ease of moves/adds/changes) outweigh any cost or performance disadvantages, especially in larger, office automation environments. It is these user benefits that drove the development of 10BASE-T and, later the 100 BASE-T and 1000BASE-T systems.

The 10BASE-T/100BASE-T Revolution

Given that:

- Structured wiring systems were being widely deployed in the late 1980s for digital telephony
- Structured wiring offers significant advantages with respect to flexibility and network management
- Competing LAN systems (namely, Token Ring) could use structured wiring

It should come as no surprise that equipment manufacturers moved quickly to develop methods to use twisted-pair wiring. Initial products in this marketplace were proprietary in nature. When it became clear that Ethernet over twisted-pair was a huge potential market, the IEEE 802.3 membership took up the task of composing a standard for Ethernet operation over UTP, using the EIA/TIA 568 building wiring standard as the model for the cabling system. 10BASE-T rapidly became the most popular method of deploying Ethernet in large organisations. This further accelerated the move to install structured wiring systems.

Following the market success of 10BASE-T, the IEEE 802.3u (Fast Ethernet) Task Force used this model of wiring and equipment interconnection and increased the channel data rate to 100 Mb/s. By the time Fast Ethernet was being developed, the model for LAN deployment had shifted so much towards structured wiring that Fast Ethernet offered no shared-media option. 10 BASE-T provided a means for accommodating a structured wiring system within an inherently shared-channel architecture. At 100 Mb/s, the only media supported uses the structured wiring model. The fact that these systems are so popular indicates that the advantages of the structured wiring system far outweigh the cost penalty.

One important outgrowth of the move to structured wiring is the new found role of the LAN hub. Star-wired Ether nets require a device at the centre of the star. In a shared-bandwidth LAN, this hub (a repeater) allows all attached devices to perceive the network as a common communications channel, even though each one has a dedicated media connection. The bandwidth is shared, but not the media.

Conclusion

This paper demonstrates that structured cabling systems, whilst having penalties in terms of cost and absolute transmission performance, show considerable cost savings to the "owner" by reducing the on costs of moves, changes and additions. These benefits far outweigh the cost of implementation making Structured Cabling the optimum choice for building wiring.

Rob Cardigan
Corporate Product Manager